TUGAS AKHIR - ME184834

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

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Surabaya
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BACHELOR THESIS – ME184834

RISK-BASED INSPECTION (RBI) ANALYSIS OF PRESSURE RELIEF DEVICE (PRD) GAS SEPARATOR PRODUCTION SYSTEM

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Memperoleh Gelar Sarjana Teknik
pada
Bidang Studi Digital Marine Operation and Maintenance (DMOM)
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ANALISIS *RISK BASED INSPECTION* (RBI) PADA *PRESSURE RELIEF DEVICE* (PRD) SISTEM *PRODUCTION GAS SEPARATOR*

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ABSTRAK

Keselamatan kerja merupakan hal pokok yang perlu dipenuhi dalam aspek produksi minyak dan gas bumi. Hal ini tidak terlepas dari karakter minyak dan gas bumi sendiri yang memiliki sifat bertekanan tinggi dan mudah meledak sehingga apabila terjadi kegagalan pada sistem maka akan berdampak buruk pada manusia, lingkungan maupun kegiatan operasi itu sendiri. Untuk mengurangi kegagalan tersebut dipasanglah suatu sistem pengaman berupa pengaplikasian *pressure relief device* (PRD) yang berfungsi untuk mengontrol dan membatasi tekanan dengan cara mengarahkan aliran kedalam jalur tambahan. Dalam proses pemurnian minyak dan gas bumi pengaplikasian PRD sendiri salah satunya terdapat pada sistem *production gas separator*. Namun, berdasarkan API 581, PRD juga memiliki risiko kegagalan sehingga setiap perusahaan minyak dan gas bumi perlu melakukan inspeksi secara rutin guna menjamin keandalan dari PRD. Salah satu pendekatan untuk mengevaluasi kritikal dari PRD untuk mengatur program inspeksi dan penjadwalannya adalah dengan menggunakan metode *Risk Based Inspection* (RBI). RBI merupakan sebuah pendekatan sistematis tentang metode pengelolaan inspeksi terhadap peralatan atau unit kerja yang didasarkan kepada tingkat risiko yang dimiliki oleh peralatan atau unit kerja tersebut. Risiko ditentukan berdasarkan perhitungan kemungkinan kegagalan (Pof) dan konsekuensi kegagalan (CoF). Penilaian risiko untuk PRD sistem *Production Gas Separator* didasarkan pada API RP 581 edisi ketiga. Setelah mengetahui tingkat risiko yang ada maka dievaluasi terhadap risiko tersebut. Risiko yang masih diterima bisa dijadikan acuan untuk menentukan waktu inspeksi berikutnya sampai mencapai *risk target*. Dari hasil yang telah dianalisa besarnya risiko pada PSV-1020A/B, PSV-1311, PSV-1312, PSV-2910, PSV-2921 dan PSV 2931 berkisar antara 0.071 m^2/year – 0.49 $m^{2/}$year untuk RBI Date dan berkisar antara 1.915 m^2/year – 7.85 $m^{2/}$year untuk RBI Plan Date. Risiko tersebut bila dimasukkan ke dalam matriks risiko memiliki kategori risiko *medium risk* dan *medium high risk.*

Kata kunci: *pressure relief device* (PRD), RBI, API 581

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RISK-BASED INSPECTION (RBI) ANALYSIS OF PRESSURE RELIEF DEVICE (PRD) GAS SEPARATOR PRODUCTION SYSTEM

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ABSTRACT

Work safety is the main thing that needs to be met in the aspect of oil and gas production. This is inseparable from the character of oil and gas itself which has high pressure and explosive nature so that if a system failure occurs, it will have a negative impact on humans, the environment, and the operations themselves. To reduce this failure a safety system is installed in the form of the application of a pressure relief device (PRD) which functions to control and limit the pressure by directing the flow into additional pathways. In the process of purifying oil and gas, the application of PRD itself is one of which is in the gas separator production system. However, based on API 581, the PRD also has a risk of failure so that every oil and gas company needs to conduct regular inspections to ensure the reliability of the PRD. One approach to evaluating the criticality of the PRD to manage its inspection and scheduling program is to use the Risk-Based Inspection (RBI) method. RBI is a systematic approach to the management method of inspection of equipment or work units based on the level of risk that is owned by the equipment or work unit. Risk is determined based on the calculation of the likelihood of failure (POF) and the consequences of failure (CoF). The risk assessment for the PRD Production Gas Separator system is based on API RP 581 third edition. After knowing the level of risk there is then evaluated against these risks. Risks that are still accepted can be used as a reference to determine the next inspection time to reach the risk target. From the results that have been analyzed the magnitude of risk in PSV-1020A / B, PSV-1311, PSV-1312, PSV-2910, PSV-2921 and PSV 2931 ranges between 0.071 m2 / year - 0.49 m2 / year for RBI Date and ranges between 1,915 m2 / year - 7.85 m2 / year for the RBI Plan Date. If the risk is included in the risk matrix it has a medium risk and medium high-risk risk category.

Keywords : *pressure relief device* (PRD), RBI, API 581

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Surabaya, Juli 2020

Penulis

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BAB 1
PENDAHULUAN

1.1 Latar Belakang

Keselamatan kerja merupakan hal pokok yang perlu dipenuhi dalam aspek industri minyak dan gas bumi. Hal ini tidak terlepas dari karakter minyak dan gas bumi sendiri yang memiliki sifat bertekanan tinggi dan mudah meledak sehingga apabila terjadi kegagalan akan timbul masalah baru yang akan berdampak pada manusia, lingkungan maupun kegiatan operasi itu sendiri. Salah satu cara untuk mengurangi kegagalan akibat tekanan yang berlebih dipasanglah sistem pengaman berupa pengaplikasian *Pressure Relief Device* (PRD). PRD merupakan perangkat pengaman yang berfungsi untuk mengontrol dan membatasi tekanan dengan cara mengarahkan aliran bertekanan menjauh dari sistem utama menuju sistem sendiri.

Pressure relief device bisa saja gagal untuk merilis *over pressure* bahkan bisa menyebabkan kegagalan pada perangkat yang dilindungi. Berdasarkan *America Petroleum Institute Recommended Practice* 581 terdapat 2 model kegagalan yang bisa terjadi pada PRD (API RP 581, 2016):

1. *Fail to Open* (FAIL)
- Macet atau gagal terbuka, Stuck or Fails to Open (FTO)
- Device hanya terbuka sebagian, Device Partially Open (DPO)
- Device terbuka diatas tekanan yang ditentukan (diatas 1.3 kali dari tekanan yang telah ditetapkan), Opens above set pressure (OASP)

2. *Leakage Failure* (LEAK)
- Kebocoran perangkat sebelumnya, Leakage Past Device (LPD)
- Device terbuka lebih awal, Spurious/Premature opening (SPO)
- Device macet untuk terbuka, Device Stuck open (DSO)

Mengingat pentingnya kegunaan dari PRD serta merupakan equipment yang tidak terlepas dari risiko kegagalan, maka melalui peraturan pemerintah no.11 Tahun 1979 yang mengatur mengenai keselamatan kerja pada permunian dan pengolahan minyak dan gas bumi. Pada Bab IV pasal 14 dan pasal 15 membahas mengenai penggunaan dan program inspeksi yang harus dilakukan guna mencegah kemungkinan bahaya-bahaya yang dapat terjadi selama proses pengolahan minyak bumi. Peraturan ini mengikat setiap perusahaan yang bergerak dalam bidang industri pengolahan minyak dan gas bumi harus melakukan inspeksi terhadap setiap equipment yang dimiliki termasuk pada PRD. Hal ini berguna menjamin keberhasilan serta keselamatan di dalam area kerja. Setiap perusahaan memiliki program dan penjadwalan inspeksi sendiri terhadap asset perusahaan.

Risk Based Inspection (RBI) adalah sebuah pendekatan sistematis tentang metode pengelolaan inspeksi terhadap peralatan atau unit kerja yang didasarkan pada tingkat resiko yang dimiliki oleh peralatan atau unit kerja tersebut. Oleh karena itu, secara umum metode RBI dapat diaplikasikan ke semua jenis industri dan sangat bergantung pada kondisi aktual dari peralatan industri yang di analisis. (Zhaoyang, 2011)

1.2 Rumusan Masalah

Dari uraian diatas maka permasalahan utama yang akan dibahas adalah sebagai berikut :

1. Bagaimana menghitung *probability and consequence* pada peralatan *pressure relief divice* (PRD) dengan menggunakan metode *risk based inspection*?
2. Bagaimana menghitung *Risk Analysis* pada peralatan *pressure relief divice* (PRD) dengan menggunakan metode *risk based inspection*?
3. Bagaimana menentukan *Inspection Planning* yang sesuai dengan kondisi tingkat *pressure relief device* tersebut?
4. Bagaimana menentukan metode inspeksi pada peralatan *pressure relief divice* (PRD) dengan menggunakan metode *risk based inspection*?

1.3 Tujuan

Tujuan yang akan dicapai dari penelitian ini adalah sebagai berikut:

1. Menentukan *probability and consequence* pada *pressure relief divice* (PRD) dengan menggunakan metode *risk based inspection.*
2. Menentukan level risiko pada *pressure relief divice* (PRD) dengan menggunakan metode *risk based inspection*
3. Menentukan jenis dan interval waktu inspeksi *pressure relief device* dengan menggunakan metode *risk based inspection*
4. menentukan metode inspeksi pada peralatan *pressure relief divice* (PRD) dengan menggunakan metode *risk based inspection*

1.4 Batasan Masalah

Berdasarkan perumusan masalah tersebut, maka batasan masalah dalam penelitian ini adalah sebagai berikut:

1. *pressure relief device* yang dilakukan penelitian adalah milik Perusahaan “X” pada sistem *production gas separator*
2. Analisa bebasis keandalan *pressure relief device* ini berpedoman pada code API RBI 581
3. Tidak menghitungkan biaya dalam inspeksi/pengujian ketika menggunakan metode *risk based inspecktion.*
4. Konsekuensi yang diperhitungkan meliputi dampak kesehatan dan keselamatan.

1.5 Manfaat Penelitian

Manfaat yang dapat diperoleh dari penulisan tugas akhir ini adalah :

1. Dapat dijadikan sebagai bahan pertimbangan bagi perusahaan dalam menentukan prioritas pelaksanaan inspeksi sebagai usaha preventif untuk meminimalkan dampak kegagalan.
2. Memperkenalkan RBI sebagai metode pengelolaan inspeksi berdasarkan analisa tingkat resiko dari *pressure relief device*
3. Meningkatkan tingkat keselamatan bagi para pekerja maupun lingkungan.

4. Dapat dijadikan sebagai bahan pertimbangan untuk mengambil keputusan dalam melaksanakan program inspeksi dan pembiayaan inspeksi

1.6 Keluaran Penelitian

Spreadsheet perhitungan penjadwalan inspeksi PRD sesuai API 581

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BAB 2
KAJIAN PUSTAKA

2.1 Kajian Penelitian Terkait

Saifulloh, Muhammad. 2018. Analisa Penjadwalan Program Inspeksi *Pressure Relief Device* (PRD) Dengan Metode *Risk Based Inspection* API 581 Pada *Central Processing Plant* Sistem *Production Gas Separator.* (Saifulloh, 2018)

Dalam tugas akhir ini peralatan yang diteliti adalah *Pressure Relief Device* (PRD). Metode yang digunakan adalah *Risk Based Inspection* (RBI) kuantitatif.

2.2 Ikhtiar Permasalahan

Keselamatan kerja merupakan hal pokok yang perlu dipenuhi dalam aspek industri minyak dan gas bumi. Hal ini tidak terlepas dari karakter minyak dan gas bumi sendiri yang memiliki sifat bertekanan tinggi dan mudah meledak sehingga apabila terjadi kegagalan akan timbul masalah baru yang akan berdampak pada manusia, lingkungan maupun kegiatan operasi itu sendiri.

Terdapat empat kemungkinan yang dapat menyebabkan terjadinya kelebihan tekanan dalam suatu proses yaitu (Hendra, 2010) :

a. Kenaikan *input* produk seperti :
   - Kegagalan dan membukanya control valve upsteam suatu vessel.
   - Kekeliruan atau ketidaksengajaan sehingga valve membuka dibagian upsteam suatu vessel
b. Penurunan *Output* produk seperti :
   - Kegagalan dan menutupnya *control valve* yang terletak di bagian *downstream* sebuah *vessel*
   - Kekeliruan atau ketidaksengajaan menutup valve yang terletak di *downstream* sebuah *vessel*
   - Kegagalan kompresor yang terpasang di bagian *downstream* sebuah *vessel*
   - Kegagalan pompa yang terpasang di *downstream*, sebuah *vessel*
c. Kenaikkan *input* bahan seperti;
   - Kegagalan suatu valve untuk menutup bahan bakar ke *fired heater*
   - Kenaikkan pemindahan panas karena kenaikkan beda suhu di dalam sebuah *reboiler*
   - Kebakaran yang terjadi sekitar sebuah *vessel*
d. Penurunan penghilangan panas seperti;
   - Kegagalan air pendingin
   - Kegagalan condenser udara
   - Kegagalan sirkulasi aliran penghilang panas

Salah satu cara untuk mengurangi kegagalan akibat tekanan yang berlebih dipasanglah sistem pengaman berupa pengaplikasian *Pressure Relief Device* (PRD). PRD merupakan perangkat pengaman yang berfungsi untuk mengontrol dan membatasi

tekanan dengan cara mengarahkan aliran bertekanan menjauh dari sistem utama menuju sistem sendiri seperti Flare system. Cara kerja dari PRD adalah apabila tekanan inlet valve melebihi dari set pressure maka valve akan membuka jalur alternative/buangan untuk mengalirkan/mengalihkan tekanan tersebut.

Beberapa kegagalan peralatan yang terjadi akibat PRD gagal menjalankan tugasnya diantaranya (Malek, 2006) :

1. Ledakan Pemanas Air pada Avon High School

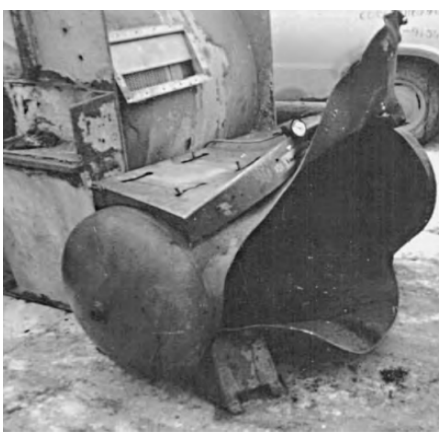
   Pada hari kamis, 11 Mei 2000, sekitar pukul 06.05 pagi . terjadi ledakan pemanas air yang bersifat *cathastropic explotion* mengakibatkan kerusakan serius pada dinding dan area sekitar. Kegagalan ini diakibatkan karena dinding boiler yang mengalami penipisan dan terjaadi kebocoran. Sehingga timbul kondisi abnormal , suhu air di bejana melebihi 212º F membuat air berubah menjadi uap. *Relief valve* yang dipasang seharusnya bisa mencegah bejana dari mencapai tekanan dan suhu yang berlebih. Pada pengujian ditentukan bahwa katup relief valve gagal beroperasi, seperti yang terdapat pada **Gambar 2.1**. Dari pengujian tersebut diketahui bahwa valve yang di set pada tekanan 150 psi baru bisa bekerja pada tekanan 184 psi.

Gambar 2.1 Water heater explosion at Avon High School
(sumber : Pressure relief device)

2. Air Tank Accident

   Air Tank digunakan dibengkel kecil dan pabrik industri besar untuk berbagai kebutuhan udara bertekanan rendah. Baru-baru ini sebuah tangki penerima udara dari unit udara bertekanan meledak disebuah lokakarya pemukulan panel di Australia. Kecelakaan itu menyebabkan kerusakan material. Alasan kegagalan diyakini tidak berfungsinya safety device dan lemahnya tanki.Seperti yang terdapat pada **Gambar 2.2** dan **Gambar 2.3** dibawah ini

Gambar 2.2 Digester system explosion in Kaiser Alumina Plant
(sumber : Pressure relief device)



Gambar 2.3 An air receiver tank explosion
(sumber : Pressure relief device)

Dikarenakan Industri pengolahan minyak dan gas bumi memiliki tingkat risiko yang berbahaya maka dikeluarkanlah Undang undang No. 1 tahun 1970 yang mengatur tentang keselamatan kerja bagi tenaga pengelola usaha minyak dan gas bumi dimana pekerja berhak mendapat perlindungan atas keselamatan dalam melakukan kerja. Aturan itu diperkuat dengan Peraturan Pemerintah No. 11 Tahun 1979 yang mengatur mengenai keselamatan kerja pada permunian dan pengolahan minyak dan gas bumi. Pada Bab IV pasal 14 dan pasal 15 membahas mengenai penggunaan dan program inspeksi yang harus dilakukan guna mencegah kemungkinan bahaya-bahaya yang dapat terjadi selama proses pengolahan minyak bumi. Peraturan ini secara langsung menyebutkan bahwa pemerintah memiliki keterlibatan langsung alam menjamin keselamatan kerja bersifat periodis, atau biasa disebut periodical Inspection/Calender Based/ Time Based Inspection yang memiliki periode 3-5 tahun sesuai dengan jenis peralatan.

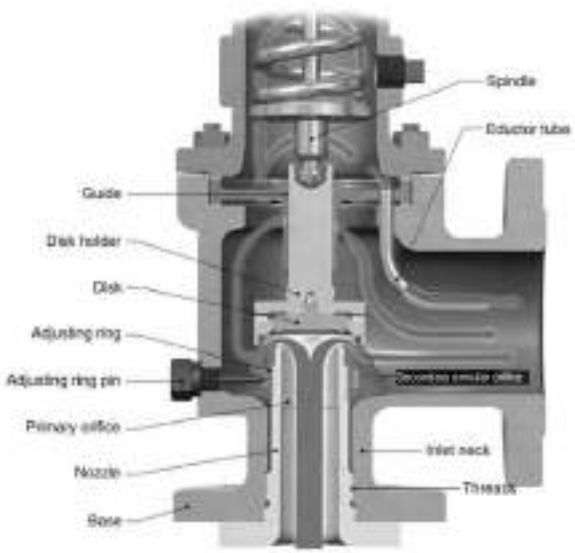
Di beberapa Negara telah mengadopsi sistem Risk Based Inspection (RBI) guna menjamin keselamatan kerja seperti Amerika serikat dan inggris. Keuntungan secara umum secara ekonomi yang didapat bila mengaplikasikan RBI oleh Negara tersebut adalah (Malek, 2006) :

a) Berkurangnya waktu shutdown
b) Berkurangnya jumlah inspeksi peralatan
c) Berkurangnya biaya setiap inspeksi

Berdasarkan latar belakang tersebut perlunya penerapan Inspeksi dengan metode *Risk Based Inspection* API RP 581 agar didapat program inspeksi yang cukup detail tapi juga ekonomis guna mencegah kegagalan pada PRD yang bisa berdampak pada keselamatan manusia,pencemaran lingkungan dan kelancaran produksi.

2.3 Pressure Relief Device

Pressure relief device merupakan peralatan mekanis yang berfungsi melindungi peralatan pabrik dari tekanan berlebih (Malek, 2006). Prinsip kerja *pressure relief device* yaitu didasarkan pada keseimbangan gaya, dimana beban pegas disetel sama dengan gaya yang diberikan pada katup disk dengan fluida inlet ketika tekana sistem berada pada tekanan yang ditetapkan dari katup. katup tidak akan terbuka jika tekanan inlet di bawah tekanan yang telah ditetapkan. Katup akan terbuka jika tekanan fluida melebihi tekanan yang ditetapkan. Skema umum PRD seperti yang ditampilkan pada **Gambar 2.4**. Katup tertutup kembali ketika tekanan saluran masuk dikurangi ke tingkat tertentu di bawah tekanan yang ditetapkan. (Hellemans, 2009)



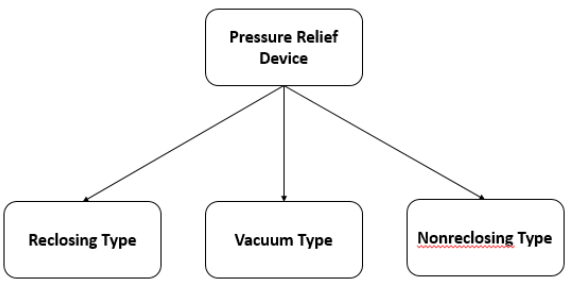
Gambar 2.4 Skema umum PRD
(sumber : Pressure relief device)

Fungsi dari PRD disebut sebagai berikut :

a) Dirancang membuka saat over pressure untuk mencegah kondisi vacuum yang berlebih.

b) Guna keamanan dan keselamatan kerja
c) Mencegah hilangnya produk
d) Mengurangi jumlah *downtime*

PRD dirancang untuk membuka saat keadaan darurat untuk mencegah *rupture* . Device sendiri juga di design untuk mencegah keadaan vacum. Pembagian PRD seperti pada **Gambar 2.5** dibawah ini.

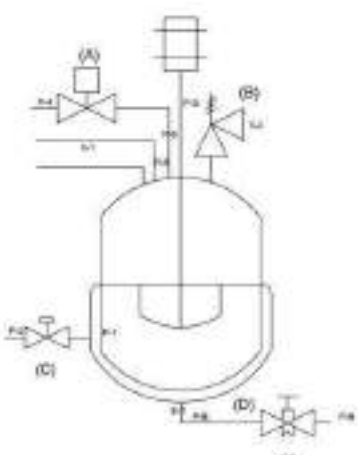


Gambar 2.5 Diagram jenis PRD
(sumber : Pressure relief device)

PRD melindungi tanki dari tekanan berlebih saja. Device ini tidak melindungi terhadap kegagalan struktur saat vessel terkena kondisi abnormal seperti suhu tinggi akibat kebakaran.

2.4 Anatomi *Overpressure*

Overpressure khususnya pada *pressure relief device* (PRD) dapat terjadi dikarenakan tekanan pada inlet valve melebihi dari tekanan yang telah ditentukan. Saat terjadi *overpressure* maka valve inlet akan terbuka dan PRD akan membuka valve untuk jalur buangan fluida. Anatomi *overpressure* untuk lebih jelasnya dapat dilihat pada **Gambar 2.6** dibawah ini.



Gambar 2.6 Anatomi *Overpressure*
(sumber : The safety Relief Valve Handbook)

Overpressure dapat terjadi jika fluida mengalir dari valve (A) dan kedua aliran valve pada separator yaitu valve (D) dan valve (C) gagal terbuka sehingga fluida dalam separator dapat melebih. Dikarenakan fluida yang penuh tersebut dapat mengakibatkan tekanan yang berlebih sehingga safety valve (B) akan membuka untuk mengalirkan fluida yang ada di dalam separator.

2.5 Wellhead Production (WHP) Sistem Production Gas Separator

Wellhead production merupakan area pengeboran dari pengolahan minyak dan gas untuk siap diproduksi dan dijual. Dalam penulisan tugas akhir ini, penulis menggunakan data dari salah satu perusahaan minyak dan gas bumi di Indonesia. PRD yang dianalisa pada penelitian ini terdapat pada sistem production gas separator.

2.6 Peraturan Pengolahan Minyak dan Gas Bumi Di Indonesia

Setiap tenaga kerja berhak mendapat perlindungan atas keselamatannya dalam melakukan pekerjaan untuk kesejahteraan hidup dan perlunya perlindungan terhadap produk yang berupa minyak dan gas bumi sehingga bisa dipakai dan dipergunakan secara aman dan efisien sehingga tidak terjadi kegagalan sistem yang bisa berdampak pada keselamatan manusia, lingkungan serta produk itu sendiri maka dikeluarkanlah peraturan maupun perundang-undangan yang berlaku diindonesia.

2.6.1 Undang-undang Nomor 1 Tahun 1970

Undang-undang ini mengatur tentang keselamatan kerja. Pada bab 3 mengenai syarat-syarat keselamatan kerja pasal 3 ayat 1 dijelaskan untuk mewujudkan keselamatan kerja perlunya (UU NO 1, 1970):

a. Mencegah dan mengurangi kecelakaan
b. Mencegah, mengurangi dan memadamkan kebakaran
c. Mencegah dan mengurangi bahaya peledakan

2.6.2 Peraturan Pemerintah No. 11 Tahun 1979

Peraturan ini mengatur tentang keselamatan kerja pada permunian dan pengolahan minyak dan gas bumi. Terdiri dari 31 Bab dan 58 pasal mengatur tata usaha dan pengawasan keselamatan kerja pada pemurnian dan pengolahan minyak dan gas bumi, wewenang dan tanggung jawab menteri pertambangan, dan dalam pelaksanaan pengawasan menyerahkan kepada Dirjen dengan hak substitusi sedang tugas dan pekerjaan pengawasan tersebut dilaksanakan oleh kepala inspeksi dan pelaksana inspeksi tambang. Peraturan pemerintah ini mengatur persyaratan teknis keselamtan dalam permunian dan pengolahan mulai dari perancangan, pembangunan pengoperasian, pemeliharaan dan perbaikan instalasi, termasuk persyaratan keselamatan untuk termasuk kesalamatan tempat kerja.

Pada Bab IV pasal 14 dan pasal 15 membahas mengenai penggunaan dan program inspeksi yang harus dilakukan guna mencegah kemungkinan bahaya-bahaya yang dapat terjadi selama proses pengolahan minyak bumi (PP NO 11, 1979).

Beberapa peraturan tersebut secara jelas mengatur suatu perusahaan minyak dan gas bumi untuk melakukan inspeksi pada peralatan penunjangnya guna

menjamin kesuksesan dalam produksi sehingga kegagalan dapat terhindari maupun diminimalisir.

2.6.3 Paraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 38 Tahun 2017

Peraturan ini menetapkan peraturan menteri energi dan sumber daya mineral tentang pemeriksaan keselamatan instalasi dan peralatan pada kegiatan usaha minyak dan gas bumi (PERMEN-ESDM NO 38, 2017). Beberapa pasal terkait meliputi :

PERMEN-ESDM-NO.38 Tahun 2017 Pasal 5 ayat 1

Untuk penjaminan terhadap pembuatan desain, pembangunan, pengoperasian, pemeliharaan, pengujian, pemeriksaan, dan pelaksanaan terhadap instalasi dan peralatan, setiap instalasi dan/atau peralatan yang digunakan dalam kegiatan usama minyak dan gas bumi wajib dilakukan inspeksi dan pemeriksaan keselamatan.

PERMEN-ESDM-NO.38 Tahun 2017 Pasal 11 ayat 2

Pemeriksaan keselamatan terhadap instalasi dan/atau peralatan yang telah beroperasi dapat dilakukan secara berkala berdasarkan :

Jangka waktu tertentu ; atau

Hasil analisis risiko

PERMEN-ESDM-NO.38 Tahun 2017 Pasal 17 ayat 1 dan 3

Persetujuan penggunaan pemeriksaan keselamatan secara berkala berdasarkan jangka waktu tertentu berlaku paling lama 4 (empat) tahun atau kurang dari jangka waktu tersebut apabila instalasi dan/atau peralatan mengalami perubahan atau diragukan kemampuannya.

Persetujuan pengunaan pemeriksaan keselamatan berdasarkan hasil analisis risiko memiliki masa berlaku berdasarkan hasil analisis risiko selama sisa umur terpenuhi.

Beberapa peraturan tersebut secara jelas mengatur suatu perusahaan minyak dan gas bumi untuk melakukan inspeksi terhadap peralatan penunjang berdasarkan metode time based maupun hasil analisis risiko untuk menjamin kesuksesan dalam produksi sehingga kegagalan dapat terhindari maupun diminimalisir.

2.7 Konsep Risiko

Berdasarkan standart AS/NZS 4360:2004 Risk Management. Risiko didefinisikan sebagai peluang terjadinya kejadian yang memiliki akibat pada objek tertentu (AS/NZS, 2004).

Kemudian berdasarkan ISO 310000:Risk Management Risiko, didefinisikan sebagai efek dari ketidakpastian dari objek. Efek disini merupakan deviasi dari keadaan normal, sedangkan objek pada pengertian tersebut memiliki aspek yang berbeda (seperti financial, kesehatan, keselamatan, dan tujuan lingkungan) dan bisa diaplikasikan pada level yang berbeda (ISO 31000).

2.7.1 Risk Anatomy

Pemahaman mengenai risiko akan lebih mudah apabila mengenal anatomi dari risiko itu sendiri. Skema anatomi risiko dapat dilihat pada **Gambar 2.6**, risiko dapat dipahami dengan 3 (tiga) pertanyaan:

a) *How likely / how frequent the combination of "source" and "cause" occurred* ?
adalah pertanyaan yang menggambarkan seberapa sering sumber risiko bertemu dengan penyebab terjadinya risiko. Sumber risiko sendiri merupakan produk yang diproses pada suatu sistem. Contoh: hidrokarbon yang mengalir dalam pipa. "*Source of Risk*" cenderung sulit untuk dikurangi eksistensinya karena berkaitan dengan kapasitas produksi itu sendri.
Cause of Risk atau penyebab risiko adalah factor-factor yang melekat pada objek yang dianalisa. Contoh dari *cause of risk* seperti : Third party Damage, Corrosion, Design, Incorrect Operation Index.

b) *What Can go Wrong ?*
Apa yang salah dengan objek yang dianalisa merupakan pendekatan untuk mengenal *risk* . risk akan terjadi apabila terjadi pertemuan antara *cause of risk* dan *source of risk.* Sehingga risiko memiliki sifat terjadi pada masa depan sehingga risiko bisa dihindari atau dikurangi dengan mengaplikasikan preventive maintenance.

c) *What are the Impact ?*
Apa akibat yang akan ditimbulkan bila risiko terjadi ? *Consequence* ini bisa meliputi kesehatan, keamanan, lingkungan, dan financial.

Gambar 2.7 *Risk Anatomi*
(Sumber : In-House Trining RBI by Dwi Priyanta)

2.7.2 *Risk Prevention Model*

Seperti yang dijelaskan pada pembahasan sebelumnya risiko terjadi pada waktu yang akan datang (*future*). Sehingga risiko bisa dicegah dengan melakukan *preventive action* maupun *Corrective Action*.

a) *Preventive Action*
Preventive Action adalah upaya-upaya pencegahan yang dilakukan untuk mencegah atau mengurangi jumlah terjadinya risiko. Upaya ini sering disebut juga dengan *Investment cost* karena dampak dari pembiayaan untuk

melakukan *preventive action* tidak langsung dirasakan. Dengan kata lain upaya ini dilakukan sebelum risiko terjadi. Seperti yang ditampilkan pada **Gambar 2.7** berikut:

Gambar 2.8 *Risk Prevention Model*
(Sumber : In-House Trining RBI by Dwi Priyanta)

b) Corrective Action

Berbeda dengan *Preventive Action, Corrective Action* dilakukan ketika risiko sudah terjadi. Contoh dari aktivitas ini seperti pemasangan *Leak Detection System* pada kasus kebocoran konten yang terdapat pada pipa. Sistem tersebut akan bekerja apabila pipa telah mengalami kebocoran. Baiaya yang dikeluarkan untuk melakukan aktifitas ini dinamakan *recovery cost* . Biasanya orang akan menganggap *Investment Cost* lebih mahal jika dibandingkan dengan *Recovery cost* karena wujudnya yang nyata adanya. Namun secara general *investment cost* lebih murah dari pada *recovery cost*. Namun hal itu juga lebih baik apabila dilakukan penilaian sendiri dengan menggunakan metode Cost Benefit Analysis.

2.8 *American Petroleum Institution* (API)

Dalam penentuan program inspeksi pada PRD ini menggunakan metode risk based inspection berdasarkan API RP 580 dan 581. *American Petroleum Institute* atau API adalah suatu organisasi perkumpulan dari berbagai macam industri di Amerika Serikat yang bergerak dibidang minyak bumi dan gas alam. Adapun tujuan dari standard tersebut adalah membantu para penggunanya dalam usaha meningkatkan efisiensi dan penghematan didalam pengoperasian usaha mereka, dengan tetap mengacu kepada peraturan perundang-undangan, menjaga keselamatan dan kesehatan masyarakat serta untuk menjaga kelestarian.

Berikut beberapa model dari API yang ada keterkaitan dengan pengolahan minyak dan gas bumi dapat dilihat pada **Tabel 2.1**

Tabel 2.1 Produk American Petroleum Institut

No.	API *code*	Judul
1	API 510	Pressure Vessel Inspection Code-Inspection, Repair, Alteration, and Rerating
2	API 570	Piping Inspection Code-Inspection, Repair, Alteration, and Rerating of Inservice Piping Systems
3	API 579	Fitness-For-Service
4	API 653	Tank Inspection, Repair, Alteration, and Reconstruction
5	API 750	Management of Process Hazards
6	API 752	Management of Hazards Associated With Location of Process Plant Buildings, CMA Managers Guide
7	API 941	Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants
8	API 580	Risk-based Inspection
9	API 581	Risk -based Inspection Technology

2.8.1 *API Recommended Practice* 580

API RP 580 merupakan salah satu produk dari API yang berisi persyaratan program minimum untuk memenuhi syarat inspeksi interval berdasarkan analisa RBI versus persyaratan berbasis aturan, dan menyediakan pedoman tambahan yang disarankan untuk menggunakan analisa risiko untuk mengembangkan rencana inspeksi yang efektif. Penggunaan RBI untuk perencanaan inspeksi tidak dipaksakan, melainkan bersifat opsional, tunduk pada pada persyaratan (API RP 580, 2016).

Program inspeksi merupakan proses yang sistematis yang dimulai dengan identifikasi fasilitas atau peralatan dan berujung pada rencana inspeksi. Hasil dari penilaian RBI yang dilakukan sesuai RP ini adalah rencana inspeksi untuk setiap bagian atau kelompok peralatan yang dinilai, yang harus mencakup :

a. Mengidentifikasi penyebab risiko
b. Metode pemeriksaan yang harus dilakukan
c. Tingkat inspeksi (Persen dari total area yang akan diperiksa atau lokasi tertentu)
d. Interval inspeksi atau tanggal pemeriksaan berikutnya (waktu)
e. Kegiatan mitigasi risiko lainnya
f. Tingkat risiko residu setelah inspeksi dan tindakan mitigasi lainnya telah dilaksanakan.

API 580 memberikan panduan untuk mengembangkan program Risk-Based Inspection (RBI) pada peralatan statis seperti perusahaan penyulingan petrokimia, pabrik proses kimia dan fasilitas produksi minyak dan gas bumi. Tujuan dari API RP 580 adalah untuk memperkenalkan prinsip dan pedoman umum minimum untuk RBI saat ini. Praktik yang direkomendasikan menyediakan metode perhitungan kuantitatif untuk menentukan rencana inspeksi.

RBI identik dengan inspeksi prioritas risiko, pemeriksaan dengan informasi risiko, dan dengan perencanaan inspeksi menggunakan metode berbasis risiko. Aset fisik diartikan sebagai seluruh fasilitas baik sebuah komponen maupun sistem yang ada di dalam perusahaan termasuk bangunan dari perusahaan itu sendiri.

2.8.2 *API Recommended Practice* 581

API RP 581 mengatur tentang metodologi inspeksi berbasis risiko, menyediakan prosedur kuantitatif untuk membuat program inspeksi dengan menggunakan metode berbasis risiko untuk peralatan statis termasuk didalamnnya adalah bejana bertekanan, pipa, tangki, *Pressure Relief Device* (PRD) dan tabung heat exchanger.

Perhitungan risiko yang terdapat pada API RP 581 melibatkan penentuan *probabilitas* kegagalan (POF) yang dikombinasikan dengan dengan konsekuensi kegagalan (COF). kagagalan didefinisikan sebagai hilangnya penahan dari tekanan yang ditentukan (batas) yang mengakibatkan kebocoran ke atmosfer dan pecahnya komponen bertekanan. Risiko meningkat sebesar kerusakan terakumulasi selama proses operasi. Tindakan inspeksi sendiri tidak mengurangi risiko dari suatu equipment, namun hal itu mengurangi ketidakpastian dan karena itu memungkinkan lebih banyak kualifikasi yang akurat dari kerusakan yang ada pada setiap komponen (API RP 581, 2016).

2.9 Risk Based Inspection (RBI)

2.9.1 Definisi RBI

RBI adalah proses manajemen dan penilaian risiko yang berfokus kepada jenis kegagalan yang disebabkan oleh menurunnya mutu material, proses RBI dilakukan dengan melakukan inspeksi pada peralatan yang berkaitan.

Tujuan dari RBI adalah untuk mengidentifikasi kerusakan/cacat yang bisa menyebabkan kecelakaan berskala besar sebelum terjadi. Juga untuk menentukan insiden apa yang yang bisa terjadi (konsekuensi) pada saat terjadinya kerusakan pada sebuah peralatan, dan seberapa sering (*probability*) insiden tersebut terjadi (API RP 580, 2016).

Pada metode RBI terjadi kompromi antara financial, bahaya dan risiko yang terjadi pada sebuah peralatan proses pada subuah plant. Tingkat risiko diprioritaskan dengan sistematis sehingga program inspeksi dapat difokuskan peralatan yang memiliki risiko tinggi, sebalinya jika tidak terlalu tinggi maka bisa disesuaikan, sehingga bisa menghemat sumberdaya.

Metodologi RBI menyediakan system yang logis, terdokumentasi dan dapat berulang untuk membuat penentuan frekuensi inspeksi, batasan inspeksi dan type dari uji tidak merusak/ *Non Destructive Examination* (NDE)

Dalam RBI risiko didefinisikan sebagai hasil kali antara probabilitas terjadinya sebuah kejadian yang telah diantisipasi dan konsekuensi dari kejadian tersebut. Secara matematis bisa ditulis sebagai berikut :

Risiko = Probabilitas x Konsekuensi…….. (2.1)

Penilaian risiko adalah proses untuk mengidentifikasi sumber bahaya, memperkirakan risiko dan mengevaluasinya.Proses penialaian risiko akan menjawab beberapa pertanyaan beriku :

a. Hal apa yang bisa membuat masalah
b. Sebarapa sering masalah tersebut bisa muncul
c. Apa konsekuensi dari masalah tersebut

Risiko bisa dituliskan dalam bentuk kuantitatif yaitu sebagai ukuran rugi persatuan waktu atau dalam bentuk kualitatif yang menjelaskan hubungan antara likelihood dan consequence dalam menentukan tingkat risiko atau yang disebut matriks risiko.tingkatan risiko diterjemahkan kedalam bentk warna sebagai berikut :

- Merah untuk risiko tinggi
- Kuning untuk risiko sedang
- Hijau untuk risiko rendah

2.9.2 Keuntungan RBI

Penggunaan metode RBI dapat meningkatkan keefektifan dan peningkatan efisiensi dari inspeksi dengan :

1. Memperbaiki manajemen keselamatan dan kesehatan kerja.
2. Menghapus kegiatan-kegiatan inspeksi yang tidak perlu-interval inspeksi berdasarkan risiko dari peralatan
3. Sumberdaya inspeksi akan focus pada peralatan yang berada pada area risiko tinggi.
4. Penghematan biaya, peralatan yang tidak memiliki masalah selama instalaasi mulai beroperasi mulai beroperasi dan problem antisipasi akan diinspeksi dalam jangka waktu yang lebih lama.
5. Informasi yang diperoleh dari inspeksi pada satu peralatan dapat digunakan untuk menentukan jangka waktu dan ruang lingkup inspeksi pada satu peralatan yang sama dan tipikal.
6. Program RBI adalah program yang dinamis, risiko selalu diperbarui setelah inspeksi atau bila peralatannya sama. Perubahan kondisi proses atau kejadian jika informasi baru merupakan informasi yang layak untuk dipertimbangkan.
7. Beberapa hal tersebut akan mengakibatkan perunahan frekuensi dan ruang lingkup inspeksi.
8. Metode yang digunakan untuk menentukan jangka waktu dan ruang lingkup didokumentasikan dan dapat digunakan lagi.
9. RBI merupakan metode yang reliabilitas dan dapat diaplikasikan dengan Code/Standart dan peraturan yang berlaku.
10. Meningkatkan kemampuan dan memperpanjang umur instalasi nuklir.
11. Optimalisasi jadwal perbaikan dan pergantian peralatan.

2.9.3 Batasan RBI

RBI tidak akan menghilangkan risiko, probabilitas dan konsekuensi risiko dari peralatan akan selalu dicantumkan. RBI berguna untuk membantu mengatur dan mengontrol risiko kepada tingkat yang masih bisa diterima dengan memprioritaskan sumberdaya kepada peralatan yang diketahui memiliki risiko tinggi.

2.9.4 RBI Untuk Pressure Relief Device

Fokus utama pada *Pressure Relief Device* (PRD) dan alasan utama terhadap inspeksi dan pengujian PRD adalah karena device bisa saja mengalami kegagalan untuk melepaskan tekanan berlebih yang dapat menyebabkan kegagalan pada perangkat yang dilindungi, terutama yang mengakibatkan *loss containment* . serta terdapat beberapa konsekuensi lain terhadap kegagalan dari PRD.

Pendekatan *Risk-based* untuk mengevaluasi tingkat kekritisan PRD untuk menetapkan frekuensi inspeksi/pengujian yang terlampir pada penelitian ini. Cakupan dari penilaian ini mencakup semua jenis spring-loaded, pilot operated dan rupture disk yang telah dibahas pada pembahasan sebelumnya.

Pendekatan mendasar dengan menggunakan *demand rate* pada device yang dikombinasikan dengan *Probability Of Failure On Demand* (POFOD) yang ditentukan dari data *specific plant* bila memungkinkan. Atau untuk pemula bisa menggunakan default data. Masukan data ini untuk menetapkan POF yang merupakan fungsi dari waktu pada pendekatan *weibul statistic* . Konsekuensi dari kegagalan PRD akan dibahas pada penjelasan berikutnya. Kombinasi dari konsekuensi dan POF terhdap waktu menghasilkan *risk value* yang semakin meningkat sepanjang interval waktu pengetesan.

Terdapat beberapa model kegagalan yang sering terjadi ketika mengevaluasi risiko yang berkaitan dengan kegagalan PRD. Untuk PRD, model kegagalannya di kelompokan menjadi 2 kategori.

a) Fail to Open (FAIL) :
   - Stuck or Fails to Open (FTO)
   - Device Partially Open (DPO)
   - Opens above set pressure (OASP)

b) Leakage Failure (LEAK)
   - Leakage Past Device (LPD)
   - Spurious/Premature opening (SPO)
   - Device Stuck open (DSO)

Kegagalan untuk membuka (FAIL) adalah model kegagalan utama, karena kegagalan ini menghasilkan potensi overpressuring peralatan yang dilindungi dan kehilangan penahanan. Karena kegagalan in menghasilkan potensi overpressuring peralatan yang dilindungi dan kehilanagan penahan. Termasuk dalam hal ini adalah saat perangkat hanya membuka sebagian (DPO), dimana konsekuensinya tidak separah FTO . API RP 581 secara konservatif menganggap setiap data yang menunjukan perangkat OASPN termasuk dalam kategori FAIL. Karena kurva POF didasarkan pada pengujian dimana kegagalan didefinisikan apabila ketika tes

dilakukan membutuhkan tekanan lebih besar dari 1.3 kali tekanan yang telah ditetapkan. Bila PRD membuka tidak melebihi 1.3 kali dari tekanan yang ditetapkan maka PRD dianggap sukses. Konsekuensi terhadap kegagalan FAIL meliputi kebakaran, ledakan pada personil dan peralatan, paparan personil terhadap cairan beracun sebagai akibat hilangnya penahan.

Perhatian sekunder dari penilaian PRD adalah kegagalan PRD untuk menahan proses saat saat beroperasi pada kondisi normal. Pada API 581 mengelompokan tiga kegagalan yang tersisia kedalam kategori LEAK. Kebocoran melewati perangkat (LPD), Pembukaan yang terlalu cepat (SPO) , dan perangkat yang terjebak membuka. (DSO) adalah kegagalan yang tidak akan mengakibatkan overpressure atau kehilangan penahan dari peralatan yang dilindungi, tetapi akan menghasilkan potensi kebocoran yang tidak dapat diterima dari sistem proses. Konsekuensi dari kebocoran melalui PRD dapat berkisar dari gangguan ringan, hilangnya sebagian produk, hingga konsekuensi yang lebih parah yang mengakibatkan proses shutdown.

2.10 Perhitungan Probabilitas

Untuk PRD, penting untuk mendefinisikan kegagalan, karena hal itu berbeda dengan jenis kegagalan perlengkapan lain. Kegagalan PRD didefinisikan sebagai kegagalan untuk membuka selama situasi darurat yang menyebabkan suatu situasi overpressure pada perangkat yang dilindungi. Sehingga mengakibatkan *loss containment* (kegagalan/tahun). Kebocoran juga merupakan suatu kegagalan. Jenis kegagalan pada PRD telah dibahas pada bagian 2.6.4.

2.10.1 Perhitungan Probabilitas Kegagalan Membuka

Perhitungan mendasar yang diterapkan pada PRD untuk kasus kegagalan membuka adalah perkiraan dari *overpressure demand case frequency* (atau demand rate), probabilitas PRD gagal untuk membuka sesuai permintaan, dan kemungkinan bahwa peralatan yang dilindungi pada tekanan tinggi kehilangan penahanan. PRD melindungi komponen peratan dari beberapa skenario *overpressure*. Kasus permintaan dan desain sistem pereda tekanan disediakan dalam API 521. Masing masing scenario ini (Kebakaran, debit yang tersumbat, dll) dapat menghasilkan tekanan berlebih yang berbeda, $P_{o,j}$, jika PRD gagal membuka ketika dibutuhkan. Selain itu, setiap scenario tekanan berlebih memiliki tingkat permintaan sendiri ,$DR_{j,}$ untuk menggambarkan perhitungan POF untuk PRD yang khusus *overpressure demand* seperti yang ditunjukan pada persamaan (2.2)

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j} \quad \text{.....Persamaan (2.2)}$$

Notasi j, perlu dihitung untuk masing-masing setiap tekanan berlebih yang memungkinkan terjadi yang berhubungan dengan PRD. $P_{f,j,}$ adalah fungsi dari waktu dan potensi tekanan berlebih. API 581 memperhitungkan peningkatan kemungkinan hilangnya penahan dari peralatan yang dilindungi karena tekanan yang berlebih yang meningkat apabila PRD gagal membuka selama kejadian darurat.

a. PRD Demand Rate

Langkah pertama dalam mengevaluasi probabilitas kegagalan PRD adalah menentukan tingkat permintaan (*demands or events/year)* yang terdapat pada PRD. API RP 581 memberikan perkiraan untuk *Initiating event frequencies*

Konsep faktor reduksi *demand rate* ,$DRRF_J$, diperkenalkan di sini untuk menjelaskan perbedaan dalam frekuensi kejadian overpressure, dan *demand rate* pada PRD. Banyak instalasi *vessel* bertekanan termasuk didalam sistem control, memiliki instrumentasi pelindung integritas tinggi, *sistem shutdown* dan lapisan perlindungan lainnya untuk mengurangi tingkat *demand rate* pada PRD. $DRRF_J$ ini digunakan untuk menjelaskan lapisan perlindungan tambahan ini.

b. PRD Probability of Failure on Demand

Tahap berikutnya adalah mendapatkan probabilitas bahwa PRD akan gagal untuk membuka atas permintaan dalam layanan. API RP 581 memberikan kegagalan default pada tingkat kegagalan permintaan yang dikembangkan dari data industri.

c. Protected Equipment Failure Frequency as a result of overpressure

Masing-masing peralatan yang dilindungi memiliki kerusakan yang disesuaikan dengan frekuensi kegagalan generic peralatan dikalikan dengan DF (damage factor). DF ditentukan berdasarkan mekanisme kerusakan yang berlaku untuk perawatan, riwayat inspeksi dan kondisi peralatan. Damage Faktor pada peralatan yang dilindungi dihitung sebagai fungsi waktu.

2.10.2 Perhitungan Probabilitas Kebocoran

Kasus kebocoran berbeda dari kasus kegagalan membuka karena POF bukan merupakan fungsi dari tingkat permintaan bukan didasarkan pada kegagalan selama operasi berkelanjutan. Data Industri Terkait dengan probabilitas kebocoran, P_l , data dalam satuan per tahun(kegagalan/tahun). Tidak ada keterkaitan dengan permintaan apapun yang diperlukan.

2.11 Perhitungan Konsekuensi

Analisis konsekuensi dilakukan untuk mengetahui dampak sebuah risiko jika terjadi pada sebuah equipment. Analisis konsekuensi ini menggunakan pendekatan area terdampak baik dalam bentuk luas area terbakar, luas area radiasi panas yang berdampak pada manusia, dan luas area terdampak racun. Adapun kategori tersebut dijelaskan dalam API 581 sebagai berikut :

- Konsekuensi kebakaran dan ledakan
  Konsekuensi ini dihitung dengan menggunakan even tree analysis (ETA) untuk mendapatkan probabilitas-probabilitas dari berbagai kemungkinan kegagalan baik pool fires, flash fires, maupun vapor cloud explosion, dan dikombinasikan dengan pemodelan komputer untuk menentukan besarnya konsekuensi. Konsekuensi area ditetukan

berdasarkan kecelakaan pada personil dan kerusakan komponen akibat radiasi suhu dan ledakan. Kerugian finansial juga ditentukan berdasarkan area yang terkena dampak keluaran fluida tersebut.

- Konsekuensi keracunan
  Dihitung dengan menggunakan pemodelan komputer untuk menentukan besarnya konsekuensi area sebagai hasil dari luasan area yang mengandung konsentrasi beracun yang terlepas ke luar ke personil dan lingkungan.
- Pelepasan non-flammable dan non-toxic
  Konsekuensi ini juga harus diperhitungkan karena keduanya dapat menyebabkan luka parah terhadap personil maupun dapat merusak komponen dari percikan bahan kimia dan pembakaran uap dengan suhu yang tinggi serta ledakan.

Dalam perhitungan analisis konsekuensi kegagalan PRD berdasarkan API 581 diawali dengan menentukan nilai *overpressure* ketika terjadi kegagalan sebagai pengganti tekanan operasi. Langkah-langkah dalam menentukan nilai *overpressure* saat terjadi kegagalan adalah sebagai berikut :

1. Menentukan daftar skenario *overpressure* yang berlaku untuk peralatan yang dilindungi oleh PRD yang dievaluasi.
2. Untuk setiap *overpressure demand case* , memperkirakan jumlah tekanan berlebih, $P_{o,j}$ yang mungkin terjadi selama *overpressure* jika PRD gagal membuka.
3. Untuk instalasi yang memiliki beberapa PRD , tentukan jumlah total area orifice PRD yang dipasang, $A_{prd,}$ mencakup area PRD yang sedang dievaluasi.
4. Kurangi *overpressure* scenario yang ditentukan pada langkah 3 dengan faktor penyesuai sesuai dengan persamaan (2.3).

$$P_{o,j} = F_a \, . \, P_{o,j} \quad \text{.....Persamaan (2.3)}$$

5. Gunakan hasil dari langkah 4 sebagai pengganti tekanan operasi, $P_{s,}$

Setelah mendapatkan nilai $P_{o,j}$ sebagai pengganti tekanan operasi, maka langkah berikutnya menyesuaikan dengan perhitungan analisis konsekuensi yang dikembangkan dalam bagian 3 API 581. Langkah-langkah tersebut sebagai berikut :

1. Menentukan fluida yang terlepas bila terjadi kegagalan berserta sifat-sifatnya, termasuk sifat didalamnya.
2. Memilih set ukuran lubang yang tercipta bila terjadi overpressure dan PRD mengalami kegagalan untuk menentukan kemungkinan konsekuensi pada perhitungan risiko.
3. Menghitung laju *loss of containment,* W_n
4. Mengestimasikan massa total dari fluida yang kemungkinan *release,* $Mass_{avail}$

5. Menentukan tipe *release, continuous* atau *instantaneous* yang digunakan untuk memodelkan dispersi dan konsekuensi.
6. Mengestimasikan dampak sistem pendeteksi dan isolasi.
7. Menentukan laju pelepasan($Rate_n$) dan massa ($Mass_n$) untuk analisis konsekuensi
8. Menghitung konsekuensi kebakaran/ledakan, $CA_{cmd,n}^{flam}$ & $CA_{inj,n}^{flam}$
9. Menghitung konsekuensi area *toxic,* CA_{inj}^{tox}
10. Menghitung *non-flammable*, *non-toxic consequence*
11. Menentukan probabilitas kerusakan akhir peralatan dan cedera personil, CA_{cmd}^{flam}, & CA_{inj}^{flam}
12. Menghitung konsekuensi akhir, CA

2.12 *Risk Ranking*

Memetakan nilai *Probability* dan *Consequency* pada matriks risiko adalah metode yang efektif untuk mempresentasikan risiko secara grafis. Probability di plotkan pada sumbu absis, bertambah besar dari titik awalnya. Pengeplotan ini menjadi tanggung jawab dari pengguna untuk mendefinisikan dan mendokumentasikan sebagai dasar untuk menentukan rentang kategori *Probability* dan *Consequency* dan target risiko yang digunakan. Studi implementasi inspeksi berbasis risiko terhadap *Central Processing Plant* (CPP) pada penelitian ini menggunakan *iso-risk line* dengan batas level risiko 40 ft^2 (3,7 m^2). **Tabel 2.2** merupakan table kategori nilai *probability of failure* dan *consequence of failure.* Terdapat beberapa pemodelan dalam *risk plotting* yang bisa digunakan seperti *risk matrix* dan *iso-risk plot.*

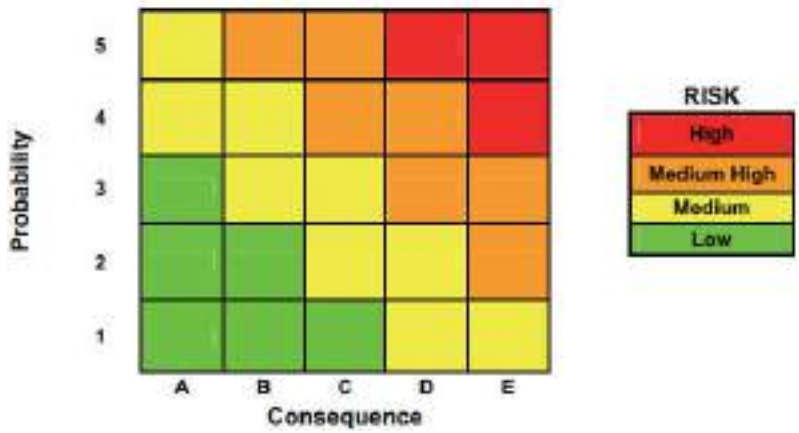
Tabel 2.2 hubungan antara nilai Probability of Failure dan Area based Consequence of failure

Probability Category		Consequence Category	
Kategori	**Probability Range**	**Kategori**	**Range (m2)**
1	Pf (t, I E) ≤ 3.06E − 05	A	CA ≤ 9.29
2	3.06E − 05 < Pf (t, I E) ≤ 3.06E − 04	B	9.29 < CA ≤ 92.9
3	3.06E − 04 < Pf (t, I E) ≤ 3.06E − 03	C	92.9 < CA ≤ 929
4	3.06E − 03 < Pf (t, I E) ≤ 3.06E − 02	D	929 < CA ≤ 9, 2 90
5	Pf (t, I E) > 3.06E − 02	E	CA > 9,290

a) Risk Matrix

Menyajikan risiko dalam matrix adalah cara efektif untuk menunjukan distribusi risiko untuk komponen dalam unit proses tanpa menggunakan nilai numeric. Dalam matrik risiko, kategori *probability* dan *consequence* disusun sedemikian rupa. Komponen risiko tertinggi mengarah kesudut

kanan atas. **Gambar 2.8** merupakan *balance risk matrix* yang digunakan dalam studi inspeksi berbasis risiko.

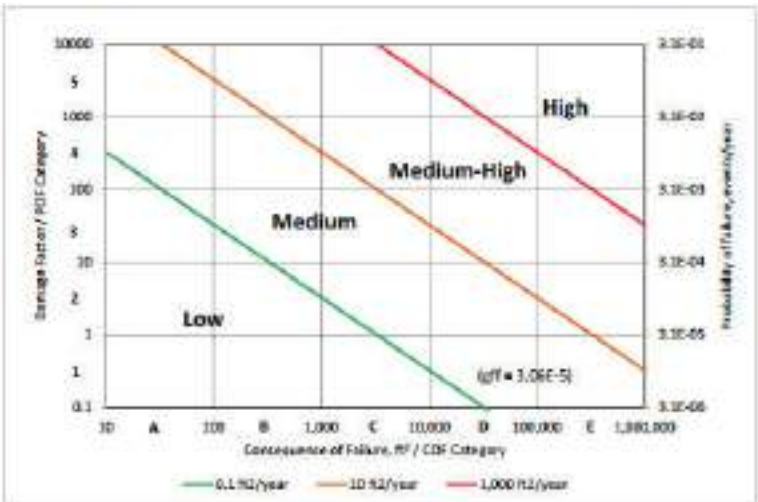


Gambar 2.9 Balance Risk Matrix
(Sumber : API RECOMMENDED PRACTICE 581)

Gambar 2.8 digunakan untuk mengetahui level risiko pada setiap equipment secara *qualitatatif*. Untuk menghilangkan *bias* dalam penentuan level risiko, batas level risiko 40 ft^2/yr (3,7 m^2/yr) digunakan.

b) Iso Risk Plot

Metode lain yang efektif dalam menyajikan hasil risiko adalah plot iso-risk. Sebuah plot iso-risk secara grafis menunjukkan *Probability* dan Nilai *Consequency* dalam log-log, grafik dua dimensi di mana risiko meningkat menuju sudut kanan atas. Komponen dekat garis risiko iso mewakili tingkat risiko yang setara. Komponen diberi peringkat berdasarkan risiko untuk inspeksi, dan rencana inspeksi dikembangkan untuk komponen berdasarkan kriteria *acceptable risk* yang ditetapkan yang telah ditentukan. **Gambar 2.9**. menjelaskan setiap level risiko pada 0.1 ft^2/yr, 10 ft^2/yr, dan 100 ft^2/yr. Karena risiko yang diterima (*risk target*) pada level kurang dari 40 ft^2/yr (3,7 m^2/yr), maka setiap *equipment* yang memiliki risiko diatas garis 40 ft^2/yr harus dilakukan inspeksi untuk mendapatkan informasi terbaru, jika sebaliknya risiko dapat diterima.



Gambar 2.10 Example Iso-Risk plot for Area Concequence
(Sumber : API RECOMMENCED PRACTICE 581)

2.13 *Inspection Planning*

Dalam suatu unit proses, Program Inspeksi dan pengetesan dibuat untuk mengetahui dan mengevaluasi penurunan mutu dikarenakan proses operasi. Karena hal itulah pada awalnya dengan tujuan memverifikasi integritas sebuah peralatan sebuah organisasi menentukan interval inspeksi berdasarkan waktu (*Time based inspection).*

Inspection planning disusun berdasarkan level risiko sebuah equipment pada saat analisis RBI dilaksanakan. Inspeksi tersebut jika dilaksanakan tidak serta merta mengurangi risiko yang terdapat pada sebuah *equipment* namun dengan melaksanakan inspeksi diharapakan mendapatkan informasi aktual pada sebuah *equipment*. Ketepatan dan akurasi sebuah informasi digunakan untuk lebih memahami kondisi sebuah *equipment* sehingga mampu mengurangi ketidakpastian (*uncertainty*) dalam analisis POF.

Inspection planning didesain untuk mendeteksi dan mengukur spesifik tipe dari korosi yang mungkin terjadi seperti *local corrosion* atau *general corrosion*, *cracking*, atau tipe kerusakan yang lainnya. Setiap jenis kerusakan memiliki metode tersendiri untuk mendekteksi dan mengukurnya. Sehingga *inspection plan* dikatakan effektif jika metode inspeksi dan luasan daerah yang di inspeksi mewakili jenis kerusakan yang mungkin terjadi. **Table 2.3** menjelaskan kategori dari *inspection effectiveness* secara umum.

Tabel 2.3 Kategori Inspection Effectiveness

Inspection Effectiveness Category	***Inspection Effectiveness Description***	***Description***
A	*Highly Effective*	*The inspection methods will correctly identify the true damage state in nearly every case (or 80-100% confidence).*

B	*Usually Effective*	*The inspection methods will correctly identify the true damage state most of the time (or 60-80% confidence).*
C	*Fairly Effective*	*The inspection methods will correctly identify the true damage state about half of the time (or 40-60% confidence).*
D	*Poorly Effective*	*The inspection methods will provide little information to correctly identify the true damage state (or 20-40% confidence).*
E	*Ineffective*	*The inspection method will provide no or almost no information that will correctly identify the true damage state and are considered ineffective for detecting the specific damage mechanism (less than 20% confidence).*

Terdapat 4 kategori *inspection effectiveness pressure relieve device*, setiap kategori memiliki metode inspeksi dan dokumentasi informasi yang berbeda-beda. **Tabel 2.4** menjelaskan kategori PRD *inspection effectiveness*.

Tabel 2.4 Kategori PRD Inspection Effectiveness

Inspection Effectiveness	***Component Type***	***Description of Inspection***
Highly Effective A	*Pressure Relief Device*	*A bench test has been performed on the PRD in the as-received condition from the unit and the initial leak pressure, opening pressure and the reseat pressure has been documented on the test form. The inlet and outlet piping has been examined for signs of excessive plugging or fouling.*
Usually Effective B	*Pressure Relief Device*	*A bench test has been performed, however, the PRD was cleaned or steamed out prior to the bench test. Additionally, a visual inspection has been performed where detailed documentation of the condition of the PRD internal components was made. An in-situ test has been performed using the actual process fluid to pressurize the system.*
Fairly Effective C	*Pressure Relief Device*	*A visual inspection has been performed without a pop test, where detailed documentation of the condition of the PRD internal components was made. A trevitest or in-situ test has been performed where the actual process fluid was not used to pressurize the system.*
Ineffective D	*Pressure Relief Device*	*Valve overhaul performed; No pop test conducted/documented*

Berdasarkan API 576 alasan untuk inspeksi dan pengetesan terhadap PRD sebagai fungsinya untuk melepaskan tekanan berlebih terhadap perlengkapan yang dilindungi karena gangguan operasional,kebakaran eksternal, dan bahaya lainnya. Bahaya ini dibahas dalam API 521. Kegagalan alat-alat penghilang tekanan berfungsi

dengan baik ketika diperlukan dapat mengakibatkan tekanan berlebih pada *vessel, exchangers, boilers*, atau peralatan lain yang dilindungi oleh PRD. Inspeksi dan pengujian pada PRD berguna untuk memastikan kondisi PRD dalam kondisi operasi yang baik hal tersebut penting untuk keselamatan *personel* dan perlindungan peralatan selama keadaan *abnormal.*

Inspeksi pada *Pressure Relief Device* harus menentukan kondisi fisik dan operasi umum perangkat, dan memastikan bahwa kinerjanya memenuhi persyaratan untuk pemasangan yang diberikan. API 576 menyediakan dua jenis inspeksi yang bisa digunakan. Metode tersebut dengan "*shop inspection/overhauls"* dan "*visual on-stream inspection"* masing-masing teknik dalam melakukan inspeksi terhadap PRD dibahas pada sub bab 2.12.1 dan 2.12.2.

2.13.1 Shop Inspection/Overhaul

Secara berkala, PRD akan di pindahkan, dibongkar, dan diperiksa. Inspeksi ini disebut sebagai "*Shop Inspection/overhauls"* (meskipun ada beberapa kasus yang bisa diselesaikan dalam lapangan). Selain itu, ketika PRD dilepaskan , *inlet* dan *outlet* pipa harus diperiksa untuk keberadaan deposit internal, dan perlu adanya catatan untuk kondisi dan pembersihannya. Berikut adalah langkah dalam *shop inspection* :

a. Keamanan
   Sebelum inspeksi dan perbaikan apapun pada PRD dijalankan, tindakan umum harus diambil untuk menjaga keamanan peralatan yang dilindungi oleh perangkat, terutama jika peralatan tersebut beroperasi. Ketika pemeriksaan dan perbaikan pada unit operasi diperlukan, operasi unit harus normal dan perlakuan yang tepat dan izin untuk pekerjaan harus diperoleh.
b. Pengidentifikasian *Valve*
   Untuk meminimalkan kesalahan dalam pengujian dan penanganan PRD, masing-masing harus membawa tanda pengidentifikasi, stensil, pelat, atau sarana lain untuk menunjukkan nomor peralatan perusahaannya. Nomor ini siap mengidentifikasi unit perangkat, peralatan yang harus dipasang pada perangkat, tekanan yang ditetapkan perangkat, dan tanggal pengujian terakhirnya.
c. Catatan Kondisi Operasi
   Riwayat operasi dari setiap PRD sejak pemeriksaan terakhir harus diperoleh dan harus mencakup informasi terkait seperti berikut:
   - Informasi tentang gangguan dan efeknya pada katup
   - Tingkat kebocoran saat dalam layanan
   - *Any other evidence* yang tidak berfungsi
   - Apakah ada *disk* yang pecah dibawah PRD telah diganti

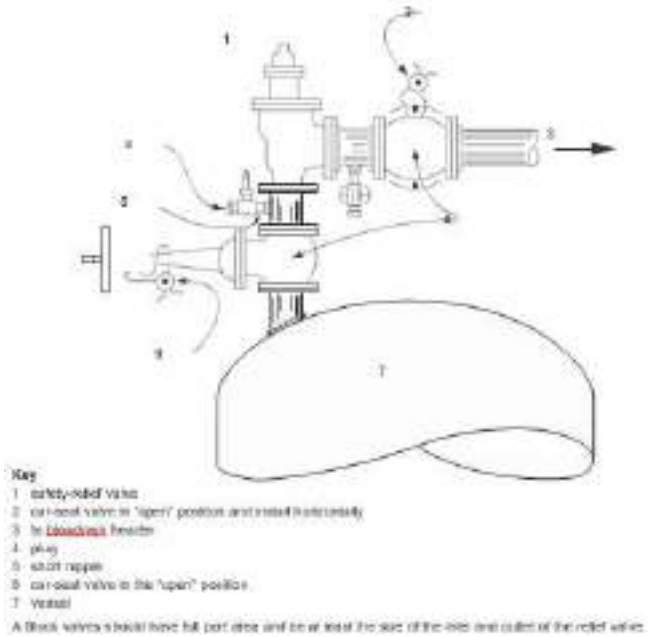
   Selain itu, catatan kinerja katup selama operasi sebelumnya harus diperiksa untuk menentukan apakah perubahan diperlukan dalam bahan atau komponen *valve* atau dalam interval pemeriksaan.
d. Pemindahan PRD dari Sistem Operasi
   Hal yang perlu diperhatikan disini pemindahan PRD dari peralatan dalam operasi harus direncanakan untuk meminimalkan durasinya. Perangkat bantuan adalah perangkat keamanan dan harus diperlakukan seperti itu,

Sebelum katup pelepas tekanan diperiksa dan / atau diperbaiki saat peralatan sedang beroperasi, tindakan pencegahan berikut harus dilakukan.

- Hanya orang yang berwenang yang harus mengisolasi perangkat bantuan dengan menutup setiap blok katup yang berdekatan di hulu atau hilir
- Ruang antara perangkat relief dan katup blok yang berdekatan harus dilepaskan ke lokasi yang aman untuk melepaskan cairan pembebanan yang terperangkap dan untuk menentukan apakah katup blok ditahan.
- ka katup blok tidak dipasang di sisi hilir perangkat pelepasan ke *header* umum, isolasi atau yang sesuai lainnya harus diterapkan untuk mencegah keluarnya aliran melalui pipa outlet terbuka jika salah satu perangkat bantuan lainnya terbuka
- Dalam situasi di mana perangkat bantuan harus diperbaiki di tempat, alat isolasi positif atau lain harus dimasukkan antara katup pelepas tekanan dan setiap katup hulu dan / atau blok hilir yang berdekatan sebelum katup pelepas tekanan bahkan sebagian dibongkar
- bagian dari pelepasan katup pelepas yang menyertai, pertimbangan serius harus diberikan untuk memasang *rupture disk* baru karena piringan dapat dengan mudah rusak. dan bisa gagal meledak pada tekanan yang tepat jika digunakan kembali.
- Semua *blinds* harus dilepas setelah perangkat bantuan diperiksa, diperbaiki, atau diganti. Katup blok pada inlet dan outlet harus dibuka dan dikunci atau disegel pada posisi itu. Gambar 2.16 menunjukkan instalasi katup tekanan-relief dengan katup blok tertutup rapat.

e. Initial Inspection

Banyak jenis endapan atau produk-produk korosi PRD yang mungkin longgar dan dapat putus selama pemindahan *valve* ke *workshop* untuk pemeriksaan, pengujian, pemeliharaan, dan pengaturan ulang. Segera setelah katup dikeluarkan dari sistem, inspeksi visual harus dilakukan. **Gambar 2.11** menunjukkan deposit sulfur dalam katup. Ketika *fouling* adalah masalah sebaiknya mengumpulkan sampel untuk pengujian dan merekam lokasi dan penampakan deposit. Setiap penghalang di katup harus dicatat dan dihilangkan. Perlu diperhatikan valve yang telah terpapar bahan berbahaya bagi manusisa atau yang mungkin mengandung bahan yang dapat menjadi sumber pengapian otomatis harus ditangani dengan tindakan pencegahan khusus.



Gambar 2.11 *Block Valves on Safety-relief Valve Inlet and Outlet Sealed Open and Bleeders Installed to Depressure Inlet and Outlet*
(Sumber : API 576 *Inspection of Pressure Relief Device)*

Gambar 2.12 Sulfur Deposits pada Body Valve
(Sumber : API 576 *Inspection of Pressure Relief Device)*

f. Inspeksi inlet dan outlet perpipaan yang berdekatan
Inspeksi perpipaan pada PRD akan sering menunjukkan kondisi perpipaan proses yang interiornya tidak terlihat. Perpipaan harus diperiksa apakah ada korosi, indikasi penipisan, dan endapan yang dapat mengganggu operasi

katup. Karakter deposit dapat menunjukkan penyebab kebocoran dari katup dalam sistem tertutup.

g. Pemindahan valve pada workshop
Pengiriman PRD yang tidak tepat dapat memiliki efek merugikan pada pengoperasian perangkat. Perangkat pelepas tekanan harus diperlakukan dengan tindakan pencegahan yang sama seperti instrumentasi, dengan hati-hati untuk menghindari penanganan kasar atau kontaminasi sebelum pemasangan. Penanganan yang tidak tepat selama transportasi ke workshop menghasilkan *tes pop* yang tidak akurat, yang dapat menyebabkan penyesuaian yang tidak tepat terhadap interval pemeriksaan perangkat.

h. Menentukan "As Received" Pop Pressure
Periksa apakah segel utuh pada penutup sekrup set tekanan dan penutup sekrup ring blowdown. Sebelum katup dibongkar, tekanan pop katup harus diperoleh. Umumnya katup pelepas tekanan dipasang pada blok uji, dan tekanan saluran masuk perlahan-lahan ditingkatkan. Tekanan saat meregangkan katup dicatat sebagai tekanan pop "As Received". Biasanya, tekanan saluran masuk tidak meningkat melebihi 150% dari tekanan katup pelepas tekanan.

i. *Visual Inspection*
Setelah tes pop "*as received*", katup harus diperiksa secara visual untuk memperkirakan kondisinya ketika dikeluarkan dari *service*. Inspeksi ini harus dilakukan oleh perbaikan katup perbaikan katup mekanik kecuali terdapat kondisi korosi, endapan, atau kondisi dicatat dalam. Hasil pemeriksaan ini harus dicatat pada formulir yang sesuai.

j. *Dismantling of Valve*
Setelah katup diterima dan pengujian dan pemeriksaan visual awal selesai, mungkin diperlukan pembongkaran untuk pemeriksaan dan perbaikan toko secara menyeluruh. Jika katup telah diuji pada interval yang sesuai yang ditetapkan sesuai dengan API 510.

k. Pembersihan dan Inspeksi bagian PRD
Untuk menjaga bagian-bagian setiap katup terpisah dari katup lain, bagian katup harus ditandai dengan benar, dipisah, dan dibersihkan secara menyeluruh. Bagian katup yang paling sering membutuhkan pembersihan adalah nozel, pegas, dan *seat*. Deposito yang sulit dihilangkan harus dibersihkan dengan pelarut, disikat dengan kawat, manik-manik kaca yang dihancurkan atau digores dengan hati-hati.

l. Pengkondisi dan penggantian Plat
Bagian yang di luar toleransi atau rusak harus diganti atau direkondisi. Rusak *spring*, *bellow,* dan komponen sekali pakai, bahkan yang tampaknya tidak rusak, harus diganti. Semua barang lembut, bahkan yang tampaknya tidak rusak, harus diganti. Suku cadang untuk katup pelepas tekanan tertentu harus diperoleh dari produsennya. Tubuh katup, *flensa,* dan kap mesin dapat direkondisi dengan cara yang sesuai untuk perbaikan pada bagian-bagian lain yang mengandung tekanan dari bahan yang sama. Jika bukti aus atau kerusakan ditemukan pada *disk* atau *nosel*, permukaan tempat duduk mereka

mungkin dikerjakan atau dibelit. Ikuti rekomendasi pabrikan saat merekondisi suku cadang katup.

m. Reassembly of Valve

Setelah katup diperiksa dan bagian-bagiannya telah direkondisi atau diganti, maka harus dipasang kembali sesuai dengan instruksi pabrik. Permukaan tempat duduk *nosel* dan piringan tidak boleh diminyaki. Jarak bebas antara bagian yang dirakit harus diperiksa. Sesuai dengan instruksi pabrikan, pegas harus disesuaikan agar meletus sedekat mungkin dengan tekanan set yang diinginkan.

n. Setting of Valve Set Pressure

Setelah katup telah direkondisi dan dipasang kembali, pegasnya harus disesuaikan untuk terakhir kalinya untuk memastikan katup akan hilang pada kondisi yang diperlukan. Meskipun prosedur uji akan bervariasi sesuai dengan praktik tanaman setempat, katup umumnya dipasang di blok uji dan tekanan udara atau air dinaikkan secara perlahan sampai katup lepas.

o. Completion of Necessary Record

Semua catatan yang diperlukan harus diselesaikan sebelum katup ditempatkan kembali ke layanan. Dengan membantu menentukan kapan harus mengganti komponen katup dan kapan harus mengundurkannya, catatan sangat penting untuk penggunaan masa depannya yang efektif.

p. Inspection, Testing, Maintenance, and setting

PRD dapat diuji untuk tekanan yang diatur dan kebocoran dengan medium pengujian gas inert melalui pemeras. Metode ini lebih rendah daripada prosedur blok uji. Ini menghasilkan hasil pengujian yang tidak akurat untuk katup-katup pelepas tekanan duduk logam kecuali volume hulu yang mencukupi disediakan yang memungkinkan katup untuk membuka hingga setengah dari daya angkat penuh. Jika volume hulu yang tersedia tidak cukup untuk menyebabkan katup pelepas tekanan mencapai sekitar setengah angkat, penggunaan perangkat pengangkat terbatas dianjurkan untuk menghindari kerusakan katup dari pemuatan benturan yang disebabkan oleh terlalu cepatnya penutupan.

2.13.2 Visual On-stream Inspection

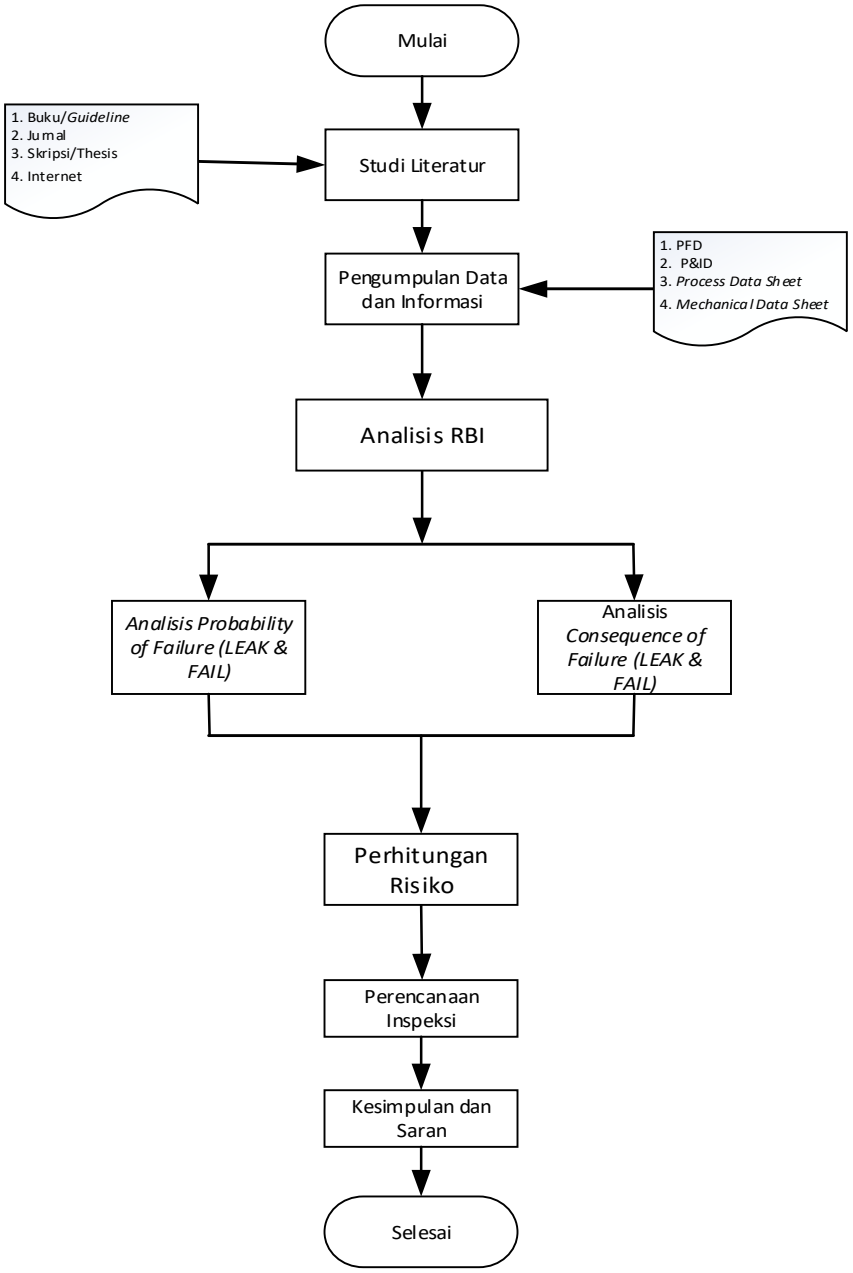
Inspeksi on-stream visual yang lengkap harus memastikan hal-hal berikut:

- Perangkat bantuan yang benar telah dipasang
- Identifikasi perusahaan (seperti *tag* atau *stensil*) menyediakan sarana untuk menetapkan tanggal tes terakhir dan pengaturan tekanan yang tepat untuk peralatan yang dilindungi oleh perangkat yang diidentifikasi.
- Informasi dalam cocok dengan catatan file peralatan dan bahwa interval uji yang ditetapkan belum terlampaui.
- Tidak ada sumbat, kerai, katup tertutup, atau obstruksi perpaan akan mencegah perangkat berfungsi dengan baik
- Segel yang dipasang untuk melindungi pengaturan pegas dan pengaturan pin cincin belum rusak.

- Perangkat bantuan tidak bocor. Katup pelepas tekanan yang telah dibuka dalam layanan sering bocor. Deteksi dan koreksi kebocoran ini menghilangkan hilangnya produk dan kemungkinan pencemaran serta mencegah fouling dan selanjutnya menempel pada katup. Jika katup adalah katup bellow, ventilasi bellow harus diperiksa untuk kebocoran.
- Lubang ventilasi terbuka dan bersih, dan perpipaan yang terhubung diarahkan ke lokasi yang aman. "Lokasi aman" bisa berarti atmosfer.
- Blok katup hulu dan hilir disegel atau dirantai dan dikunci pada posisi yang tepat. Perangkat yang memastikan bahwa katup blok dalam posisi yang tepat termasuk mengunci pita plastik, segel mobil, rantai dan gembok, dan perangkat penguncian khusus yang dibuat khusus untuk jenis katup blok tertentu. Kondisi lapangan harus mencerminkan diagram perpipaan dan instrumentasi yang berlaku (P & ID).
- Ventilasi, pemipaan debit, dan *nipple* kecil didukung dengan benar untuk menghindari kerusakan atau kebocoran. nipple yang tidak didukung atau berlebih dapat rusak selama pemeliharaan dan getaran.
- Pengaliran tubuh katup dan saluran ventilasi tumpukan terbuka.
- Setiap pengangkat tuas dapat dioperasikan dan diposisikan dengan benar.
- Pelipatan, insulasi, atau pembersihan panas yang sangat penting untuk operasi yang tepat dari sistem bantuan masih utuh dan beroperasi dengan benar.
- Alat pengukur yang dipasang sebagai bagian dari kombinasi piringan pecah dan katup pelepas tekanan atau alat untuk memeriksa tekanan antara katup pelepas tekanan dan katup blok dapat diservis. Verifikasi bahwa tidak ada penumpukan tekanan antara *rupture disk* dan PRD
- Setiap disk yang pecah diorientasikan dengan benar.
  Meskipun interval yang dipilih untuk inspeksi on-stream harus bervariasi dengan keadaan dan sejarah inspeksi, inspeksi visual yang mencakup pemeriksaan kebocoran dan kerusakan getaran harus mengikuti setiap operasi PRD. Personil yang ditugaskan ke unit proses dapat melakukan inspeksi ini asalkan mereka berpengalaman untuk mengenali kebocoran atau kerusakan getaran apa pun.

BAB 3
METODOLOGI PENELITIAN

Bab III dalam tugas akhir ini berisi skema pengerjaan. Bab ini menjadi inti dalam langkah-langkah yang dilakukan dalam melakukan analisa dan perhitungan guna mendapatkan tingkat level resiko dan perencanaan inspeksi, dapat dilihat pada **Gambar 3.1.**



Gambar 3.1 *Flow Chart* Pengerjaan Tugas Akhir

3.1 Studi literatur

Studi literatur dilakukan dengan tujuan untuk merangkum teori-teori dasar, acuan secara umum dan khusus, serta untuk memperoleh berbagai informasi pendukung lainnya yang berhubungan dengan pengerjaan penelitian ini. Studi literature dilakukan dengan cara membaca dan merangkum isi buku/*guideline*, skripsi/thesis yang berhubungan dengan tugas akhir, mencari jurnal ataupun mencari definisi-definisi istilah dalam tugas akhir, dan dengan melakukan diskusi dengan dosen pembimbing. **Tabel 3.1** menunjukkan hasil studi literatur yang telah dilakukan.

Tabel 3.1 Hasil studi literatur

Referensi	Hasil yang didapatkan
Penilaian Resiko dan Penjadwalan program Inspeksi pada *Pressure Relief Device* dengan Menggunakan metode *Risk Based Inspection* (RBI)	Referensi dalam menyusun latar belakang, metodologi penelitian, dan judul tugas akhir
Studi Aplikasi *Risk Based Inspection PRD* pada beberapa penilitian sebelumnya	Referensi tambahan dalam menyusun latar belakang dan metodologi penelitian
Oil and gas production handbook An introduction to oil and gas production, transport, refining and petrochemical industry	Referensi tambahan pengertian *Central Processing Plant* Sistem *Production Gas Separator*
Guideline : a. API 580 b. API 581	Pedoman dalam menyusun langkah-langkah dalam perhitungan *Risk Based Inspection*
Pustaka Internet	Definisi istilah *Pressure Relief Device*, jenis-*jenis PRD*, dll
Diskusi dengan dosen pembimbing	- *PRD* yang berfungsi untuk melindungi separator berjumlah 1. - Fluida di dalam *PRD* ialah *Gas alam mentah yang berasal dari wellhead* sehingga tekanan pada separator sangat tinggi. - Referensi dalam menyusun latar belakang, tujuan. Manfaat, dan rumusan masalah
Handbook of Non Destructive Evaluation	- Pengenalan program-program inspeksi NDE - Referensi dalam menyusun tinjauan pustaka

3.2 Pengumpulan Data dan Informasi

Metode pengumpulan data dilakukan dengan mengumpulkan data dari data yang dimiliki oleh dosen pembimbing yang berasal dari salah satu perusahaan pengolahan minyak dan gas bumi di Indonesia. Data yang dibutuhkan meliputi PFD, P&ID

Production Gas Separator system, jenis fluida yang di proses, desain dan operasional PRD, Laporan interval waktu dan biaya Inspeksi, dan data-data lain yang mendukung dalam pengerjaan tugas akhir ini.

Untuk melakukan analisis secara kuantitatif inspeksi berbasis risiko *Pressure relieve Device* (PRD) diperlukan data-data seperti berikut:

- *No*
- *PRD TAG*
- *Type of PRD*
- *P&ID*
- *Max. Allowed Working Pressure, PSI*
- *Failure on Demand Model Available*
- *Leakage Model Available*
- *Fluid Severity*
- *History of Excessive Actuation*
- *History of Chatter*
- *Fluid Severity for Leakage*
- *PRD Contains Soft Seats (O-Rings)*
- *Rupture Disk Upstream of the PRD*
- *Installed Piping Vibration*
- *Pulsating or Cyclical Service (stream dari disp. Pump)*
- *Discharge Location*
- *Last Installation/Inspection-Refurbish Date*
- *Plan Date*
- *Regulatory Inspection Interval(yrs)*
- *Protected Equipment*
- *Inlet diameter, in*

Data-data yang telah didapatkan nantinya akan digunakan dalam melakukan perhitungan probability of failure (LEAK & FAIL), consequence of failure (LEAK & FAIL), risiko, penjadwalan program inspeksi, kesimpulan dan saran.

3.3 Pengerjaan Tahap Awal RBI

Pada tahap ini perlunya beberapa *adjustment* yang perlu ditentukan sebelum melakukan perhitungan probabilitas maupun konsekuensi. Hal-hal yang perlu ada adjustment dalam melakukan penilaian menggunakan metode RBI pada PRD meliputi :

3.3.1. Pemilihan Tipe PRD

API 581 memberikan pilihan tipe PRD yang digunakan untuk dianalisa. Terdapat beberapa jenis PRD :

- Conventional spring loaded PRV (default)
- Balanced bellows PRV
- Pilot-operated PRV
- PRV with Rupture disk
- Rupture disk only

3.3.2. Menentukan Tingkat Bahaya Fluida yang Beroperasi

Dalam menentukan tingkat bahaya pada PRD. Pada API 581 pada table 7.4, jenis severity pada kasus fail dibagi menjadi mild, moderate dan severe. Salah satu Factor yang mempengaruhi adalah temperature fluida yang melewati PRD.

- Mild : temperature rendah kurang dari 500 ^{0}F
- Moderate : temperature berkisar 500 ^{0}F
- Severe : temperature lebih dari 500 ^{0}F

3.3.3. Menentukan penyebab terjadinya tekanan berlebih

Penyebab terjadinya over pressure/ tekanan berlebih adalah karena beberapa factor berikut :

- Fire, Power Failure
- Blocked Discharge
- Loss of cooling water
- Electrical Power Failure
- Control Valve fail Close at outlet
- Control Valve fail open at inlet
- Runaway chemical reaction
- Tube rupture
- Tower P/A or Reflux pump failure
- Thermal/ Hydraoulic expansion relief
- Liquid Overfilling

3.3.4. Menentukan Equipment yang Dilindungi

Dalam analisa ini, equipment yang dilindungi adalah Separator yang terdapat pada Produktion gas separator system. Sehingga perlu adanya penilaian RBI untuk separator itu sendiri.

3.3.5. Memasukan Histori Inspeksi terhadap PRD

Hasil dari analisa RBI adalah menentukan inspeksi selanjutnya untuk PRD. Sehingga perlu adanya data inspeksi terakhir yang pernah dilaksanakan oleh suatu perusahaan, seperti :

- Tanggal
- Durasi
- Keefektifan inspeksi
- Hasil dari inspeksi

3.4 Analisis *Probability FAIL & LEAK*

Setelah pengerjaan tahap awal RBI pada PRD maka akan dilakukan analisa *probability of failure* baik tipe kegagalan berupa FAIL maupun LEAK. Seperti yang dijelaskan pada bagian 2.9

3.4.1. perhitungan probabilitas POF

Berikut prosedur perhitungan yang digunakan untuk menentukan probabilitas kegagalan PRD untuk membuka pada inspeksi interval.

a) Langkah 1 – pilih interval inspeksi, t_{insp}
b) Langkah 2 – menentukan weibul parameter ,β dan η_{def}
c) Langkah 3 – Menentukan *adjustment Factor* , F_c
d) Langkah 4 – Menentukan *environment adjustment Factor*. F_{env}
e) Langkah 5 – menghitung Modified Characteristic life, $\eta_{mod.}$ Menggunakan persamaan (3.1)

$$\eta_{mod} = F_c + F_{env} + \eta_{def} \quad (3.1)$$

f) Langkah 6 – Sesuai dengan sejarah inspeksi pada PRD, mengelaskan hasil catatan inspeksi menggunakan table *inspection effectiveness*
g) Langkah 7 – meng-update modified characteristic life, η_{mod}

h) Langkah 8 – untuk setiap pemodedelan tekanan berlebih, tentukan *adjustment factor,* $F_{o,j,}$ menggunakan persamaan (3.1

$F_{op,j} = 1.0$ Untuk, $\frac{Po,j}{Pset}$

$F_{op,j} = 0.2$ Untuk $\frac{Po,j}{Pset}$

$F_{op,j} = 1 - \frac{1}{3.375}.\left(\frac{Po,j}{Pset} - 1.3\right)$ Untuk keadaan yang lain

(3.2)

i) Langkah 9 – untuk setiap scenario tekanan berlebih. Tentukan *adjustment factor* . $EF_{j.}$

j) Langkah 10 – menentukan *Demand rate reduction factor,* $DRRF_{j,}$ yang dihitung berdasarkan lapisan perlindungan yang bisa mengurangi kemungkinan terjadinya tekanan berlebih.

k) Langkah 11 – Untuk setiap *over pressure demand case* . tentukan *demand rate* dari PRD*,* $DR_{j,}$

l) Langkah 12 - Menentukan Maximum *Allowable Working Pressure* (MAWP)

m) Langkah 13 - Mengestimasikan Damage Factor

n) Langkah 14 - Menghitung POF pada perlengkapan yang dilindungi sesuai dengan *overpressure.* $P_{f,j.}$ menggunakan persamaan (3.3)

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{3.464837.\frac{Po,j}{MAWP}} \quad (3.3)$$

o) Langkah 15 – menghitung POF, mengguakan persamaan (3.4)

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j} \quad (3.4)$$

3.4.2. Perhitungan Probabilitas POL

Berikut prosedur perhitungan yang digunakan untuk menentukan probabilitas kegagalan PRD karena bocor pada inspeksi interval.

a) Langkah 1 – pilih interval inspeksi, t_{insp}

b) Langkah 2 – menentukan weibul parameter ,β dan η_{def}

c) Langkah 3 – Menentukan *adjustment Factor* , F_s

d) Langkah 4 – Menentukan *environment adjustment Factor.* F_{env}

e) Langkah 5 – menghitung Modified Characteristic life, $\eta_{mod.}$ Menggunakan persamaan (3.5)

$$\eta_{mod} = F_s + F_{env} + \eta_{def} \quad (3.5)$$

f) Langkah 6 – Mengelaskan hasil catatan inspeksi menggunakan table *inspection effectiveness*

g) Langkah 7 – meng-update modified characteristic life, η_{mod}

h) Langkah 8 – menghitung *probability of LEAK* untuk PRD dengan menggunakan persamaan (3.6)

$$P_{l,j}^{prd} = P_l^{prd}.\ F_{set}$$

(3.6)

3.5 Analisis *Consequences FAIL & LEAK*

Konsekuensi Dalam penentuan konsekuensi dibedakan menjadi dua, yakni konsekuensi area dan konsekuensi berdasarkan biaya. Pada tugas akhir ini akan dilakukan analisis konsekuensi level 1 berdasarkan area. factor yang menjadi alasan tidak digunakannya risiko berdasarkan biaya karena tidak adanya data yang lengkap terkait biaya terhadap asset yang dimiliki, sehingga jika dipaksakan menggunakan pendekatan data biaya secara umum dikhawatirkan analisis perhitungan tidak *valid*.

Dalam perhitungan analisis konsekuensi kegagalan PRD berdasarkan API 581 diawali dengan menentukan nilai *overpressure* ketika terjadi kegagalan sebagai pengganti tekanan operasi. Langkah-langkah dalam menentukan nilai *overpressure* saat terjadi kegagalan adalah sebagai berikut :

1. Menentukan daftar skenario *overpressure* yang berlaku untuk peralatan yang dilindungi oleh PRD yang dievaluasi. Tabel 7.2 memberikan daftar *overpressure demand case* yang secara kusus dibahas. Panduan panduan tambahan tentang *overpressure demand case* dan sistem pereda tekanan disediakan dalam API 521.
2. Untuk setiap *overpressure demand case*, memperkirakan jumlah tekanan berlebih, $P_{o,j}$ yang mungkin terjadi selama overpressure jika PRD gagal membuka. Tabel 7.3 memberikan panduan pada bagian ini.
3. Untuk instalasi yang memiliki beberapa PRD, tentukan jumlah total area orifice PRD yang dipasang, $A_{prd,}$ mencakup area PRD yang sedang dievaluasi. Hitung faktor penyesuaian *overpressure*, $F_{a,}$ sesuai dengan persamaan (3.7).

$$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \tag{3.7}$$

4. Kurangi *overpressure* scenario yang ditentukan pada langkah 3 dengan faktor penyesuai sesuai dengan persamaan (3.8).

$$P_{o,j} = F_a \,.\, P_{o,j} \tag{3.8}$$

5. Gunakan hasil dari langkah 4 sebagai pengganti tekanan operasi, $P_{s,}$

Setelah mendapatkan nilai $P_{o,j}$ sebagai pengganti tekanan operasi, maka langkah berikutnya menyesuaikan dengan perhitungan analisis konsekuensi yang dikembangkan dalam bagian 3 API 581. Langkah-langkah tersebut sebagai berikut :

1. Menentukan fluida yang terlepas bila terjadi kegagalan berserta sifat-sifatnya, termasuk sifat didalamnya.
   Fluida representative yang paling sesuai dengan fluida yang terkandung dalam equipment yang dilindungi oleh PRD akan dievaluasi dan dipilih dari fluida *representative* seperti yang ditampilkan pada table 4.1 lampiran 4.
2. Memilih set ukuran lubang yang tercipta bila terjadi *overpressure* dan PRD mengalami kegagalan untuk menentukan kemungkinan konsekuensi pada perhitungan risiko.
   Ukuran lubang saat fluida *release* didasarkan pada tipe peralatan dan ukurannya.

3. Menghitung laju *loss of containment*
   Laju pelepasan bergantung pada sifat-sifat fisik material (fluida), fase awal, kondisi proses pengoperasian, dan ukuran lubang pelepasan yang telah ditentukan. Laju pelepasan dihitung dengan menggunakan persamaan 2.13 apabila tekanan penyimpanan lebih besar dari tekanan transisi.

$$W_n = \frac{C_d}{C_2} x A_n x P_s \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ T_s}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad (3.9)$$

   Laju pelepasan dapat dihitung menggunakan rumusan 2.14 berikut ini apabila tekanan penyimpanan kurang dari tekanan transisi.

$$W_n = \frac{C_d}{C_2}\ x\ A_n\ x\ P_s \sqrt{\left[\left(\frac{MW\ .g_c}{R\ .T_s}\right)\left(\frac{2k}{k-1}\right)\left(\frac{P_{atm}}{P_s}\right)^{\frac{2}{k}}\left(1 - \left(\frac{P_{atm}}{P_s}\right)^{\frac{k-1}{k}}\right)\right]} \quad (3.10)$$

   Nilai P_s menyesuaikan dengan nilai $P_{o,j}$ yang telah ditentukan pada pembahasan sebelumnya.
4. Mengestimasikan massa total dari fluida yang kemungkinan *release*
   Perhitungan analisis konsekuensi kegagalan PRD pada API 581 memberikan pemodelan dengan mengkombinasikan peralatan lain yang dapat berkontribusi menambah massa fluida yang terlepas. Massa fluida yang terlepas dapat dihitung menggunakan persamaan (3.11).

$$Mass_{avail} = \min\left[\left(mass_{comp} + mass_{add,n}\right), mass_{inv}\right] \quad (3.11)$$

   Dimana :
   $Mass_{comp}$: massa peralatan yang dilindungi oleh PRD yang dianalisis
   $Mass_{add}$: massa tambahan yang dapat terlepas selama 3 menit
   $Mass_{inv}$: massa komponen lain yang terdapat dalam *inventory group*

   - Menghitung massa komponen yang dilindungi oleh PRD yang dianalisis, $Mass_{comp,}$ menggunakan persamaan (3.12) di bawah ini
     $Mass_{comp} = \rho$ x V peralatan (3.12)
   - Menghitung massa fluida yang terkandung pada masing-masing peralatan yang termasuk dalam *inventory froup*, $Mass_{comp,i}$.. peralatan yang termasuk dalam satu *inventory group* dibatasi oleh katup yang secara otomatis maupun manual bisa ditutup untuk mencegah aliran lebih lanjut apabila terjadi kegagalan pada PRD saat terjadi *overpressure* pada peralatan yang dilindungi oleh PRD.
   - Menghitung massa total pada *inventory group*, $Mass_{inv}$.

$$\sum mass_{inv} = \sum_{i=1}^{n} mass_{comp,i}$$

   - Menghitung *flow rate* untuk diameter 8 inch menggunakan persamaan 3.13 di bawah ini :

$$W_{max8} = \frac{C_d}{C_2} x A_8 x P_s \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ T_s}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad (3.13)$$

- Menghitung massa fluida tambahan, $mass_{add,n}$, untuk masing-masing ukuran lubang pelepasan, yang dapat menambah jumlah massa fluida dalam peralatan selama 3 menit dengan menggunakan rumus 3.14 berikut ini :

  $$mass_{add,n} = 180\ x \min[W_n, W_{max8}] \quad (3.14)$$

5. Menentukan tipe *release, continuous* atau *instantaneous* yang digunakan untuk memodelkan disperse dan konsekuensi. API RBI memberikan dua pemodelan tipe pelepasan yaitu :

   a. *Instantaneous Release* – pelepasan sesaat atau *puff release* adalah pelepasan yang terjadi dengan sangat cepat sehingga cairan menyebar seperti awan yang besar atau *pool*.
   b. *Continuous Release* – pelepasan terus-menerus atau *plume release* adalah pelepasan yang terjadi selama jangka waktu yang lama, yang memungkinkan cairan untuk menyebar dalam bentuk elips memanjang (tergantung kondisi cuaca).

   Besarnya waktu untuk masing-masing ukuran lubang pelepasan dihitung menggunakan persamaan 3.15 berikut ini :

   $$t_n = \frac{C_3}{W_n} \quad (3.15)$$

6. Mengestimasikan dampak sistem pendeteksi dan isolasi pada besarnya pelepasan

   Perusahaan pengolahan petrokimia, biasanya memiliki berbagai sistem *deteksi, isolasi*, dan *mitigasi* yang dirancang untuk mengurangi efek dari pelepasan bahan-bahan berbahaya

7. Menentukan laju pelepasan dan massa untuk analisis konsekuensi

   Laju pelepasan (lb/s) *continuous* dihitung dengan persamaan (3.16), perhitungan tersebut digunakan sebagai input analisis konsekuensi.

   $Rate_n = W_n\ (1\text{-}fact_{di})$ (3.16)

   Sedangkan persamaan (3.17) digunakan untuk menghitung massa pelepasan *instantaneous.*

   $Mass_n = \min\ [(rate_n\ x\ Id_n), mass_{avail,n}]$ (3.17)

   Dimana :
   Raten : laju pelepasan (lb/s)
   Idn : durasi kebocoran (second)

8. Menghitung konsekuensi kebakaran/ledakan

   Konsekuensi area diestimasikan dari perhitungan laju pelepasan (untuk pelepasan *continuous*) atau masa pelepasan (untuk pelepasan *instantaneous).*

   a. Menghitung konsekuensi area *component damage*

      Konsekuensi area *component damage* dibedakan menjadi 4, yaitu:

      - *Auto-ignition Not Likely, Continuous Release*

        Konsekuensi area *Component Damage Auto-ignition Not Likely, Continuous Release,* dapat dihitung menggunakan rumusan (3.18) berikut ini:

        $$CA_{cmd,n}^{AINL-CONT} = a(rate_n)^b.(1 - fact_{mit}) \quad (3.18)$$

- *Auto-ignition Likely, Continuous Release*
  Konsekuensi area *Component Damage Auto-ignition Likely, Continuous Release,* dapat dihitung menggunakan rumusan (3.19) berikut ini:
  $$CA_{cmd,n}^{AIL-CONT} = a(rate_n)^b.(1 - fact_{mit}) \quad (3.19)$$
- *Auto-ignition Not Likely, Instantaneous Release*
  Konsekuensi area *Component Damage Auto-ignition Not Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (3.20) berikut ini :
  $$CA_{cmd,n}^{AINL-INST} = \min[\{a\,(mass_n)^b\}, C_7].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (3.20)$$
- *Auto-ignition Likely, Instantaneous Release*
  Konsekuensi area *Component Damage Auto-ignition Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (3.21) berikut ini:
  $$CA_{cmd,n}^{AIL-INST} = \min[\{a\,(mass_n)^b\}, C_7].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (3.21)$$

b. Menghitung konsekuensi area *personel injury*
- *Auto-ignition Not Likely, Continuous Release*
  Konsekuensi area *Personel Injury, Auto-ignition Not Likely, Continuous Release,* dapat dihitung menggunakan rumusan (3.22) berikut ini:
  $$CA_{inj,n}^{AINL-CONT} = [a\,(effrate_n^{AINL-CONT})^b].(1 - fact_{mit}) \quad (3.22)$$
- *Auto-ignition Likely, Continuous Release*
  Konsekuensi area *Personel Injury, Auto-ignition Likely, Continuous Release,* dapat dihitung menggunakan rumusan (3.23) berikut ini:
  $$CA_{inj,n}^{AIL-CONT} = [a\,(effrate_n^{AIL-CONT})^b].(1 - fact_{mit}) \quad (3.23)$$
- *Auto-ignition Not Likely, Instantaneous Release*
  Konsekuensi area *Personel Injury, Auto-ignition Not Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (3.24) berikut ini:
  $$CA_{inj,n}^{AINL-INST} = [a\,(effrate_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (3.24)$$
- *Auto-ignition Likely, Instantaneous Release*
  Konsekuensi area *Personel Injury, Auto-ignition Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (3.25) berikut ini:
  $$CA_{inj,n}^{AIL-INST} = [a\,(effrate_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (3.25)$$

c. Menghitung *instantaneous*/*continuous blending factor* untuk masing-masing ukuran lubang pelepasan menggunakan persamaan 3.26, 3.27, atau 3.28 yang sesuai.
- Nilai *blending factor* untuk tipe pelepasan *continuous* dihitung menggunakan persamaan 2.30 berikut ini :
  $$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad (3.26)$$
  Dengan nilai C_5 = 55.6

- Nilai *blending factor instantaneous* apabila konstanta tidak disediakan maka nilai digunakan persamaan 2.31 di bawah ini:
$$fact_n^{IC} = 0.0 \quad (3.27)$$
- Nilai *blending factor* untuk pelepasan *instantaneous* tidak disediakan, sehingga digunakan persamaan 2.32 di bawah ini :
$$fact_n^{IC} = 1.0 \quad (3.28)$$

d. Menghitung *AIT blending factor* menggunakan 3.29, 3.30, dan 3.31 yang sesuai.
$$fact^{AIT} = 0 \quad (3.29)$$
$$apabila\ T_s + C_6 \leq AIT$$
$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2\ x\ C_6} \quad (3.30)$$
$$apabila\ T_s + C_6 > AIT > T_s - C_6$$
$$fact^{AIT} = 1 \quad (3.31)$$
$$apabila\ T_s - C_6 \geq AIT$$

e. Menghitung *continuous*/*instantaneous blended consequence area* menggunakan rumusan 3.32 sampai 3.35 berdasarkan konsekuensi area yang sudah dihitung sebelumnya.
$$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST}\ x\ fact_n^{IC} + CA_{cmd,n}^{AIL-CONT}\ x\ (1 - fact_n^{IC}) \quad (3.32)$$
$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST}\ x\ fact_n^{IC} + CA_{cmd,n}^{AINL-CONT}\ x\ (1 - fact_n^{IC}) \quad (3.33)$$
$$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST}\ x\ fact_n^{IC} + CA_{inj,n}^{AIL-CONT}\ x\ (1 - fact_n^{IC}) \quad (3.34)$$
$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST}\ x\ fact_n^{IC} + CA_{inj,n}^{AINL-CONT}\ x\ (1 - fact_n^{IC}) \quad (3.35)$$

f. Menghitung AIT *blended consequence area* untuk kerusakan komponen menggunakan rumusan 3.36 dan untuk cedera personel dengan menggunakan rumusan 3.37 di bawah ini.
$$CA_{cmd,n}^{flam} = CA_{cmd,n}^{AIL}\ x\ fact^{AIT} + CA_{cmd,n}^{AINL}\ x\ (1 - fact^{AIT}) \quad (3.36)$$
$$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL}\ x\ fact^{AIT} + CA_{inj,n}^{AINL}\ x\ (1 - fact^{AIT}) \quad (3.37)$$

9. Menghitung konsekuensi area *toxic*

Dalam perhitungan ini perlu menganalisis apakah terdapat kandungan asam sulfida (H_2S) dalam fluida yang terdapat pada komponen yang dilindungi oleh PRD.

Fluida yang terdapat pada *plant* yang dijadikan seumber data penelitian ini mengandung asam sulfide (H_2S) sebesar 0.10% sehingga konsekuensi area *toxic* perlu dihitung.

a. Menghitung durasi *effective release of the toxic*

Untuk setiap lubang *release yang dipilih,* hitung durasi *effective release of the toxic* dengan persamaan (3.38).
$$ld_n^{tox} = \min\left(3000\ ,\ \left\{\frac{mass_n}{W_n}\right\},\ \{60.ld_{max,n}\}\right) \quad (3.38)$$

b. Menentukan percentase *toxic,* $mfrac^{tox}$
pada materi yang ter-*release,* fluida yang *release* adalah fluida murni, $mfrac^{tox}$ = 1,00. Dalam perhitungan ini juga perlu diperhatikan jika ada lebih dari satu kandungan zat yang beracun (*toxic*) , prosedur ini dapat diulang untuk setiap komponen beracun.
H_2S = 0.1%
$mfrac^{tox}$ = 0.001

c. Menghitung *release rate* dan *release mass* untuk fluida *toxic*
untuk setiap skenario ukurang lubang *release*, hitung laju pelepasan *toxic*, $rate_n^{tox}$, dan massa massa yang terbuang, $mass_n^{tox}$, untuk digunakan sebagai analisis perhitungan konsekuensi *area toxic* dengan menggunakan persamaan (3.39) dan (3.40)

$$rate_n^{tox} = mfrac^{tox}.W_n \quad (3.39)$$

$$mass_n^{tox} = mfrac^{tox}.mass_n \quad (3.40)$$

d. Menghitung konsekuensi area *toxic,* $CA_{inj,n}^{tox}$
Hitung konsekuensi area toxic, $CA_{inj,n}^{tox}$ menggunakan persamaan (3.41) untuk kasus *continous release ,* dan persamaan (3.42) untuk kasus *instantaneous release.*

$$CA_{inj,n}^{tox-CONT} \quad (3.41)$$

$$CA_{inj,n}^{tox-INST} \quad (3.42)$$

e. Mengulang langkah a-d bila ada *toxic* yang lain
Pada analisis kali ini, *toxic* yang terkandung dalam fluida pada peralatan yang dilindungi oleh PRD hanya H_2S

f. Menghitung konsekuensi *final toxic*
Menghitung konsekuensi area *final toxic* yang dialami oleh perorangan dengan menggunakan persamaan (3.43).

$$CA_{inj}^{tox} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad (3.43)$$

10. Menghitung *non-flammable*, *non-toxic consequence*
Konsekuensi *non-flammable* dan *non-toxic* dihitung pada fluida yang tidak mudah terbakar dan tidak beracun, namun berbahaya. Salah satu contohnya ialah kabut. Fluida yang dianalisis dalam tugas akhir ini dominan adalah methane. Fluida methane merupakan fluida yang tidak berwarna namun mudah terbakar, sehingga tidak termasuk dalam kategori ini.
11. Menentukan probabilitas kerusakan akhir peralatan dan cedera personil
Konsekuensi area untuk kerusakan komponen dapat dihitung dengan menggunakan persamaan 3.45 berikut ini :

$$CA_{cmd}^{flam} = \left(\frac{\sum_{n=1}^{4} gff_n \, x \, CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad (3.45)$$

Konsekuensi area untuk cedera personel dapat dihitung dengan menggunakan persamaan 3.46 berikut ini :

$$CA_{inj}^{flam} = \left(\frac{\sum_{n=1}^{4} gff_n \, x \, CA_{inj,n}^{flam}}{gff_{total}}\right) \quad (3.46)$$

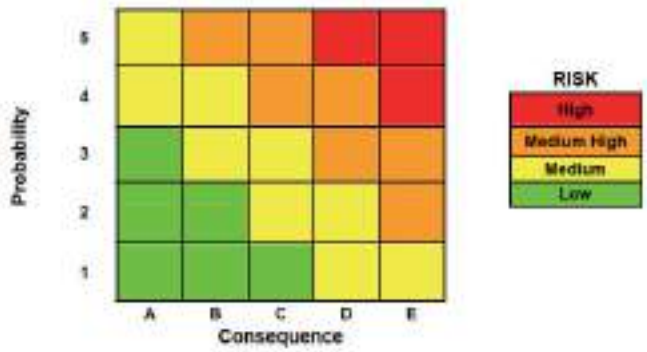
12. Menghitung konsekuensi akhir
    Konsekuensi area akhir untuk kerusakan komponen dihitung dengan persamaan 3.47 berikut ini :
    $$CA_{cmd} = \max\left[CA_{cmd}^{flam}, CA_{cmd}^{tox}, CA_{cmd}^{nfnt}\right] \quad (3.47)$$
    Konsekuensi area akhir untuk cedera personel dihitung dengan persamaan 3.48 berikut ini :
    $$CA_{inj} = \max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right] \quad (3.48)$$
    Konsekuensi akhir dihitung menggunakan rumusan 3.49 di bawah ini:
    $$CA = \max\left[CA_{cmd}, CA_{inj}\right] \quad (3.49)$$

3.6 Penentuan Level Resiko

Setelah diketahui *probability of failure* dan *consequence of failure* dari *PRD* maka akan dapat ditentukan level resikonya dengan menggunakan software *Microsoft excell*. Level resiko yang didapatkan dapat berada pada tingkat resiko berikut ini:

a. Low risk
b. Medium High risk
c. Medium risk
d. *High risk*

Berikut contoh untuk *Risk Matrik* API 581. **Gambar 3.2** merupakan *balance risk matrix* yang digunakan dalam studi inspeksi berbasis risiko.



Gambar 3.2 *Risk Matrik*
(Sumber : API RECOMMENCED PRACTICE 581)

3.7 *Inspection Planning*

Inspection planning dikembangkan dari analisis beberapa sumber data. Pemeriksaan atau inspeksi harus dijadwalkan pada interval dengan mempertimbangkan hal-hal berikut ini:

a. Tipe kerusakan dapat dilihat pada API 581.
b. Peluang metode NDE untuk mengidentifikasi kerusakan
c. Interval maksimum seperti yang ditetapkan pada code dan standart

3.8 Kesimpulan dan Saran

Langkah terakhir ialah pengambilan keputusan dari hasil perbandingan inspeksi yang telah diterapkan pada perusahaan terkait. Pada tahapan terakhir ini nantinya akan diambil kesimpulan dari serangkaian analisa tugas akhir ini. Pada tahapan ini juga akan dirumuskan usulan-usulan atau saran yang dapat dijadikan referensi pengambilan keputusan selanjutnya.

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BAB 4
RENCANA DAN JADWAL KEGIATAN

4.1 DATA PRD

Dalam perhitungan *risk based inspection* (RBI) dibutuhkan data mengenai desain dan konstruksi *PRD*, data operasional *PRD*, data fluida gas yang disimpan didalam *perlengkapan yang dilindungi*, data inspeksi dan data-data lain yang mendukung dalam tugas akhir ini. Data-data tersebut akan diolah sesuai dengan rumusan perhitungan yang terdapat pada API 581 baik dalam perhitungan *probability* maupun *consequence*. Di bawah ini merupakan penjelasan lebih detail mengenai data-data yang akan dianalisis :

4.1.1 Data General

Data General adalah data umum yang harus dimiliki oleh setiap PRD. Data ini teridiri dari : *Tag Number, quantity, service, protection item no., nozzle, PID Number , Design Type, Bonnet Type, Nace Requirement.* Data-data ini berfungsi sebagai identitas PRD yang dianalisis agar tidak terjadi kesalahan *equipment.*

4.1.2 Process Condition

Merupakan data yang melekat pada PRD selama proses berlangsung. Pada data ini didapatkan data fluid, *state, required capacity, molecular weight, Operating Pressure, Set Pressure, Operating Temperatur, Reliefing Temperatur, Back Pressure, % Allowable Overpressure, Overpressure Factor, Compressible Factor, Laten Heat of Vaporation, Ratio of Specific Heats (Cp/Cv), Relief Density, Relief Viscosity, Barometric Pressure.* Dari inputan data ini digunakan untuk menghitung probabilitas kegagalan dan konsekuensinya.

4.1.3 Design Condition

Data yang menerangkan karakteristik yang dialami oleh PRD saat di design. Data ini meliputi : design pressure dan design temperature.

4.1.4 Basis and Selection

Data yang menerangkan standart yang digunakan dalam mendesain maupun kontruksi PRD. Data ini meliputi : *Design Code, Sizing Basis, Calculated area , Selected Area, Orifice Designation*.

4.1.5 Connection

Untuk mengetahui data perihal karakteristik pada sambungan PRD bisa melihat pada bagian data ini. Data ini meliputi : Size inlet / outlet, Rating (in/out), facing.

4.1.6 Materials

Data kontruksi material yang digunakan dalam pembuatan PRD. Data ini meliputi *: Body and Bonnet, Seat and Rings, Resilient Seat Seal, Guide and Rings, Spring*.

Data PRD yang saya analisa seperti yang dirangkum pada **Tabel 4.1** hingga **Tabel 4.6** berikut :

Tabel 4.1 Data Pressure Relief Device PSV-1020A/B

GENERAL	
Tag Number	: PSV-1020A/B
Service	: Production Separator V-1020
Noozle (full/semi)	: FULL
PID No.	: BTJT-A-B-1010
Design Type	: Conventional
Bonnet Type	: Closed
Nace Requirement	: Yes
PROCESS CONDITIONS	
Fluid	: Hydrocarbon
State	: Gas
Required Capacity	: 4220 lb/h
Molecular Weight	: 24.97
Operating Pressure	: 134.9 psig
Set Pressure	: 512.7 psig
Operating Temperatur	: 473.2 ºF
Reliefing Temperatur	: 473.2 ºF
Back Pressure	: 23.1 psig
% Allowable Overpressure	: 21%
Overpressure Factor	: -
Compressible Factor	: 0.853
Laten Heat of Vaporation	:-
Ratio of Specific Heats (Cp/Cv)	: 1.332
Relief Density	: 3.78 Lb/ft^2
Relief Viscosity	: 0.016 cP
Barometric Pressure	: 14.7 psia
DESIGN CONDITION	
Design Pressure	: 512.7 psig
Design Temperatur	: 500 ºF

Tabel 4.2 Data Pressure Relief Device PSV-1311

GENERAL	
Tag Number	: PSV-1311
Service	: WHP to FPSO Gas Sweeping Heater
Noozle (full/semi)	: FULL
PID No.	: BTJT-A-B-1011
Design Type	: Conventional
Bonnet Type	: Closed
Nace Requirement	: Yes
PROCESS CONDITIONS	
Fluid	: Hydrocarbon
State	: Gas
Required Capacity	: 42.77 lb/h
Molecular Weight	: 21

GENERAL	
Operating Pressure	: 162.4 psig
Set Pressure	: 1450 psig
Operating Temperatur	: 990 ºF
Reliefing Temperatur	: 990 ºF
Back Pressure	: 94.3 psig
% Allowable Overpressure	: 21%
Overpressure Factor	: -
Compressible Factor	: 1.028
Laten Heat of Vaporation	:-
Ratio of Specific Heats (Cp/Cv)	: 1.134
Relief Density	: 3.78 Lb/ft^2
Relief Viscosity	: - cP
Barometric Pressure	: 14.69 psia
DESIGN CONDITION	
Design Pressure	: 1450 psig
Design Temperatur	: 1000 ºF

Tabel 4.3 Data Pressure Relief Device PSV-1312

GENERAL	
Tag Number	: PSV-1312
Service	: WHP to FPSO Liquid Pig Launcher L-1
Noozle (full/semi)	: FULL
PID No.	: BTJT-A-B-1011
Design Type	: Conventional
Bonnet Type	: Closed
Nace Requirement	: Yes
PROCESS CONDITIONS	
Fluid	: Hydrocarbon
State	: Gas
Required Capacity	: 1126.6 lb/h
Molecular Weight	: 27.06
Operating Pressure	: 127.63 psig
Set Pressure	: 1464.9 psig
Operating Temperatur	: 638.96 ºF
Reliefing Temperatur	: 638.96 ºF
Back Pressure	: 110.23 psig
% Allowable Overpressure	: 21%
Overpressure Factor	: -
Compressible Factor	: 0.707
Laten Heat of Vaporation	:-
Ratio of Specific Heats (Cp/Cv)	: 1.646
Relief Density	: - Lb/ft^2
Relief Viscosity	: - cP
Barometric Pressure	: 14.7 psia
DESIGN CONDITION	
Design Pressure	: 1450 psig

GENERAL	
Design Temperatur	: 1000 ºF

Tabel 4.4 Data Pressure Relief Device PSV-2910

GENERAL	
Tag Number	: PSV-2910
Service	: WHP to FPSO Gas Pig Launcher
Noozle (full/semi)	: FULL
PID No.	: BTJT-A-B-1012
Design Type	: Conventional
Bonnet Type	: Closed
Nace Requirement	: Yes
PROCESS CONDITIONS	
Fluid	: Hydrocarbon
State	: Gas
Required Capacity	: 149 lb/h
Molecular Weight	: 23.81
Operating Pressure	: 127.6 psig
Set Pressure	: 512.7 psig
Operating Temperatur	: 990 ºF
Reliefing Temperatur	: 990 ºF
Back Pressure	: 18.42 psig
% Allowable Overpressure	: 21%
Overpressure Factor	: -
Compressible Factor	: 1.006
Laten Heat of Vaporation	:-
Ratio of Specific Heats (Cp/Cv)	: 1.112
Relief Density	: - Lb/ft^2
Relief Viscosity	: - cP
Barometric Pressure	: 14.7 psia
DESIGN CONDITION	
Design Pressure	: 512.7 psig
Design Temperatur	: 1000 ºF

Tabel 4.5 Data Pressure Relief Device PSV-2921

GENERAL	
Tag Number	: PSV-2921
Service	: FPSO to WHP Export Gas Pig Launcher
Noozle (full/semi)	: FULL
PID No.	: BTJT-A-B-1015
Design Type	: Conventional
Bonnet Type	: Closed
Nace Requirement	: Yes
PROCESS CONDITIONS	
Fluid	: Hydrocarbon
State	: Gas

GENERAL	
Required Capacity	: 2323 lb/h
Molecular Weight	: 21
Operating Pressure	: 1320 psig
Set Pressure	: 1465 psig
Operating Temperatur	: 397 ºF
Reliefing Temperatur	: 397 ºF
Back Pressure	: 81.94 psig
% Allowable Overpressure	: 21%
Overpressure Factor	: -
Compressible Factor	: 0.961
Laten Heat of Vaporation	:-
Ratio of Specific Heats (Cp/Cv)	: 1.276
Relief Density	: - Lb/ft^2
Relief Viscosity	: - cP
Barometric Pressure	: 14.7 psia
DESIGN CONDITION	
Design Pressure	: 1465 psig
Design Temperatur	: 1000 ºF

Tabel 4.6 Data Pressure Relief Device PSV-2931

GENERAL	
Tag Number	: PSV-2931
Service	: WHP to ORF Export Gas Pig Launcher
Noozle (full/semi)	: FULL
PID No.	: BTJT-A-B-1016
Design Type	: Conventional
Bonnet Type	: Closed
Nace Requirement	: Yes
PROCESS CONDITIONS	
Fluid	: Hydrocarbon
State	: Gas
Required Capacity	: 1660 lb/h
Molecular Weight	: 21
Operating Pressure	: 1030 psig
Set Pressure	: 1465 psig
Operating Temperatur	: 614.1 ºF
Reliefing Temperatur	: 614.1 ºF
Back Pressure	: 108.3 psig
% Allowable Overpressure	: 21%
Overpressure Factor	: -
Compressible Factor	: 1.005
Laten Heat of Vaporation	:-
Ratio of Specific Heats (Cp/Cv)	: 1.192
Relief Density	: - Lb/ft^2
Relief Viscosity	: - cP
Barometric Pressure	: 14.7 psia

GENERAL	
DESIGN CONDITION	
Design Pressure	: 1465 psig
Design Temperatur	: 1000 ºF

4.2 Data Komposisi Fluida

Kandungan fluida yang diproses pada sistem ini bisa diketahui dengan melihat data perusaan pada file *heat material balance* (HMB). Data tersebut bisa dilihat pada table dibawah ini dan yang tercantum pada **Lampiran 1. Tabel 4.7** hingga **Tabel 4.10** menjelaskan kandungan fluida pada sistem

Tabel 4.7 Kandungan fluida pada sistem Production Gas Separator

Composition	Symbol	Amount
Nitrogen	N_2	0.68
Carbon Dioxide	CO_2	1.05
Methane	CH_4	72.25
Ethane	C_2H_6	7.9
Propane	C_3H_8	6.84
i-Butane	i-C_4H_{10}	1.9
n-Butane	n-C4H_{10}	2.4
i-Pentane	i-C_5H_{12}	5.01
n-Pentane	n-C_5H_{12}	0.47
Hexane Plus	C_6^+	1.5

Tabel 4.8 Kandungan fluida pada WHP to FPSO

Composition	Symbol	Amount
Nitrogen	N_2	0.68
Carbon Dioxide	CO_2	1.05
Methane	CH_4	72.25
Ethane	C_2H_6	7.9
Propane	C_3H_8	6.84
i-Butane	i-C_4H_{10}	1.9
n-Butane	n-C4H_{10}	2.4
i-Pentane	i-C_5H_{12}	5.01
n-Pentane	n-C_5H_{12}	0.47
Hexane Plus	C_6^+	1.5

Tabel 4.9 Kandungan fluida pada sistem FPSO to WHP

Composition	Symbol	Amount
Nitrogen	N_2	0.6
Carbon Dioxide	CO_2	0.008
Methane	CH_4	86.02
Ethane	C_2H_6	4.36

Composition	Symbol	Amount
Propane	C_3H_8	5.74
i-Butane	i-C_4H_{10}	1.51
n-Butane	n-$C4H_{10}$	1.7
i-Pentane	i-C_5H_{12}	0.01
n-Pentane	n-C_5H_{12}	0.032
Hexane Plus	C_6^+	0.02

Tabel 4.10 Kandungan fluida pada sistem WHP to ORF

Composition	Symbol	Amount
Nitrogen	N_2	0
Carbon Dioxide	CO_2	0.23
Methane	CH_4	85.82
Ethane	C_2H_6	1.35
Propane	C_3H_8	5.74
i-Butane	i-C_4H_{10}	1.51
n-Butane	n-$C4H_{10}$	1.78
i-Pentane	i-C_5H_{12}	3.52
n-Pentane	n-C_5H_{12}	0.03
Hexane Plus	C_6^+	0.02

Dari data tersebut diketahui bahwa fluida yang paling dominan adalah methane dari seluruh sistem aliran fluida yang bersifat sangat mudah terbakar.

4.3 Analisi Risiko

Untuk kepentingan laporan, pada laporan ini ditampilkan analisis perhitungan untuk PSV-1020A/B sedangkan detail perhitungan bisa dilihat pada lampiran 2 sampai 4. Sedangkan perhitungan untuk PSV-1311 ;PSV-1312; PSV-2910; PSV-2921; dan PSV-2931 akan dirangkung pada tabel 4.11 sampai 4.15.

4.3.1 Analisis Probabilitas PRD gagal Membuka PSV-1020A/B

Perhitungan mendasar yang diterapkan pada PRD untuk kasus kegagalan membuka adalah dengan mengestimasikan *overpressure demand case frequency* (atau tingkat permintaannya), untuk perhitungan PoF gagal membuka secara detail tercantuk pada **Lampiran 2.1**

Probabilitas PRD gagal untuk membuka saat dibutuhkan, dan probabilitas bahwa peralatan yang dilindungi pada tekanan berlebih akan mengalami *loss containment.* Sehingga bisa dibuat persamaan (4.1).

$$P_{f,j}^{prd} = P_{fod,j} \,.\, DR_j . P_{f,j} \qquad \text{Persamaan (4.1)}$$

Langkah langkah dalam menghitung probabilitas PRD gagal membuka adalah sebagai berikut :

1. Menentukan Inspection Interval, $t_{ins.}$ Disini diestimasikan selama 4 tahun . sesuai dengan PERMEN ESDM no.38 tahun 2017 yang mengatur untuk melakukan inspeksi dengan metode *time based* selama 4 tahun sekali.
2. Menentukan weibull parameter β and η_{def} yang disesuaikan dengan table 7.5 pada lampiran 2.1, dengan beberapa indikator dari fluida yang didapat dari

data PRD yang tertera pada lampiran 1. Adapun indikator yang berperan meliputi :

- *Fluid Service* : Methane
  Fluid service dipilih berdasarkan kandungan fluida dominan yang terdapat pada *equipment* yang dilindungi oleh PRD. Fluid service bisa dilihat pada data HMB *(Heat Material Balance)* yang terdapat pada laporan ini pada lampiran 1
- *Typical Temperature :* 473.2 ºf
- *Fluid Severity: Mild*
  Kategori *fluid severity* bisa ditentukan dengan mengacu pada temperature pada fluida yang melewati PRD. table 7.4 pada lampiran 2.1 menyediakan acuan dalam penentuan jenis *fluid severity*
- *Design Type PRD: Conventional*
- *Discharge Location* : *discharge to flare with flare recovery system*
  Penilaian *discharge location* dengan mengacu pada P&ID *(Piping & Instrument Diagram)* . pada gambar yang terdapat pada P&ID, PRD terhubung dengan sistem *flare* sehingga *discharge location* masuk dalam kategori *discharge to flare with flare recovery system.*

Dari beberapa indikator diatas kemudian diplotkan dalam table 7.5 yang terdapat pada lampiran 2.1. sehingga didapat nilai weibull parameter sebagai berikut

$\beta = 1.80$ dan $\eta_{def} = 37{,}875$

3. Menentukan *adjustment factor.* karena PRD yang dianaisa berjenis *Conventional* dan sistem discharge terhubung ke *flare* maupun closed system. Sehingga nilai Fc adalah 0.75
4. Menentukan environment factor,F_{env} dengan mempertimbangkan lingkungan berkontribusi membuat kegagalan pada PRD. Table 7.6 pada lampiran 2.1 menyediakan *adju stment factor* yang bergantung dengan temperature operasi. Pada PSV-1020A/B memiliki *Typical Temperature* 473.2 ºf sehingga Nilai pada penilaian ini nilai Fenv adalah 1.0
5. Hasil dari beberapa perhitungan sebelumnya di modifikasi dengan persamaan (4.2).

   $$\eta_{mod} = F_c . F_{env} . \eta_{def} \qquad (4.2)$$

   $\eta_{mod} = 28.41$
6. Apabila PRD sudah pernah diinspeksi. Maka data bisa meninjau hasil inspeksi. Apakah PRD sukses atau gagal. Apakah mengalami kebocoran atau tidak. Sehingga bisa menentukan *confidence Factor.* $C_{fi..}$
   a. Menentukan *inspection Effectiveness*
      Tidak terdapat bukti telah dilakukannya inspeksi terhadap PSV-1020A/B sehingga pada perhitungan ini diasumsikan PRD memiliki *inspection Effectiveness type* D. untuk penjelasan tipe D dan tipe lainnya disediakan pada table 7.16 pada 2.1
   b. Menentukan *confidence factors,* C_{fi}

Apabila PRD pernah diinspeksi sebelumnya, perlu adanya pencatatan terhadap kondisi PRD apakah PASS/FAIL maupun NO LEAK/LEAK sehingga bisa menentukan *confidence factors,* C_{fi} , dengan menggunakan data yang terdapat pada table 7.8 pada lampiran 2.1. C_{fi} digunakan untuk setiap inspeksi yang telah dilaksanakan. Pada PSV-1020A/B mendapatkan nilai $C_{fi} = 0.5$

c. Menentukan waktu durasi jarak,$t_{dur,i}$ setiap dilakukannya inspeksi. Perhitungan $t_{dur,I}$ menggunakan persamaan (4.3).

$t_{dur,I}$ = RBI date – Last Inspection (4.3)

$t_{dur,I}$ = RBI Plan date – Last Inspection (4.4)

karena PSV-1020A/B dilakukan inspeksi pada tanggal 17 juni 2016 dan RBI date dilakukan tanggal 15 maret 2020, kemudian sesuai dengan rekomendasi PERMEN ESDM no.38 tahun 2017 untuk plan date dilakukan setiap 4 tahun sekali sehingga

$t_{dur,I}$ = 4 tahun (RBI Date)

$t_{dur,I}$ = 8 tahun (RBI Plan Date)

d. Menentukan apakah PRD itu akan dibongkar atau tidak, mengikuti tabel 7.7 seperti yang tertera pada lampiran 2.1. untuk type conventional menggunakan persamaan (4.5)

$$F_{set} = 1 - \left(\frac{0.90 - min\left(\frac{P_s}{P_{set}}\right)}{0.90} \right) \quad (4.5)$$

F_{set} = 0.292

7. Mulai dari catatan inspeksi paling awal, η_{mod} perlu diperbarui dengan mengacu pada langkah 5. Adapun langkah dalam mengupdate η_{mod}

a. Menghitung POF Sebelumnya, $P_{f,Prior}^{prd}$

Menghitung POF sebelumnya berdasarkan persamaan (4.6). inputan berasal dari beberapa langkah yang sudah dijelaskan dilangkah sebelumnya. Untuk catatan inspeksi yang pertama $\eta_{upd} = \eta_{mod}$

$$P_{f,Prior}^{prd} = 1 - \exp\left[- \left(\frac{t}{\eta upd} \right)^{\beta} \right] \quad (4.6)$$

RBI Date $P_{f,Prior}^{prd}$ = 0.02892

RBI Plan Date $P_{f,Prior}^{prd}$ = 0.09714

b. Menghitung POF passing, $P_{p,Prior}^{prd}$, Sebelumnya dengan menggunakan persamaan (4.7)

$$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd} \quad (4.7)$$

RBI Date $P_{p,Prior}^{prd}$ = 0.97107

RBI Plan Date $P_{p,Prior}^{prd}$ = 0.90286

c. Menentukan kondisional POF, $P_{f,Prior}^{prd}$

Kondisional POF bisa dijitung dengan menggunakan persamaan (4.8).

$$P_{f,cond}^{prd} = (1 - CF_{pass}) . P_{p,prior}^{prd} \quad (4.8)$$

RBI Date $P_{f,cond}^{prd}$ = 0.48554

RBI Plan Date $P_{f,cond}^{prd}$ = 0.45143

d. Menghitung weighted POF, $P_{f,wgt}^{prd}$

POF perlu dilakukan perhitungan pembobotan dengan menggunakan persamaan (4.9). persamaan tersebut dipilih dari table 7.9 lampiran 2.1

$$P_{f,wgt}^{prd} = P_{f,cond}^{prd} \quad (4.9)$$

RBI Date $P_{f,wgt}^{prd}$ = 0.48554

RBI Plan Date $P_{f,wgt}^{prd}$ = 0.45143

e. Menentukan *updated characteristic life*,η_{upd}

Penentuan *updated characteristic life* dengan menggunakan persamaan (4.8) dan *weighted* POF.

$$\eta_{upd} = \frac{t}{\left(-ln\left[1-P_{f,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}} \quad (4.10)$$

η_{upd} = 10.62

f. Ulangi langkah ke-7 untuk masing-masing catatan inspeksi yang tersedia untuk PRD dengan menggunakan persamaa (4.11).

$$P_{f,Prior}^{prd} = 1-\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right] \quad (4.11)$$

RBI Date $P_{f,Prior}^{prd}$ = 0.02892

RBI Plan Date $P_{f,Prior}^{prd}$ = 0.45143

8. Menentukan PRD POFOD

Untuk POFOD perlu adanya *adjustment Factor,* $F_{op,j,}$ akibat dari *overpressure scenario*. Yang telah dijelaskan pada bagian failure mode.

Fop,j = 0.2

Sehingga dengan menggunakan persamaan (4.12) didapat hasil

$$P_{fod,j} = P_{fod}\, x\, F_{op,j} \quad (4.12)$$

RBI Date $P_{fod,j}$ = 0.00578

RBI Plan Date $P_{fod,j}$ = 0.09029

9. Mengestimasi *initiating event frequency* , $E_{f,j.}$dengan mengacu pada table 7.2 dan 7.3 pada lampiran 4A. Didapat skenario *overpressure* adalah *fire* dan *overfiliing.* Sehingga didapat nilai

Ef (fire) = 0.004

Ef (Overfilling) = 0.1

10. Mengingat adanya proteksi lain selain PRD itu sendiri untuk mencegah sistem mengalami kegagalan maka perlunya adanya kredit dengan mengestimasi *demand rate reduction factor*. dengan mengacu pada table 7.2 pada lampiran 4A sehingga didapat :

DRRFf (fire) = 0.1

DRRFf (Overfilling) = 0.1

11. Untuk setiap kasus overpressure, hitung *demand rate* (DR) pada PRD menggunakan persamaan (4.13) :

$$DR_j = EF_{j.} \ . DRRF_j \quad (4.13)$$

Fire case

DR_{fire} = 0.0004 demands/year

overfilling case

$DR_{overfilling}$ = 0.01 demands/year

12. Menentukan *Maximum Allowable Working Pressure* . diketahui dari data sheet bahwa tekanan operasi sebesar 512.7 psig. Dan 21*% Allowable Working Pressure* sehingga didapat nilai MAWP adalah 620.4 psig.
13. Menentukan nilai *Damage Factor*

Demage factor terhadap peralatan yang dilindungi oleh PRD berdasarkan fungsi waktu. DF harus ditentukan pada interval pemeriksaan PRD. DF dapat ditentukan dengan menggunakan data yang tersedia oleh API 581 pada table 7.10 yang dalam laporan ini terdapat pada lampiran 2.1

DF = 20

14. Menghitung nilai POF terhadap kemungkinan *loss of containment*.. Pf,j. dengan menggunakan persamaan (4.14).

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{3.464837..\frac{Po,j}{MAWP}} \quad (4.14)$$

Pf,j = 2.E-05 Failure/year

15. Setelah perhitungan dari langkah 1 sampai 14 dilakukan. Maka bisa menghitung POF menggunakan persamaan (4.1)

RBI Date

Fire Case

$$P_{f,fire}^{prd} = P_{fod,fire}.DR_{fire}.P_{f,fire} \quad (4.15)$$

$P_{f,fire}^{prd}$ = 5.51219E-11 failures/year

Overfilling Case

$$P_{f,overfilling}^{prd} = P_{fod,overfilling}.DR_{overfilling}.P_{f,overfilling} \quad (4.16)$$

$P_{f,fire}^{prd}$ = 1.37805E-09 failures/year

RBI Plan Date

Fire Case

$$P_{f,fire}^{prd} = P_{fod,fire}.DR_{fire}.P_{f,fire} \quad (4.15)$$

$P_{f,fire}^{prd}$ = 8.60413E-10 failures/year

Overfilling Case

$$P_{f,overfilling}^{prd} = P_{fod,overfilling}.DR_{overfilling}.P_{f,overfilling} \quad (4.16)$$

$P_{f,fire}^{prd}$ = 2.15103E-08 failures/year

4.3.2 Analisis Probabilitas PRD *LEAK* PSV-1020A/B

Kasus kebocoran berbeda dengan kasus kegagalan membuka karena POL bukan merupakan fungsi dari *demand rates*, melainkan didasarkan pada kegagalan selama operasi berkelanjutan. Data Industri terkait dengan probabilitas kebocoran, data dalam satuan pertahun (Kegagalan/tahun). Dan tidak terdapat perkalian dengan tingkat permintaan (*demand rate).* Berikut langkah-langkah dalam menghitung Probabilitas PRD LEAK, POL :

1. Menentukan Inspection Interval, $t_{ins.}$ Disini diestimasikan selama 4 tahun . sesuai dengan PERMEN ESDM no.38 tahun 2017 yang mengatur untuk melakukan inspeksi dengan metode *time based* selama 4 tahun sekali.
2. Menentukan weibull parameter β and η_{def} yang disesuaikan dengan table 7.5 pada lampiran 2.1, dengan beberapa indikator dari fluida yang didapat dari data PRD yang tertera pada lampiran 1. Adapun indikator yang berperan meliputi :
   - *Fluid Service* : Methane
     Fluid service dipilih berdasarkan kandungan fluida dominan yang terdapat pada *equipment* yang dilindungi oleh PRD. Fluid service bisa dilihat pada data HMB *(Heat Material Balance)* yang terdapat pada laporan ini pada lampiran 1
   - *Typical Temperature :* 473.2 ºf
   - *Fluid Severity: Mild*
     Kategori *fluid severity* bisa ditentukan dengan mengacu pada temperature pada fluida yang melewati PRD. table 7.4 pada lampiran 2.1 menyediakan acuan dalam penentuan jenis *fluid severity*
   - *Design Type PRD: Conventional*
   - *Discharge Location* : *discharge to flare with flare recovery system*
     Penilaian *discharge location* dengan mengacu pada P&ID *(Piping & Instrument Diagram)* . pada gambar yang terdapat pada P&ID, PRD terhubung dengan sistem *flare* sehingga *discharge location* masuk dalam kategori *discharge to flare with flare recovery system.*

   Dari beberapa indikator diatas kemudian diplotkan dalam table 7.5 yang terdapat pada lampiran 2.1. sehingga didapat nilai weibull parameter sebagai berikut
   $\beta = 1.80$ dan $\eta_{def} = 37{,}875$
3. Menentukan *adjustment factor.* karena PRD yang dianaisa berjenis *Conventional* dan sistem discharge terhubung ke *flare* maupun closed system. Sehingga nilai Fc adalah 0.75
4. Menentukan environment factor,F_{env} dengan mempertimbangkan lingkungan berkontribusi membuat kegagalan pada PRD. Table 7.6 pada lampiran 2.1 menyediakan *adju stment factor* yang bergantung dengan temperature operasi. Pada PSV-1020A/B memiliki *Typical Temperature* 473.2 ºf sehingga Nilai pada penilaian ini nilai Fenv adalah 0.8
5. Hasil dari beberapa perhitungan sebelumnya di modifikasi dengan persamaan (4.17).

$\eta_{mod} = F_c . F_{env} . \eta_{def}$ (4.17)

$\eta_{mod} = 37.88$

6. Apabila PRD sudah pernah diinspeksi. Maka data bisa meninjau hasil inspeksi. Apakah PRD sukses atau gagal. Apakah mengalami kebocoran atau tidak. Sehingga bisa menentukan *confidence Factor.* $C_{fi..}$
   a. Menentukan *inspection Effectiveness*
      Tidak terdapat bukti telah dilakukannya inspeksi terhadap PSV-1020A/B sehingga pada perhitungan ini diasumsikan PRD memiliki *inspection Effectiveness type* D. untuk penjelasan tipe D dan tipe lainnya disediakan pada table 7.16 pada 2.1
   b. Menentukan *confidence factors,* C_{fi}
      Apabila PRD pernah diinspeksi sebelumnya, perlu adanya pencatatan terhadap kondisi PRD apakah PASS/FAIL maupun NO LEAK/LEAK sehingga bisa menentukan *confidence factors,* C_{fi} , dengan menggunakan data yang terdapat pada table 7.8 pada lampiran 2.1. C_{fi} digunakan untuk setiap inspeksi yang telah dilaksanakan. Pada PSV-1020A/B mendapatkan nilai $C_{fi} = 0.5$
   c. Menentukan waktu durasi jarak,$t_{dur,i}$ setiap dilakukannya inspeksi. Perhitungan $t_{dur,I}$ menggunakan persamaan (4.3).
      $t_{dur,I}$ = RBI date – Last Inspection (4.18)
      $t_{dur,I}$ = RBI Plan date – Last Inspection (4.19)
      karena PSV-1020A/B dilakukan inspeksi pada tanggal 17 juni 2016 dan RBI date dilakukan tanggal 15 maret 2020, kemudian sesuai dengan rekomendasi PERMEN ESDM no.38 tahun 2017 untuk plan date dilakukan setiap 4 tahun sekali sehingga
      $t_{dur,I}$ = 4 tahun (RBI Date)
      $t_{dur,I}$ = 8 tahun (RBI Plan Date)
7. Mulai dari catatan inspeksi paling awal, η_{mod} perlu diperbarui dengan mengacu pada langkah 5. Adapun langkah dalam mengupdate η_{mod}
   a. Menghitung POF Sebelumnya, $P_{l,Prior}^{prd}$
      Menghitung POF sebelumnya berdasarkan persamaan (4.20). inputan berasal dari beberapa langkah yang sudah dijelaskan dilangkah sebelumnya. Untuk catatan inspeksi yang pertama $\eta_{upd} = \eta_{mod}$
      $P_{l,Prior}^{prd}$=1-exp$\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$ (4.20)
      RBI Date $P_{l,Prior}^{prd}$ = 0.01733
      RBI Plan Date $P_{l,Prior}^{prd}$ = 0.05907
   b. Menghitung POF passing, $P_{p,Prior}^{prd}$, Sebelumnya dengan menggunakan persamaan (4.21)
      $P_{p,Prior}^{prd}$= 1- $P_{l,prior}^{prd}$ (4.21)
      RBI Date $P_{p,Prior}^{prd}$ = 0.98267

RBI Plan Date $P_{p,Prior}^{prd}$ = 0.94093

c. Menentukan kondisional POF, $P_{f,Prior}^{prd}$

Kondisional POF bisa dijitung dengan menggunakan persamaan (4.22).

$$P_{l,cond}^{prd} = (1\text{-}CF_{pass}).P_{p,prior}^{prd} \quad (4.22)$$

RBI Date $P_{l,cond}^{prd}$ = 0.49133

RBI Plan Date $P_{l,cond}^{prd}$ = 0.47046

d. Menghitung weighted POF, $P_{f,wgt}^{prd}$

POF perlu dilakukan perhitungan pembobotan dengan menggunakan persamaan (4.23). persamaan tersebut dipilih dari table 7.9 lampiran 2.1

$$P_{l,wgt}^{prd} = P_{f,cond}^{prd} \quad (4.23)$$

RBI Date $P_{l,wgt}^{prd}$ = 0.49133

RBI Plan Date $P_{l,wgt}^{prd}$ = 0.47046

e. Menentukan *updated characteristic life*,η_{upd}

Penentuan *updated characteristic life* dengan menggunakan persamaan (4.24) dan *weighted* POF.

$$\eta_{upd} = \frac{t}{\left(-ln\left[1-P_{l,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}} \quad (4.24)$$

η_{upd} = 10.29

8. Menghitung *probability of leakage* untuk PRD yang dianalisis berdasarkan persamaan (4.25)

$$P_{l,Prior}^{prd}=1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right] \quad (4.25)$$

RBI Date P_{l}^{prd} = 0.01733

RBI Plan Date P_{l}^{prd} = 0.47046

9. Probabilitas kebocoran PRD perlu disesuaikan berdasarkan pada sistem yang beroperasi berada disekitar PRD dengan menggunakan persamaan (4.26)

$$P_{l,j}^{prd} = P_{l}^{prd} . F_{set} \quad (4.26)$$

F_{set} adalah *adjustment factor* untuk rasio tekanan operasi terhadap *set pressure.*

$$F_{set} = 1\text{-}\left(\frac{0.90-min\left(\frac{P_S}{P_{set}}\right)}{0.90}\right) \quad (4.27)$$

F_{set} = 0.29

RBI Date $P_{l,j}^{prd}$ = 0.0051 failures/year

RBI Plan Date $P_{l,j}^{prd}$ = 0.1375 failures/year

4.3.3 Analisis Konsekuensi area kegagalan PRD

Pada laporan ini hanya ditulis tahap perhitungan konsekuensi untuk PSV-1020A/B, Sedangkan untuk Untuk PSV-1311, PSV-1312, PSV-2910, psv-2921 dan PSV-2931 detail perhitungan bisa dilihat pada lampiran 3.

Setiap kasus permintaan overpressure, hitung konsekuensi area, $C_{f,j}^{prd}$, dari penahan kerugian dari peralatan yang dilindungi menggunakan rosedur yang dijelaskan di API 581 bab 3. Gunakan *overpressure for demand* dengan menggunakan hasil Po,j untuk mengganti Ps. Berikut merupakan langkah dalam menghitung Po,j :

1. Menentukan daftar skenario *overpressure* yang berlaku untuk peralatan yang dilindungi oleh PRD yang dievaluasi. Tabel 7.2 lampiran 3 memberikan daftar *overpressure demand case* yang secara kusus dibahas. Panduan panduan tambahan tentang *overpressure demand case* dan sistem pereda tekanan disediakan dalam API 521. *Overpressure demand cases* untuk PRD meliputi:
   - *Fire*
   - *Liquid Overfilling*
2. Untuk setiap *overpressure demand case* , memperkirakan jumlah tekanan berlebih, $P_{o,j}$ yang mungkin terjadi selama overpressure jika PRD gagal membuka. Tabel 7.3 lampiran 3 memberikan panduan dalam menentukan *overpressure potential* untuk *overpressure scenario fire* dan *liquid overfilling*. sehingga didapatkan persamaan (4.28) dan (4.29).
   Fire case
   $P_{o,fire}$ = 4 x MAWP (4.28)
   $P_{o,fire}$ = 2481.6 psig
   overfilling case
   $P_{o,foverfilling}$ = 4 x MAWP (4.29)
   $P_{o,foverfilling}$ = 2481.6 psig

3. Untuk instalasi yang memiliki beberapa PRD, tentukan jumlah total area orifice PRD yang dipasang, $A_{prd,}$ mencakup area PRD yang sedang dievaluasi. Hitung factor penyesuaian *overpressure*, $F_{a,}$ sesuai dengan persamaan (4.30).
   $$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \quad (4.30)$$
   Karena instalasi memiliki 2 PRD yaitu PSV-1020A dan PSV-1020B sehingga nilai dari F_a = 0.7071068
4. Kurangi *overpressure* scenario yang ditentukan pada langkah 3 dengan factor penyesuai sesuai dengan persamaan (4.31).
   Fire case
   $$P_{o,j} = F_a \, . \, P_{o,j} \quad (4.31)$$
   $P_{o,j}$ = 1754.8 psig

overfilling case

$P_{o,j} = F_a \, . \, P_{o,j}$

$P_{o,j} = 1754.8$ psig

5. Gunakan hasil dari langkah 4 sebagai pengganti tekanan operasi, $P_{s,}$

Setelah mendapatkan nilai $P_{o,j}$ sebagai pengganti tekanan operasi, maka langkah berikutnya menyesuaikan dengan perhitungan analisis konsekuensi yang dikembangkan dalam bagian 3 API 581. Langkah-langkah tersebut sebagai berikut :

1. Menentukan fluida yang terlepas bila terjadi kegagalan berserta sifat-sifatnya, termasuk sifat didalamnya.
   Fluida representative yang paling sesuai dengan fluida yang terkandung dalam equipment yang dilindungi oleh PRD akan dievaluasi dan dipilih dari fluida representative seperti yang ditampilkan pada table 4.1 lampiran 3.
   a. Memilih kelompok fluida representative
      Fluida representative dipilih berdasarkan kandungan paling dominan dari fluida yang terdapat pada *equipment* yang dilindungi oleh PRD. Fluida yang terdapat pada sistem *production gas separator* berupa gas alam yang memiliki kandungan 72.25% methane yang termasuk dalam gugus C_1-C_2.
   b. Menentukan fase penyimpanan fluida
      Fase fluida yang disiman dalam pipa yang dilidungi oleh PRD PSV-1020A/B adalah Gas
   c. Menentukan sifat-sifat fluida yang tersimpan dengan data yang telah disediakan oleh API 581 dalam hal ini terdapat pada table 3.
      MW = 23.00 (kg/kg-mol)

      AIT = 1036 °F

      CP = 52.732 j/kmol-k

      K = 1.1872

      NBP = -193 °F

2. Memilih set ukuran lubang yang tercipta bila terjadi overpressure dan PRD mengalami kegagalan untuk menentukan kemungkinan konsekuensi pada perhitungan risiko.
   a. Ukuran lubang saat fluida *release* didasarkan pada tipe peralatan dan ukurannya. Pada kasus PRD ukuran lubang *small, medium, large* dan *rupture*.
   b. Menentukan nilai frekuensi kegagalan *generic,* gff, berdasarkan table 3.1 lampiran 3. sehingga didapatkan :
      - *Small* = 8.00E-06
      - *Medium* = 2.00E-05
      - *Large* = 2.00E-06
      - *Rupture* = 6.00E-07
      - Gff total = 3.06E-05

3. Menghitung laju *loss of containment*
Laju pelepasan bergantung pada sifat-sifat fisik material (fluida), fase awal, kondisi proses pengoperasian, dan ukuran lubang pelepasan yang telah ditentukan. Laju pelepasan dihitung dengan menggunakan persamaan 4.32 apabila tekanan penyimpanan lebih besar dari tekanan transisi

$$W_n = C_d \cdot K_{v,n} \cdot \boldsymbol{\rho}_1 \cdot \frac{A_n}{c_1}\sqrt{\frac{2g_c(p_s - p_{atm})}{\boldsymbol{\rho}_1}} \quad (4.32)$$

Dimana :
Cd = *discharge coefficient* direkomendasikan bernilai 0.9
k = *Ideal Gas Specific Heat Capacity Ratio* menggunakan pendekatan konservatif bernilai 1
$\boldsymbol{\rho}_1$ = density 250.51 lb/ft^3
A_n = *Release hole size area*
C_1 = *Convertion Factor* bernilai 31623
Ps = tekanan penyimpanan (psi), Nilai P_s menyesuaikan dengan nilai $P_{o,j}$ yang telah ditentukan pada pembahasan sebelumnya bernilai 1755 psi
Patm= tekanan atmosfer (psi) bernilai 14.69
gc = konstanta gravitasi lb_m-ft/lb_f-$s^{2,}$ bernilai0.98
Menentukan *release hole size area* dengan menggunakan persamaan (4.33)

$$A_n = \frac{\boldsymbol{\pi} d_n^2}{4} \quad (4.33)$$

D_n adalah diameter *equipment* yang dilindungi oleh PRD
$A_1 =$ 3E-05 m^2
$A_2 =$ 5E-04 m^2
$A_3 =$ 0.008 m^2
$A_4 =$ 0.13 m^2
Sehingga laju *loss of containment* dapat dihitung sebagai berikut:

$$W_n = C_d \cdot K_{v,n} \cdot \boldsymbol{\rho}_1 \cdot \frac{A_n}{c_1}\sqrt{\frac{2g_c(p_s - p_{atm})}{\boldsymbol{\rho}_1}}$$

$W_1 =$ 0.06257 kg/s
$W_2 =$ 1.00144 kg/s
$W_3 =$ 5.11836 kg/s
$W_4 =$ 256.304 kg/s

4. Mengestimasikan massa total dari fluida yang kemungkinan *release*
Perhitungan analisis konsekuensi kegagalan PRD pada API 581 memberikan pemodelan dengan mengkombinasikan peralatan lain yang dapat berkontribusi menambah massa fluida yang terlepas. Massa fluida yang terlepas dapat dihitung menggunakan persamaan (4.34).

$$Mass_{avail} = \min\left[\left(mass_{comp} + mass_{add,n}\right), mass_{inv}\right] \quad (4.34)$$

Dimana :

$Mass_{comp}$: massa peralatan yang dilindungi oleh PRD yang dianalisis
$Mass_{add}$: massa tambahan yang dapat terlepas selama 3 menit
$Mass_{inv}$: massa komponen lain yang terdapat dalam *inventory group*

- Menghitung massa komponen yang dilindungi oleh PRD yang dianalisis, $Mass_{comp,}$ menggunakan persamaan (4.35) di bawah ini
  $Mass_{comp} = \rho$ x V peralatan (4.35)
  OD = 3006 mm = 3.006 m
  L = 8800 mm = 8.8 m
  $V_{tot} = 62.222\ m^3$
  $V_{vap} = 31.111\ m^3$
  $\rho_{vap} = 8.86\ kg/m^3$
  Sehingga,
  $Mass_{comp} = 275.96$ kg
- Menghitung massa fluida yang terkandung pada masing-masing peralatan yang termasuk dalam *inventory froup*, $Mass_{comp,i}$. peralatan yang termasuk dalam satu *inventory group* dibatasi oleh katup yang secara otomatis maupun manual bisa ditutup untuk mencegah aliran lebih lanjut apabila terjadi kegagalan pada PRD saat terjadi *overpressure* pada peralatan yang dilindungi oleh PRD.
- Menghitung massa total pada *inventory group*, $Mass_{inv}$.
  $$\sum mass_{inv} = \sum_{i=1}^{n} mass_{comp,i}$$
  volume inventory adalah 275.96 kg.
- Menghitung *flow rate* untuk diameter 8 inch dengan *release hole size area* sebesar 32450 mm^2 menggunakan persamaan (4.36) di bawah ini :
  $$W_{max8} = \frac{C_d}{C_2} x A_8 x P_s \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ T_s}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad (4.36)$$
  $W_{max8} = 64.153$ kg/s
- Menghitung massa fluida tambahan, $mass_{add,n}$, untuk masing-masing ukuran lubang pelepasan, yang dapat menambah jumlah massa fluida dalam peralatan selama 3 menit dengan menggunakan rumus (4.37) berikut ini :
  $mass_{add,n} = 180\ x \min[W_n, W_{max8}]$ (4.37)
  $mass_{add,1} = 11.263$ kgs
  $mass_{add,2} = 180.26$ kgs
  $mass_{add,3} = 921.3$ kgs
  $mass_{add,4} = 11547$ kgs

5. Menentukan tipe *release, continuous* atau *instantaneous* yang digunakan untuk memodelkan dispersi dan konsekuensi

API RBI memberikan dua pemodelan tipe pelepasan yaitu :

a. *Instantaneous Release* – pelepasan sesaat atau *puff release* adalah pelepasan yang terjadi dengan sangat cepat sehingga cairan menyebar seperti awan yang besar atau *pool*.
b. *Continuous Release* – pelepasan terus-menerus atau *plume release* adalah pelepasan yang terjadi selama jangka waktu yang lama, yang memungkinkan cairan untuk menyebar dalam bentuk elips memanjang (tergantung kondisi cuaca).

Penentuan tipe pelepasan ditentukan berdasarkan kriteria dibawah ini :

- Apabila ukuran lubang pelepasan adalah 6.35 mm [0.25 inch], maka tipe pelepasan adalah *continuous*.
- Apabila waktu (t_n) kurang dari 180 dt atau massa yang terlepas lebih dari 4.536 kgs [10.000 lbs] maka tipe pelepasan adalah *instantaneous*.

Besarnya waktu untuk masing-masing ukuran lubang pelepasan dihitung menggunakan persamaan (4.38) berikut ini :

$$t_n = \frac{C_3}{W_n} \quad (4.38)$$

C_3 = factor konfersi SI dan US = 4536 kgs
t_1 = 72489.86 s (*Continuous*)
t_2 = 4529.49 s (*Continuous*)
t_3 = 886.22 s (*Continuous*)
t_4 = 17.698 s (*instantaneous*)

6. Mengestimasikan dampak sistem pendeteksi dan isolasi pada besarnya pelepasan.

   Perusahaan pengolahan petrokimia, biasanya memiliki berbagai sistem deteksi, isolasi, dan mitigasi yang dirancang untuk mengurangi efek dari pelepasan bahan-bahan berbahaya. Tabel 4.5 lambiran 3 menunjukan kriteria sistem deteksi dan isolasi .

   a. Menentukan sistem deteksi dan isolasi yang terdapat di dalam unit.
      Jenis support yang terpasang pada *pressure vessel* ialah *safety valve*, *transmitter*, LALL, LAHH, *hand valve*, *check valve*, *fire detector*, dll, yang digunakan untuk mendeteksi pada saat terjadi kebocoran. Sedangkan untuk sistem isolasi tidak perlu diaktifkan oleh operator di *control room*.
   b. Memilih klasifikasi sistem deteksi yang sesuai berdasarkan Tabel 4.5 Lampiran 3
      Dari penjelasan langkah 1 di atas maka dapat ditentukan klasifikasi sistem deteksi yaitu A.
   c. Memilih klasifikasi sistem isolasi yang sesuai berdasarkan Tabel 4.5 Lampiran 3.
      Berdasarkan penjelasan di langkah 1 dapat ditentukan klasifikasi sistem isolasi ialah A.
   d. Menentukan faktor reduksi, $fact_{di}$, menggunakan Tabel 4.6 Lampiran 3
      Dari Tabel B.6 Lampiran 3 untuk sistem deteksi A dan sistem isolasi A nilai *reduction factor*, $fact_{di}$, adalah 0.25

e. Menentukan durasi kebocoran total untuk masing-masing ukuran lubang pelepasan yang telah dipilih, $Id_{max,n}$, menggunakan Tabel 4.7 lampiran 3 . Nilai durasi kebocoran dari Tabel B.7 Lampiran 3, dapat disimpulkan :
   - Id_{max} untuk ¼ inch : 20 menit
   - Id_{max} untuk 1 inch : 10 menit
   - Id_{max} untuk 4 inch : 5 menit

7. Menentukan laju pelepasan dan massa untuk analisis konsekuensi
   a. Laju pelepasan (lb/s) *continuous* dihitung dengan persamaan (4.39), perhitungan tersebut digunakan sebagai input analisis konsekuensi.
   $Rate_n = W_n\ (1\text{-}fact_{di})$ (4.39)
   $rate_1 = 0.047$ kg/s
   $rate_2 = 0.751$ kg/s
   $rate_3 = 3.839$ kg/s
   $rate_4 = 192.2$ kg/s
   b. Untuk setiap ukuran lubang rilis, hitung ukuran lubang pelesan, hitung durasi kebocoran,ld_n, pelepasan menggunakan persamaaan (4.40)
   $$ld_n = \min\left[\left\{\frac{mass_{avail,n}}{rate_n}\right\}, \{60, ld_{max,n}\}\right] \quad (4.40)$$
   $ld_1 = 1200$ s
   $ld_2 = 367.4$ s
   $ld_3 = 71.89$ s
   $ld_4 = 1.436$ s
   c. Hitung *release mass* menggunakan persamaan (4.41) berdasarkan *release rate,* $rate_n$, *leak duration,*ld_n, dan *available mass.*
   $$mass_n = \min\left[\{rate_n . id_n\}, mass_{avail,n}\right] \quad (4.41)$$
   $mass_1 = 56.317$ kg
   $mass_2 = 275.955$ kg
   $mass_3 = 275.955$ kg
   $mass_4 = 275.955$ kg

8. Menghitung konsekuensi kebakaran/ledakan
   Konsekuensi area diestimasikan dari perhitungan laju pelepasan (untuk pelepasan *continuous*) atau masa pelepasan (untuk pelepasan *instantaneous).*
   a. Menentukan faktor pengurang pencegahan konsekuesni area, $fact_{mit,}$ yang dijelaskan pada table 4.10 lampiran 3. sehingga didapat nilai *consequence area mitigation reduction factor,* $fact_{mit} = 0.25$
   b. Menghitung factor koreksi, $eneff_n$ dengan menggunakan persamaan (4.42).
   $$eneff_n = 4.\ log_{10}[C_4\ .\ mass_n] - 15 \quad (4.42)$$
   $eneff_n = 5.376187$
   $eneff_n = 8.136989$
   $eneff_n = 8.136989$
   $eneff_n = 8.136989$
   c. Menghitung konsekuensi area *component damage*

Konsekuensi area *component damage* dibedakan menjadi 4, yaitu:

- *Auto-ignition Not Likely, Continuous Release*

  Konsekuensi area *Component Damage Auto-ignition Not Likely, Continuous Release,* dapat dihitung menggunakan rumusan (4.43) berikut ini:

  $CA_{cmd,n}^{AINL-CONT} = a(rate_n)^b.(1 - fact_{mit})$ (4.43)

  Nilai (a) dan (b) diambil dari table 4.8 lampiran 3

  a = 8.7

  b = 0.98

  $CA_{cmd,1}^{AINL-CONT} = 0.325$ m^2

  $CA_{cmd,2}^{AINL-CONT} = 4.911$ m^2

  $CA_{cmd,3}^{AINL-CONT} = 24.3$ m^2

  $CA_{cmd,4}^{AINL-CONT} = 1125$ m^2

- *Auto-ignition Likely, Continuous Release*

  Konsekuensi area *Component Damage Auto-ignition Likely, Continuous Release,* dapat dihitung menggunakan rumusan (4.44) berikut ini:

  $CA_{cmd,n}^{AIL-CONT} = a(rate_n)^b.(1 - fact_{mit})$ (4.44)

  Nilai (a) dan (b) diambil dari table 4.8 lampiran 3

  a = 55.0

  b = 0.95

  $CA_{cmd,1}^{AIL-CONT} = 2.259$ m^2

  $CA_{cmd,2}^{AIL-CONT} = 31.43$ m^2

  $CA_{cmd,3}^{AIL-CONT} = 148.1$ m^2

  $CA_{cmd,4}^{AIL-CONT} = 6095.2$ m^2

- *Auto-ignition Not Likely, Instantaneous Release*

  Konsekuensi area *Component Damage Auto-ignition Not Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (4.45) berikut ini :

  $CA_{cmd,n}^{AINL-INST} = \{a\ (mass_n)^b\}.\left(\frac{1-fact_{mit}}{eneff_n}\right)$ (4.45)

  Nilai (a) dan (b) diambil dari table 4.8 lampiran 3

  a = 6.5

  b = 0.67

  $CA_{cmd,1}^{AINL-INST} = 13.50$ m^2

  $CA_{cmd,2}^{AINL-INST} = 25.87$ m^2

  $CA_{cmd,3}^{AINL-INST} = 25.87$ m^2

  $CA_{cmd,4}^{AINL-INST} = 25.87$ m^2

- *Auto-ignition Likely, Instantaneous Release*

  Konsekuensi area *Component Damage Auto-ignition Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (4.46) berikut ini:

$CA_{cmd,n}^{AIL-INST} = \{a\ (mass_n)^b\}.\left(\frac{1-fact_{mit}}{eneff_n}\right)$ (4.46)

Nilai (a) dan (b) diambil dari table 4.8 lampiran 3

a = 163.7

b = 0.62

$CA_{cmd,1}^{AINL-INST} = 277.99\ m^2$

$CA_{cmd,2}^{AINL-INST} = 492\ m^2$

$CA_{cmd,3}^{AINL-INST} = 492\ m^2$

$CA_{cmd,4}^{AINL-INST} = 492\ m^2$

d. Menghitung konsekuensi area *personel injury*

- *Auto-ignition Not Likely, Continuous Release*

Konsekuensi area *Personel Injury, Auto-ignition Not Likely, Continuous Release,* dapat dihitung menggunakan rumusan (4.47) berikut ini:

$CA_{inj,n}^{AINL-CONT} = [a\ (effrate_n^{AINL-CONT})^b].(1 - fact_{mit})$ (4.47)

Nilai (a) dan (b) diambil dari table 4.9 lampiran 3

a = 21.8

b = 1.00

$CA_{inj,1}^{AINL-CONT} = 0.77\ m^2$

$CA_{inj,2}^{AINL-CONT} = 12.3\ m^2$

$CA_{inj,3}^{AINL-CONT} = 62.85\ m^2$

$CA_{inj,4}^{AINL-CONT} = 3147\ m^2$

- *Auto-ignition Likely, Continuous Release*

Konsekuensi area *Personel Injury, Auto-ignition Likely, Continuous Release,* dapat dihitung menggunakan rumusan (4.48) berikut ini:

$CA_{inj,n}^{AIL-CONT} = [a\ (effrate_n^{AIL-CONT})^b].(1 - fact_{mit})$ (4.48)

Nilai (a) dan (b) diambil dari table 4.9 lampiran 3

a = 143

b = 0.92

$CA_{inj,1}^{AIL-CONT} = 6.438\ m^2$

$CA_{inj,2}^{AIL-CONT} = 82.41\ m^2$

$CA_{inj,3}^{AIL-CONT} = 369.7\ m^2$

$CA_{inj,4}^{AIL-CONT} = 13535\ m^2$

- *Auto-ignition Not Likely, Instantaneous Release*

Konsekuensi area *Personel Injury, Auto-ignition Not Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (4.49) berikut ini:

$CA_{inj,n}^{AINL-INST} = [a\ (mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right)$ (4.49)

Nilai (a) dan (b) diambil dari table 4.9 lampiran 3

a = 12.5

b = 0.67

$CA_{inj,1}^{AINL-INST} = 25.88$ m^2
$CA_{inj,2}^{AINL-INST} = 49.60$ m^2
$CA_{inj,3}^{AINL-INST} = 49.60$ m^2
$CA_{inj,4}^{AINL-INST} = 49.60$ m^2

- *Auto-ignition Likely, Instantaneous Release*

  Konsekuensi area *Personel Injury, Auto-ignition Likely, Instantaneous Release,* dapat dihitung menggunakan rumusan (4.50) berikut ini:

  $$CA_{inj,n}^{AIL-INST} = [a\ (mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (4.50)$$

  Nilai (a) dan (b) diambil dari table 4.9 lampiran 3
  a = 474
  b = 0.63
  $CA_{inj,1}^{AINL-INST} = 838.04$ m^2
  $CA_{inj,2}^{AINL-INST} = 1506.97$ m^2
  $CA_{inj,3}^{AINL-INST} = 1506.97$ m^2
  $CA_{inj,4}^{AINL-INST} = 1506.97$ m^2

e. Menghitung *instantaneous*/*continuous blending factor* untuk masing-masing ukuran lubang pelepasan menggunakan persamaan 4.51dan 4.52.

- Nilai *blending factor* untuk tipe pelepasan *continuous* dihitung menggunakan persamaan 4. berikut ini :

  $$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad (4.51)$$

  Dengan nilai $C_5 = 25.2$
  $fact_1^{IC} = 0.0018651$
  $fact_2^{IC} = 0.0298016$
  $fact_3^{IC} = 0.1523413$
  $fact_4^{IC} = 1$

- Nilai *blending factor* untuk pelepasan *instantaneous* tidak disediakan, sehingga digunakan persamaan 4.51 di bawah ini :

  $fact_n^{IC} = 1.0$ (4.51)

f. Menghitung *AIT blending factor* menggunakan rumusan 4.52, 4.53, dan 4.54 yang sesuai.

$$fact^{AIT} = 0 \quad (4.52)$$
$$apabila\ T_s + C_6\ \leq AIT$$
$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2\ x\ C_6} \quad (4.53)$$
$$apabila\ T_s + C_6 > AIT > T_s - C_6$$
$$fact^{AIT} = 1 \quad (4.54)$$
$$apabila\ T_s - C_6\ \geq AIT$$

Dimana :
$T_s = 70°c$

$C_6 = 55.6$
AIT = 1036°f
$T_s + C_6 = 398.8$ K
$T_s - C_6 = 287.6$ K
Sehingga, $T_s + C_6 <$ AIT dan $T_s - C_6 <$ AIT
Maka :
$fact^{AIT} = 0$

g. Menghitung *continuous*/*instantaneous blended consequence area* menggunakan rumusan 4.55 sampai 4.58 berdasarkan konsekuensi area yang sudah dihitung sebelumnya.

- Besarnya *continuous blended consequence area component damage auto-ignition likely*

$$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} x\, fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} x\, (1 - fact_n^{IC}) \quad (4.55)$$

$CA_{cmd,1}^{AIL} = 2.7732$ m^2
$CA_{cmd,2}^{AIL} = 45.1514$ m^2
$CA_{cmd,3}^{AIL} = 200.4545$ m^2
$CA_{cmd,4}^{AIL} = 492.0012$ m^2

- Besarnya *instantaneous blended consequence area personel injury auto-ignition likely*

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} x\, fact_n^{IC} + CA_{inj,n}^{AINL-CONT} x\, (1 - fact_n^{IC}) \quad (4.56)$$

$CA_{inj,1}^{AINL} = 7.9887$ m^2
$CA_{inj,2}^{AINL} = 124.865$ m^2
$CA_{inj,3}^{AINL} = 542.973$ m^2
$CA_{inj,4}^{AINL} = 1506.9686$ m^2

- Besarnya *continuous blended consequence area component damage auto-ignition not likely*

$$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} x\, fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} x\, (1 - fact_n^{IC}) \quad (4.57)$$

$CA_{cmd,1}^{AIL} = 0.3495$ m^2
$CA_{cmd,2}^{AIL} = 5.5362$ m^2
$CA_{cmd,3}^{AIL} = 24.5402$ m^2
$CA_{cmd,4}^{AIL} = 25.8745$ m^2

- Besarnya *instantaneous blended consequence area personel injury auto-ignition not likely*

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} x\, fact_n^{IC} + CA_{inj,n}^{AINL-CONT} x\, (1 - fact_n^{IC}) \quad (4.58)$$

$CA_{inj,1}^{AINL} = 0.8163$ m^2
$CA_{inj,2}^{AINL} = 13.4075$ m^2
$CA_{inj,3}^{AINL} = 60.8348$ m^2

$CA_{inj,4}^{AINL} = 49.5995$ m^2

h. Menghitung AIT *blended consequence area* untuk kerusakan komponen menggunakan rumusan 4.59 dan untuk cedera personel dengan menggunakan rumusan 4.60 di bawah ini.

- Besarnya AIT *blended consequence area* untuk *component damage*

$$CA_{cmd,n}^{flam} = CA_{cmd,n}^{AIL} \, x \, fact^{AIT} + CA_{cmd,n}^{AINL} x \, (1 - fact^{AIT}) \quad (4.59)$$

$CA_{cmd,1}^{flam} = 0.3495$ m^2

$CA_{cmd,2}^{flam} = 5.5362$ m^2

$CA_{cmd,3}^{flam} = 24.5402$ m^2

$CA_{cmd,4}^{flam} = 25.8745$ m^2

- Besarnya AIT *blended consequence area* untuk *personel injury* adalah :

$$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} \, x \, fact^{AIT} + CA_{inj,n}^{AINL} x \, (1 - fact^{AIT}) \quad (4.60)$$

$CA_{inj,1}^{flam} = 0.8163$ m^2

$CA_{inj,2}^{flam} = 13.4075$ m^2

$CA_{inj,3}^{flam} = 60.8348$ m^2

$CA_{inj,4}^{flam} = 49.5995$ m^2

i. Menghitung konsekuensi area (probabilitas tertimbang pada setiap ukuran lubang rilis) untuk *component damage* dan *personel injury* mengikuti tabel gff seperti yang ada pada lampiran 3 menggunakan rumusan 4.61 dan 4.62 di bawah ini.

- Besarnya *consequence area* untuk *component damage*

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad (4.61)$$

$CA_{cmd}^{flam} = 5.82$ m^2

- Besarnya *consequence area* untuk *personel injury*

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad (4.62)$$

$CA_{inj}^{flam} = 13.925$ m^2

9. Menghitung konsekuensi area *toxic*

Dalam perhitungan ini perlu menganalisis apakah terdapat kandungan fluida yang beracun seperti yang terdapat pada tabel 4.113 pada lampian 3 dalam fluida yang terdapat pada komponen yang dilindungi oleh PRD. Dikarenakan pada PRD ini tidak terdapat kandungan fluida yang beracun maka untuk step ini tidak perlu dilakukan perhitungan.

10. Menghitung *non-flammable*, *non-toxic consequence*
    a. Untuk uap
       Uap termasuk berbahaya jika terpapar pada suhu tinggi. Secara umum, uap Nerada pada uhu 100^0C (212^0 f) keluar dari lubang pada equipment. Pendekatan yang digunakan disini adalah terjadi di atas suhu 60^0C. Dalam hal separator produksi bekerja maksimal pada suhu 100^0C. Jadi kebocoran uap berpotensi terjadi. Untuk menghitung hal tersebut dapat menggunakan persamaan 4.63 dan 4.64 dibawah ini :

       $$CA_{inj,n}^{CONT} = C_9 . Rate_n \quad (4.63)$$

       $CA_{inj,1}^{CONT}$ = 0.00578 m^2

       $CA_{inj,2}^{CONT}$ = 0.9237 m^2

       $CA_{inj,3}^{CONT}$ = 0.47220 m^2

       $$CA_{inj,n}^{CONT} = C_{10} mass_n^{0.6384} \quad (4.64)$$

       $CA_{inj,4}^{CONT}$ =154.68 m^2
    b. Untuk acids dan caustic
       Dikarenakan fluida methane tidak termasuk jadi bisa dianggap 0
    c. Menghitung konsekuensi area untuk setiap ukuran lubang pelepasan menggunakan persamaan 4.65 berikut ini :

       $$CA_{inj,n}^{leak} = CA_{inj,n}^{INST} \, x \, fact_n^{IC} + CA_{inj,n}^{CONT} x \, (1 - fact_n^{IC}) \quad (4.65)$$

       $CA_{inj,1}^{leak}$ = 0.00577 m^2

       $CA_{inj,2}^{leak}$ = 0.08962 m^2

       $CA_{inj,3}^{leak}$ = 0.40026 m^2

       $CA_{inj,1}^{leak}$ = 154.6823 m^2
    d. Menghitung konsekuensi area non flammable, non toxic personal injury menggunakan persamaan 4.66 berikut ini :

       $$CA_{inj}^{nfnt} = \left(\frac{\Sigma \, gff_n \, . \, CA_{inj,n}^{leak}}{gff_{total}} \right) \quad (4.66)$$

       CA_{inj}^{nfnt} = 3.119 m^2
11. Menentukan probabilitas kerusakan akhir peralatan dan cedera personil
    Konsekuensi area untuk kerusakan komponen dapat dihitung dengan menggunakan persamaan 4.67 berikut ini :

    $$CA_{cmd}^{flam} = CAcmd \quad (4.67)$$

    CA_{cmd} = 5.82 m^2

    Konsekuensi area untuk cedera personel dapat dihitung dengan menggunakan persamaan 4.68 berikut ini :

    $$CA_{inj} = \max \left[CA_{inj}^{flam}, \, CA_{inj}^{tox}, \, CA_{inj}^{nfnt} \right] \quad (4.68)$$

    CA_{inj} = 13.925 m^2
12. Menghitung konsekuensi akhir

Konsekuensi akhir dihitung menggunakan rumusan 4.69 di bawah ini:

$$CA = \max\left[CA_{cmd}, CA_{inj}\right] \quad (4.69)$$

$CA = 13.93\ \text{m}^2$

Berikut ini Rangkuman perhitungan risiko untuk PSV-1311, PSV-1312, PSV-2910, PSV-2921 dan PSV-2931 seperti yang ditampilkan pada **Tabel 4.11** sampai **Tabel 4.15**

Tabel 4.11 Ragkuman perhitungan risiko PSV-1311

No	ITEM	Symbol	Unit	RBI DATE	RBI Plan date	Remark
1	Probability of Failure (fire case)	$P_{f,j}^{prd}$	*Failure / year*	1.67E-10	4.76E-10	Step 13-POF to Open
2	Probability of Failure (overfilling case)	$P_{f,j}^{prd}$	*Failure / year*	4.18E-09	5.96E-08	Step 15-POF to Open
3	Probability of leakage	$P_{l,j}^{prd}$	*Failure / year*	0.0061	0.0953	Step 9-POF to Leakage
4	PRD demand rate (fire case)	DR_j	*Demands / year*	0.0004		Step 11-POF to Open
5	PRD demand rate (overfilling case)	DR_j	*Demands / year*	0.01		Step 11-POF to Open
6	PRD POFOD	$Pfod,J$	*Failure / year*	0.03168	0.09029	Step 18-POF to Open
7	POF overpressure	Pf,j	*Failure / year*	1.32E-05		Step 14-POF to Open
8	PRD POL	P_l^{prd}	*Failure / year*	0.02892	0.45143	Step 8-POF to Leakage
9	Set Pressure Factor	F_{set}		0.2111		Step 6.4-POF to Open
10	Release rate	W_1	Kg/s	0.2499		Step 3.4-COF
		W_2	Kg/s	3.9998		Step 3.4-COF
		W_3	Kg/s	20.4428		Step 3.4-COF
		W_4	Kg/s	1023.685		Step 3.4-COF
11	Equipment mass	$mass_{comp}$	Kg	6.6176		Step 4.2-COF
12	Inventory mass	$mass_{inv}$	Kg	6.6176		Step 4.4-COF
13	COF equipment	CA_{cmd}	m^2	13.070		Step 11.1-COF
14	COF injury	CA_{inj}	m^2	32.372		Step 11.2-COF
15	Consequence area	$\boldsymbol{CA}$	m^2	32.37		Step 11.3-COF
16	Risk Area		m^2/year	0.179	3.085	Step 1.3-RISK
17	Inspection date			17/6/2026		Step 3-RISK
18	Inspection Effectifness			4B	5B	Step 2-RISK

Tabel 4.12 Ragkuman perhitungan risiko PSV-1312

No	ITEM	Symbol	Unit	RBI DATE	RBI Plan date	Remark
1	Probability of Failure (fire case)	$P_{f,j}^{prd}$	*Failure / year*	1.42E-10	2.22E-09	Step 13-POF to Open
2	Probability of Failure (overfilling case)	$P_{f,j}^{prd}$	*Failure / year*	3.55E-09	5.55E-08	Step 15-POF to Open
3	Probability of leakage	$P_{l,j}^{prd}$	*Failure / year*	0.0054	0.0843	Step 9-POF to Leakage
4	PRD demand rate (fire case)	DR_j	*Demands / year*	0.0004		Step 11-POF to Open
5	PRD demand rate (overfilling case)	DR_j	*Demands / year*	0.01		Step 11-POF to Open
6	PRD POFOD	$Pfod,J$	*Failure / year*	0.02892	0.45143	Step 18-POF to Open
7	POF overpressure	Pf,j	*Failure / year*	1.23E-05		Step 14-POF to Open
8	PRD POL	P_l^{prd}	*Failure / year*	0.02892	0.45143	Step 8-POF to Leakage
9	Set Pressure Factor	F_{set}		0.1867		Step 6.4-POF to Open
10	Release rate	W_1	Kg/s	0.252		Step 3.4-COF
		W_2	Kg/s	4.041		Step 3.4-COF
		W_3	Kg/s	20.653		Step 3.4-COF
		W_4	Kg/s	1085.185		Step 3.4-COF
11	Equipment mass	$mass_{comp}$	Kg	26.4702		Step 4.2-COF
12	Inventory mass	$mass_{inv}$	Kg	26.4702		Step 4.4-COF
13	COF equipment	CA_{cmd}	m^2	36.490		Step 11.1-COF
14	COF injury	CA_{inj}	m^2	90.657		Step 11.2-COF
15	Consequence area	$\boldsymbol{CA}$	m^2	90.66		Step 11.3-COF
16	Risk Area		m^2/year	0.49	7.632	Step 1.3-RISK
17	Inspection date			24/2/2025		Step 3-RISK
18	Inspection Effectifness			4B	5B	Step 2-RISK

Tabel 4.13 Ragkuman perhitungan risiko PSV-2910

No	ITEM	Symbol	Unit	RBI DATE	RBI Plan date	Remark
1	Probability of Failure (fire case)	$P_{f,j}^{prd}$	*Failure / year*	2.26E-10	3.53E-09	Step 13-POF to Open
2	Probability of Failure (overfilling case)	$P_{f,j}^{prd}$	*Failure / year*	5.65E-09	8.82E-08	Step 15-POF to Open
3	Probability of leakage	$P_{l,j}^{prd}$	*Failure / year*	0.008	0.1249	Step 9-POF to Leakage
4	PRD demand rate (fire case)	DR_j	*Demands / year*	0.0004		Step 11-POF to Open
5	PRD demand rate (overfilling case)	DR_j	*Demands / year*	0.01		Step 11-POF to Open
6	PRD POFOD	$Pfod,J$	*Failure / year*	0.02892	0.45143	Step 18-POF to Open
7	POF overpressure	Pf,j	*Failure / year*	1.95E-05		Step 14-POF to Open
8	PRD POL	P_l^{prd}	*Failure / year*	0.02892	0.45143	Step 8-POF to Leakage
9	Set Pressure Factor	F_{set}		0.2766		Step 6.4-POF to Open
10	Release rate	W_1	Kg/s	0.088		Step 3.4-COF
		W_2	Kg/s	1.414		Step 3.4-COF
		W_3	Kg/s	7.227		Step 3.4-COF
		W_4	Kg/s	361.877		Step 3.4-COF
11	Equipment mass	$mass_{comp}$	Kg	105.881		Step 4.2-COF
12	Inventory mass	$mass_{inv}$	Kg	105.881		Step 4.4-COF
13	COF equipment	CA_{cmd}	m^2	25.210		Step 11.1-COF
14	COF injury	CA_{inj}	m^2	62.850		Step 11.2-COF
15	Consequence area	$\boldsymbol{CA}$	m^2	62.85		Step 11.3-COF
16	Risk Area		m^2/year	0.503	7.85	Step 1.3-RISK
17	Inspection date			31/12/2024		Step 3-RISK
18	Inspection Effectifness			4B	5B	Step 2-RISK

Tabel 4.14 Ragkuman perhitungan risiko PSV-2921

No	ITEM	Symbol	Unit	RBI DATE	RBI Plan date	Remark
1	Probability of Failure (fire case)	$P_{f,j}^{prd}$	*Failure / year*	1.14E-10	1.78E-09	Step 13-POF to Open
2	Probability of Failure (overfilling case)	$P_{f,j}^{prd}$	*Failure / year*	2.85E-09	4.45E-08	Step 15-POF to Open
3	Probability of leakage	$P_{l,j}^{prd}$	*Failure / year*	0.0019	0.0518	Step 9-POF to Leakage
4	PRD demand rate (fire case)	DR_j	*Demands / year*	0.0004		Step 11-POF to Open
5	PRD demand rate (overfilling case)	DR_j	*Demands / year*	0.01		Step 11-POF to Open
6	PRD POFOD	$Pfod,J$	*Failure / year*	0.02892	0.45143	Step 18-POF to Open
7	POF overpressure	Pf,j	*Failure / year*	9.85E-06		Step 14-POF to Open
8	PRD POL	P_l^{prd}	*Failure / year*	0.01733	0.47046	Step 8-POF to Leakage
9	Set Pressure Factor	F_{set}		0.11		Step 6.4-POF to Open
10	Release rate	W_1	Kg/s	0.2517		Step 3.4-COF
		W_2	Kg/s	4.0285		Step 3.4-COF
		W_3	Kg/s	20.5898		Step 3.4-COF
		W_4	Kg/s	1031.0421		Step 3.4-COF
11	Equipment mass	$mass_{comp}$	Kg	532.4823		Step 4.2-COF
12	Inventory mass	$mass_{inv}$	Kg	532.4823		Step 4.4-COF
13	COF equipment	CA_{cmd}	m^2	53.19		Step 11.1-COF
14	COF injury	CA_{inj}	m^2	127.02		Step 11.2-COF
15	Consequence area	$\boldsymbol{CA}$	m^2	127.02		Step 11.3-COF
16	Risk Area		m^2/year	0.241	6.58	Step 1.3-RISK
17	Inspection date			21/3/2026		Step 3-RISK
18	Inspection Effectifness			4C	5C	Step 2-RISK

Tabel 4.15 Ragkuman perhitungan risiko PSV-2931

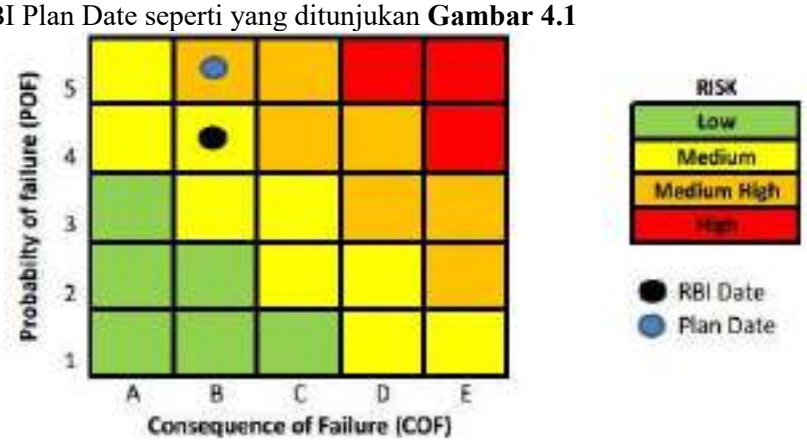
No	ITEM	Symbol	Unit	RBI DATE	RBI Plan date	Remark
1	Probability of Failure (fire case)	$P_{f,j}^{prd}$	*Failure / year*	1.14E-10	1.78E-09	Step 13-POF to Open
2	Probability of Failure (overfilling case)	$P_{f,j}^{prd}$	*Failure / year*	2.85E-09	4.45E-08	Step 15-POF to Open
3	Probability of leakage	$P_{l,j}^{prd}$	*Failure / year*	0.0032	0.0497	Step 9-POF to Leakage
4	PRD demand rate (fire case)	DR_j	*Demands / year*	0.0004		Step 11-POF to Open
5	PRD demand rate (overfilling case)	DR_j	*Demands / year*	0.01		Step 11-POF to Open
6	PRD POFOD	$Pfod,J$	*Failure / year*	0.02892	0.45143	Step 18-POF to Open
7	POF overpressure	Pf,j	*Failure / year*	9.85E-06		Step 14-POF to Open
8	PRD POL	P_l^{prd}	*Failure / year*	0.02892	0.45143	Step 8-POF to Leakage
9	Set Pressure Factor	F_{set}		0.11		Step 6.4-POF to Open
10	Release rate	W_1	Kg/s	0.252		Step 3.4-COF
		W_2	Kg/s	4.029		Step 3.4-COF
		W_3	Kg/s	20.590		Step 3.4-COF
		W_4	Kg/s	1031.042		Step 3.4-COF
11	Equipment mass	$mass_{comp}$	Kg	431.8835		Step 4.2-COF
12	Inventory mass	$mass_{inv}$	Kg	431.8835		Step 4.4-COF
13	COF equipment	CA_{cmd}	m^2	51.50		Step 11.1-COF
14	COF injury	CA_{inj}	m^2	123.80		Step 11.2-COF
15	Consequence area	$\boldsymbol{CA}$	m^2	123.80		Step 11.3-COF
16	Risk Area		m^2/year	0.396	6.153	Step 1.3-RISK
17	Inspection date			17/6/2026		Step 3-RISK
18	Inspection Effectifness			4C	5C	Step 2-RISK

4.3.4 Penentuan tingkat risiko pada PRD sistem production gas separator

Besarnya risiko yang telah dihitung secara detail pada lampiran 1-3 akan menjadi dasar untuk penentuan level risiko PRD yang akan di rangkum dalam bab ini.

a. Menghitung dan menentukan besarnya risiko pada PSV-1020A/B
   - Menentukan kategori PoF
     Kategori probabilitas kegagalan ditentukan oleh penjumlahan probabilitas kegagalan membuka dan kebocoran setiap tahun sebesar 5.10E-03 failure/year untuk RBI Date dan 1.38E-01 failure/year untuk RBI Plan Date.
     Kategori probabilitas kegagalan adalah 4 untuk RBI Date dan 5 untuk RBI Plan Date. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.
   - Menentukan kategori CoF
     Kategori konsekuensi area kegagalan dipengaruhi oleh besarnya kegagalan akhir peralatan. Besarnya konsekuensi akhir dari PSV-1020A/B adalah CoF = 13.93 m^2 = 149.89 ft^2
     Kategori konsekuensi kegagalan adalah B. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

   Sehingga bila diplotkan kedalam matrix risiko PSV-1020A/B memiliki kategori risiko *medium risk* untuk RBI Date dan *medium high risk* untuk RBI Plan Date seperti yang ditunjukan **Gambar 4.1**



Gambar 4.1 Risiko saat ini PSV-1020A/B

b. Menghitung dan menentukan besarnya risiko pada PSV-1311
   - Menentukan kategori PoF
     Kategori probabilitas kegagalan ditentukan oleh penjumlahan probabilitas kegagalan membuka dan kebocoran setiap tahun sebesar 6.10E-03 failure/year untuk RBI Date dan 9.53E-02 failure/year untuk RBI Plan Date.

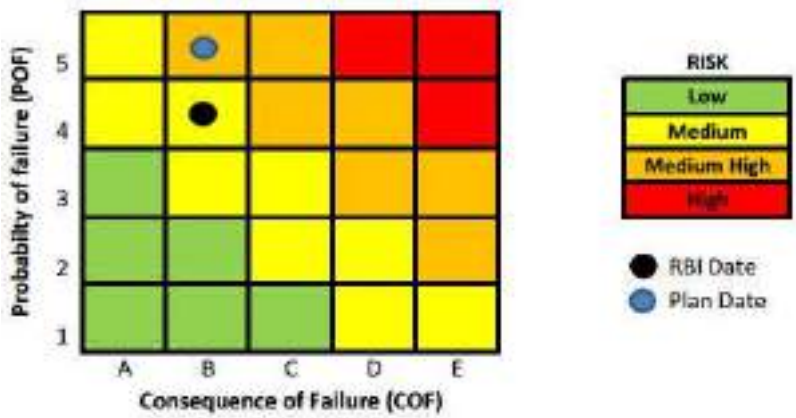
Kategori probabilitas kegagalan adalah 4 untuk RBI Date dan 5 untuk RBI Plan Date. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

- Menentukan kategori CoF

  Kategori konsekuensi area kegagalan dipengaruhi oleh besarnya kegagalan akhir peralatan. Besarnya konsekuensi akhir dari PSV-1311 adalah CoF = 32.37 m^2 = 348.45 ft^2

  Kategori konsekuensi kegagalan adalah B. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

Sehingga bila diplotkan kedalam matrix risiko PSV-1311 memiliki kategori risiko *medium risk* untuk RBI Date dan *medium high risk* untuk RBI Plan Date seperti yang ditunjukan **Gambar 4.2**



Gambar 4.2 Risiko saat ini PSV-311

c. Menghitung dan menentukan besarnya risiko pada PSV-1312

- Menentukan kategori PoF

  Kategori probabilitas kegagalan ditentukan oleh penjumlahan probabilitas kegagalan membuka dan kebocoran setiap tahun sebesar 5.40E-03 failure/year untuk RBI Date dan 8.43E-02 failure/year untuk RBI Plan Date.

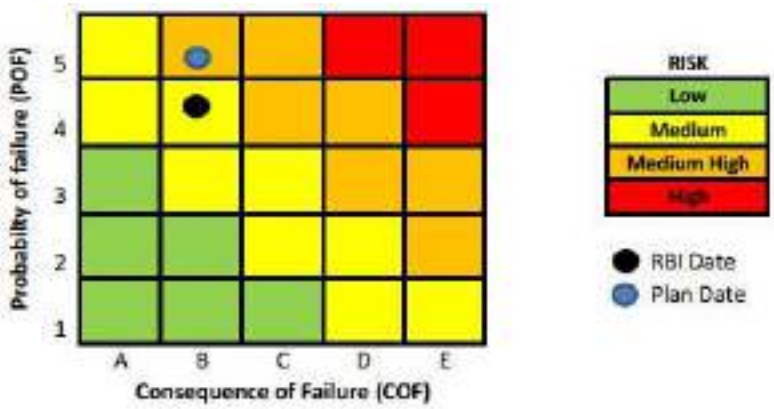
  Kategori probabilitas kegagalan adalah 4 untuk RBI Date dan 5 untuk RBI Plan Date. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

- Menentukan kategori CoF

  Kategori konsekuensi area kegagalan dipengaruhi oleh besarnya kegagalan akhir peralatan. Besarnya konsekuensi akhir dari PSV-1312 adalah CoF = 90.66 m^2 = 975.82 ft^2

  Kategori konsekuensi kegagalan adalah B. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

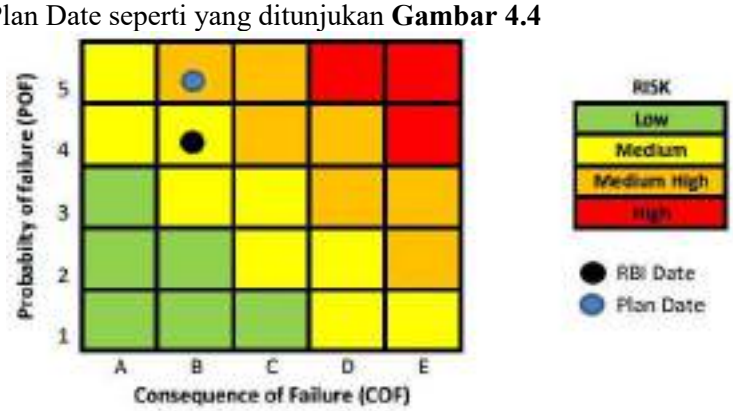
Sehingga bila diplotkan kedalam matrix risiko PSV-1312 memiliki kategori risiko *medium risk* untuk RBI Date dan *medium high risk* untuk RBI Plan Date seperti yang ditunjukan **Gambar 4.3**



Gambar 4.3 Risiko saat ini PSV-1312

d. Menghitung dan menentukan besarnya risiko pada PSV-2910
   - Menentukan kategori PoF
     Kategori probabilitas kegagalan ditentukan oleh penjumlahan probabilitas kegagalan membuka dan kebocoran setiap tahun sebesar 8.00E-03 failure/year untuk RBI Date dan 1.25E-01 failure/year untuk RBI Plan Date.
     Kategori probabilitas kegagalan adalah 4 untuk RBI Date dan 5 untuk RBI Plan Date. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.
   - Menentukan kategori CoF
     Kategori konsekuensi area kegagalan dipengaruhi oleh besarnya kegagalan akhir peralatan. Besarnya konsekuensi akhir dari PSV-2910 adalah CoF = 62.85 m^2 = 676.53 ft^2
     Kategori konsekuensi kegagalan adalah B. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

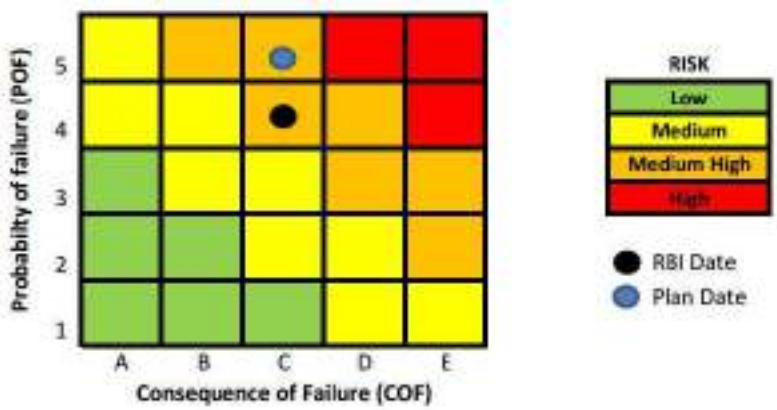
   Sehingga bila diplotkan kedalam matrix risiko PSV-2910 memiliki kategori risiko *medium risk* untuk RBI Date dan *medium high risk* untuk RBI Plan Date seperti yang ditunjukan **Gambar 4.4**



Gambar 4.4 Risiko saat ini PSV-2910

e. Menghitung dan menentukan besarnya risiko pada PSV-2921
   - Menentukan kategori PoF
     Kategori probabilitas kegagalan ditentukan oleh penjumlahan probabilitas kegagalan membuka dan kebocoran setiap tahun sebesar 1.90E-03 failure/year untuk RBI Date dan 5.18E-02 failure/year untuk RBI Plan Date.
     Kategori probabilitas kegagalan adalah 4 untuk RBI Date dan 5 untuk RBI Plan Date. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.
   - Menentukan kategori CoF
     Kategori konsekuensi area kegagalan dipengaruhi oleh besarnya kegagalan akhir peralatan. Besarnya konsekuensi akhir dari PSV-2910 adalah CoF = 127.02 m^2 = 1367.2 ft^2
     Kategori konsekuensi kegagalan adalah C. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

   Sehingga bila diplotkan kedalam matrix risiko PSV-2921 memiliki kategori risiko *medium high risk* untuk RBI Date dan RBI Plan Date seperti yang ditunjukan **Gambar 4.5**

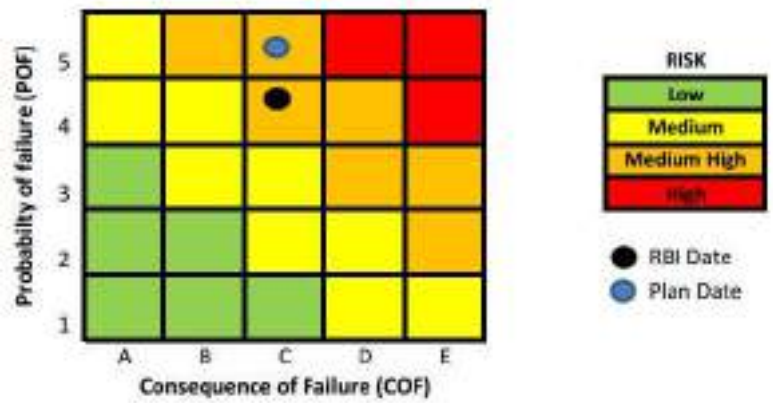


Gambar 4.5 Risiko saat ini PSV-2921

f. Menghitung dan menentukan besarnya risiko pada PSV-2931
   - Menentukan kategori PoF
     Kategori probabilitas kegagalan ditentukan oleh penjumlahan probabilitas kegagalan membuka dan kebocoran setiap tahun sebesar 3.20E-03 failure/year untuk RBI Date dan 4.97E-02 failure/year untuk RBI Plan Date.
     Kategori probabilitas kegagalan adalah 4 untuk RBI Date dan 5 untuk RBI Plan Date. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.
   - Menentukan kategori CoF
     Kategori konsekuensi area kegagalan dipengaruhi oleh besarnya kegagalan akhir peralatan. Besarnya konsekuensi akhir dari PSV-2910 adalah CoF = 123.8 m^2 = 1332.5 ft^2

Kategori konsekuensi kegagalan adalah C. Kategori probabilitas dapat dilihat pada table 4.1 lampiran 4.

Sehingga bila diplotkan kedalam matrix risiko PSV-2931 memiliki kategori risiko *medium high risk* untuk RBI Date dan RBI Plan Date seperti yang ditunjukan **Gambar 4.6**



Gambar 4.6 Risiko saat ini PSV-2931

4.4 *Inspection Planning*

Inspection Planning disusun berdasarkan level risiko sebuah *equipment* pada saat analisis RBI dilaksanakan, untuk keperluan laporan perhitungan inspeksi hanya untuk PSV-1020A/B sedangkan untuk PSV-1311, PSV-1312, PSV-2910, PSV-2921 dan PSV-2931 selengkapnya bisa dilihat pada lampiran 4. Langkah-langkah dalam menentukan *inspection planning* ialah :

1. Menghitung *target inspection date*
   Target date didapatkan dengan cara melakukan interpolasi nilai RBI Date dan RBI Plan Date. Dalam menentukan target date, digunakan nilai risk targer 3.71 m^2 untuk menentukan tahun inspeksi, seperti yang ada pada **Tabel 4.16** di bawah ini :

Tabel 4.16 Perhitungan Inspection Date

Data	Date	Time since RBI Assessment	Risk Area
RBI Date	15/3/2020	0	0.071
Risk Target	?	?	3.71
Plan Date	15/3/2024	11	1.9147

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}$$

$$Y = 0 + \left(\frac{3.71 - 0.071}{1.9147 - 0.071}\right)(11 - 0)$$

Y = 21.71 tahun

Sehingga,

Berdasarkan standart API 510 memberikan rekomendasi interval inspeksi maksimal untuk Pressure Reliev Device yaitu 10 tahun dari inspeksi terakhir. Sehingga untuk jadwal inspeksi selanjutnya yaitu pada tanggal 17 juni 2026.

2. Menentukan *Inspection Effectiveness*

   Inspection Effectiveness ditentukan hingga mendapatkan nilai inspection confidence factors sehingga risiko saat inspection date *acceptable.* Pada analisa penelitian ini direkomendasikan minimal menggunakan inspection effectiveness kategori C dengan mengaplikasikan *Visual on-stream Inspection.* Adapun *Visual on-stream Inspection* telah dibahas pada pada bab 2.12.2.

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BAB 5
KESIMPULAN DAN SARAN

5.1 Kesimpulan

Kesimpulan dari penelitian yang dilakukan terhadap PRD yang dianalisis dengan metode RBI API 581 adalah :

1. Besarnya risiko pada PSV-1020A/B, PSV-1311, PSV-1312, PSV-2910, PSV-2921 dan PSV 2931 berkisar antara 0.071 m^2/year – 0.49 m^2/year untuk RBI Date dan berkisar antara 1.915 m^2/year – 7.85 m^2/year untuk RBI Plan Date. Berikut Rangkuman hasil RBI Date pada **Tabel 5.1** dan Rangkuman hasil RBI Plan Date **Tabel 5.2.**

Tabel 5.1 Ragkuman RBI Date

NO	PSV	POF (*failure/year*)	COF (m^2)	RISK (m^2/*year*)
1	1020A/B	5.10E-03	13.93	0.071
2	1311	6.10E-03	32.37	0.197
3	1312	5.04E-03	90.66	0.49
4	2910	8.00E-03	62.85	0.503
5	2921	1.90E-03	127.02	0.241
6	2931	3.20E-03	123.80	0.396

Tabel 5.2 Ragkuman RBI Plan Date

NO	PSV	POF (*failure/year*)	COF (m^2)	RISK (m^2/*year*)
1	1020A/B	1.38E-01	13.93	1.915
2	1311	9.53E-02	32.37	3.085
3	1312	8.43E-02	90.66	7.642
4	2910	1.25E-01	62.85	7.85
5	2921	5.18E-02	127.02	6.58
6	2931	4.97E-02	123.80	6.153

2. Besarnya risiko untuk seluruh PRD yang dianalisis bila dimasukan kedalam matriks risiko memiliki kategori risiko *medium risk* dan *medium high risk.* Dan merupakan tingkat risiko yang dapat diterima. **Tabel 5.3** merupakan rangkuman hasil Kategori Risiko yang telah dianalisa

Tabel 5.3 Ragkuman Kategori Risiko

NO	PSV	Kategori	
		RBI Date	RBI Plan Date
1	1020A/B	4B	5B
2	1311	4B	5B
3	1312	4B	5B
4	2910	4B	5B
5	2921	4C	5C
6	2931	4C	5C

Warna kuning menunjukkan bahwa risiko berada pada level ***medium***, dan warna oranye menunjukkan nilai risiko berada pada level ***medium-high***.

3. Inspection planning untuk *pressure relief device :*
   a. PSV-1020A/B diestimasi pada tahun ke-10 setelah dilakukan analisis RBI, yaitu pada tanggal 17 Juni 2026
   b. PSV-1311 diestimasi pada tahun ke-10 setelah dilakukan analisis RBI, yaitu pada tanggal 17 Juni 2026
   c. PSV-1312 diestimasi pada tahun ke-9 setelah dilakukan analisis RBI, yaitu pada tanggal 24 Februari 2025
   d. PSV-2910 diestimasi pada tahun ke-8 setelah dilakukan analisis RBI, yaitu pada tanggal 31 Desember 2024
   e. PSV-2921 diestimasi pada tahun ke-10 setelah dilakukan analisis RBI, yaitu pada tanggal 21 Maret 2026
   f. PSV-2931 diestimasi pada tahun ke-10 setelah dilakukan analisis RBI, yaitu pada tanggal 17 Juni 2026
4. Metode inspeksi yang diharapkan dapat diaplikasikan adalah dilaksanakannya inspeksi secara visual tanpa melakukan test *pop,* dimana dokumentasi rinci kondisi komponen internal PRD dilakukan.
5. Hasil perhitungan menggunakan metode RBI beberapa PRD menunjukan kurun waktu inspeksi untuk PRD yang lebih lama dibandingkan ketentuan dari API 571,yaitu setiap 10 tahun sekali. Perbedaan jadwal inspeksi tersebut dapat disebabkan oleh data yang kurang lengkap.

5.2 Saran

1. Penggunaan metode RBI dalam menentukan risiko tidak secara langsung menurunkan risiko, sehingga perlu adanya *trial & eror* dengan sering melakukan penilaian RBI untuk mendapatkan data yang *update* sehingga factor ketidak pastian berkurang.
2. Tidak tersedia data biaya pada asset yang dimiliki, sehingga penilaian hanya menggunakan konsekuensi area. Seharusnya pihak perusahaan dapat melakukan perhitungan konsekuensi biaya sehingga bisa menganalisis *cost benefit analisis* dalam penentuan penggunaan metode *time-based* maintenance maupun *risk-based inspection* serta menentukan jenis inspeksi yang dilakukan.

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ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 1:

DATA PRESSURE RELIEF DEVICE

PSV-1020A/B

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

Lampiran 1 = Data Pressure Relief Device

1 GENERAL

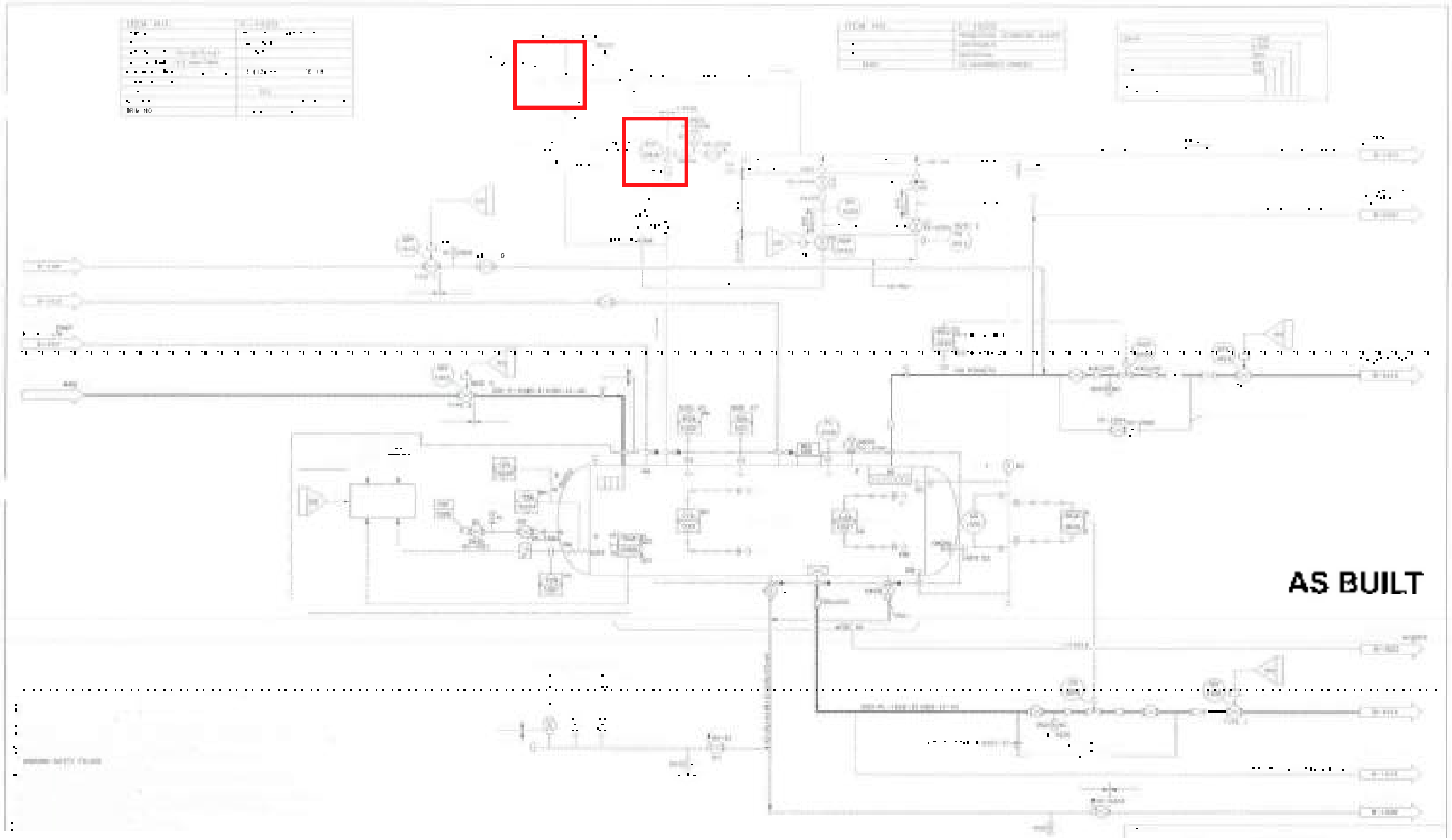
Tag Number	:	PSV-1020A/B	
Service	:	Production Separator V-1020	
Noozle (full/semi)	:	FULL	
PID No.	:	BTJT-A-B-1010	
Design	:	SAFETY-RELIEF	
Type	:	Conventional	
Bonnet Type	:	Closed	
Nace Requirement	:	Yes	

2 PROCESS CONDITIONS

Fluid		:	Hydrocarbon	
State		:	Gas	
Required Capacity		:	4220	lb/h
Molecular Weight		:	24.97	
Operating Pressure		:	134.9	psig
Set Pressure		:	512.7	psig
Operating Temperatur		:	473.2	^{o}F
Reliefing Temperatur		:	473.2	^{o}F
Back Pressure	Constant	:	0	psig
	Variable	:	0	psi
	Total	:	23.1	psig
% Allowable Overpressure		:	21%	
Overpressure Factor		:	-	
Compressible Factor		:	0.853	
Laten Heat of Vaporation		:	-	Btu/lb
Ratio of Specific Heats (Cp/C		:	1.331	
Relief Density		:	3.78	Lb/ft^2
Relief Viscosity		:	0.016	cP
Barometric Pressure		:	14.7	psia

3 DESIGN CONDITION

Design Pressure	:	512.7	psig
Design Temperatur	:	500	^{o}F


AS BUILT

CASE 1 : MAXIMUM GAS FLOW RATE (AUGUST 2016)

Stream Name		1	1A	1B	1C	1D	1E	2	2A	2B	2C	2D	2E	3	4	4A	5	6	7	8	9	10
Description		Wellhead Flowline U/S of choke NAG	Wellhead Flowline (B72_A_P1) U/S of choke - Long String	Wellhead Flowline (B74_C_P1) U/S of choke - Long String	Wellhead Flowline (B74_D_P1) U/S of choke - Long String	Wellhead Flowline (B72_C_P1) U/S of choke - Long String	Wellhead Flowline (B74_E_P1) U/S of choke - Long String	Wellhead Flowline D/S of choke - Short String (NAG)	Wellhead Flowline (B72_A_P1) D/S of choke - Long String	Wellhead Flowline (B74_C_P1) D/S of choke - Long String	Wellhead Flowline (B74_D_P1) D/S of choke - Long String	Wellhead Flowline (B72_C_P1) D/S of choke - Long String	Wellhead Flowline (B74_E_P1) D/S of choke - Long String	Inlet to Production Separator	Production Separator Gas Outlet	Gas Pipeline to FPSO	Liquid Pipeline to FPSO	Export Gas from FPSO to WHP (Note 7)	Export Gas from WHP to DNF (Note 6)	Gas Lift	Gas Inlet to FPSO (Note 6)	Liquid Inlet to FPSO (Note 6)
MIXTURE																						
Vapour Fraction		1.0000	0.2955	0.4203	0.2920	0.3055	0.2955	1.0000	0.3159	0.4233	0.2840	0.3115	0.2975	0.4147	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0041	0.0019
Temperature	C	75.0	75.0	71.0	72.0	75.0	74.0	66.4	69.2	70.2	71.4	74.3	73.4	70.3	70.3	70.2	70.5	65.8	72.9	65.8	52.1	69.7
Pressure	kPag	2959	2959	1934	1934	1934	1934	930	930	930	930	930	930	930	930	930	880	880	9101	7120	0101	755	522
Pressure	bar g	29.6	29.6	19.3	19.3	19.3	19.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	8.8	8.8	91.0	71.2	84.8	7.6	5.2
Mass Flow	kg/h	26300.60	110228.76	22227.17	82356.85	29194.58	8478.20	26300.60	110228.76	22227.17	82356.85	29194.58	8478.20	289534.66	9280.71	9280.71	1966598.17	80517.40	72509.32	7845.82	92836.71	1966598.17
Molar Flow	kgmol/h	449.11	841.38	3550.51	685.08	2545.47	898.18	449.11	841.38	3550.51	685.08	2545.47	898.18	9400.90	3899.75	3899.75	5501.15	3033.67	3452.38	373.55	3899.75	5501.15
Molecular Weight		58.9	131.0	6.3	120.2	32.4	32.5	58.9	131.0	6.3	120.2	32.4	32.5	30.8	23.8	23.8	35.8	26.6	21.0	21.0	23.8	35.8
Heat Flow	kW	-9821	-53720	-205650	-44662	-163516	-58496	-9821	-53720	-205650	-44662	-163516	-58496	-541951	-96396	-96396	-451503	-86559	-78265	-8434	-96396	-451503
Mass Heat Capacity	kJ/kg-C	2.60	2.58	2.60	2.61	2.51	2.72	2.97	2.60	2.78	2.91	2.89	2.91	2.81	2.14	2.14	2.13	2.72	2.61	2.72	2.11	2.13
Mass Density	kg/m3	21.04	108.95	20.76	43.84	41.06	43.17	7.04	35.96	29.38	28.79	37.14	28.84	27.10	8.87	8.43	870.51	75.62	61.13	75.42	7.80	731.73
GAS PHASE																						
Std Gas Flow	MMm3/h	10.85	5.56	33.39	4.46	17.62	5.95	10.85	5.95	33.54	4.51	17.74	5.99	87.21	87.24	87.24	0.01	85.76	77.23	8.36	85.80	0.23
Std Gas Flow	MMSCFD	9.00	4.88	29.81	4.01	15.79	5.33	9.00	5.33	29.95	4.05	15.89	5.36	78.12	78.15	78.15	0.02	76.83	69.19	7.49	76.91	0.21
Molar Flow	kgmol/h	449.11	248.67	1492.34	200.05	787.71	265.75	449.11	263.81	1495.40	201.36	792.94	267.56	3898.54	3899.75	3899.75	1.13	3833.67	3452.38	373.55	3899.75	10.47
Actual Gas Flow	ACT m3/h	403.02	217.56	3621.21	466.87	1934.34	650.66	1205.17	710.89	4009.69	540.36	2146.41	732.19	10461.78	10470.75	11011.23	3.19	1067.56	1188.11	104.02	11747.65	46.67
Mass Flow	kg/h	8478.39	5617.78	37106.48	4089.82	19834.55	6870.73	8478.39	5309.98	37431.64	5508.85	29061.87	6740.84	92780.89	92836.71	92836.71	27.22	89517.40	72509.32	7845.82	94859.53	286.14
Molecular Weight		18.9	22.6	24.9	24.9	25.2	25.1	18.9	23.7	25.0	25.1	25.3	25.2	23.8	23.8	23.8	24.1	21.0	21.0	21.0	23.8	27.3
Mass Heat Capacity	kJ/kg-C	2.40	2.50	2.13	2.13	2.14	2.14	2.27	2.13	2.12	2.13	2.13	2.13	2.14	2.14	2.14	2.14	2.72	2.61	2.72	2.06	2.06
Z Factor		0.95	0.93	0.96	0.96	0.96	0.96	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.86	0.86	0.86	0.86	0.97	0.97
Thermal Conductivity	W/m-K	0.041	0.038	0.034	0.034	0.035	0.035	0.038	0.035	0.034	0.034	0.034	0.034	0.035	0.035	0.035	0.035	0.047	0.043	0.047	0.033	0.037
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Mass Density	kg/m3	21.04	26.82	10.25	10.25	10.25	10.25	7.04	6.86	9.33	9.34	9.35	9.35	8.87	8.87	8.43	8.54	75.42	61.13	75.42	7.80	6.13
Cp/Cv (Gamma)		1.32	1.30	1.23	1.23	1.22	1.22	1.27	1.23	1.22	1.22	1.22	1.22	1.23	1.23	1.23	1.23	1.46	1.44	1.46	1.24	1.20
OIL PHASE																						
Mass Flow	kg/h	---	111155.91	29678.59	9354.51	33942.01	12226.33	---	10545.33	39426.24	9334.07	33751.47	12159.37	107029.65	0.00	---	100954.00	---	---	---	80.05	106703.77
Liquid Vol Flow @Std Cond	m3/h	---	113.25	46.51	10.96	39.75	14.32	---	12.29	46.14	10.93	39.46	14.22	124.78	0.00	---	134.68	---	---	---	0.10	134.26
Liquid Vol Flow @Std Cond	bbl/day	---	25.06	7021	1655	6000	2162	---	1859	6963	1653	5957	2147	18836	0	---	18823	---	---	---	15	18754
Actual Volume Flow	m3/h	---	13.99	48.76	11.50	41.81	15.05	---	12.85	48.32	11.41	41.47	14.93	130.61	0.00	---	130.53	---	---	---	0.11	129.94
Molecular Weight		---	174.5	196.6	197.0	198.1	197.7	---	205.6	199.4	199.5	200.2	200.3	203.1	205.3	---	205.6	---	---	---	110.1	206.7
Mass Heat Capacity	kJ/kg-C	---	2.16	2.13	2.13	2.14	2.14	---	2.11	2.12	2.13	2.14	2.13	2.12	2.12	---	2.12	---	---	---	2.09	2.11
Thermal Conductivity	W/m-K	---	0.103	0.109	0.109	0.109	0.109	---	0.111	0.110	0.110	0.110	0.110	0.111	0.111	---	0.111	---	---	---	0.107	0.112
Viscosity	cP	---	1.20	1.54	1.54	1.50	1.51	---	1.76	1.62	1.59	1.55	1.56	1.72	1.72	---	1.72	---	---	---	0.49	1.79
Mass Density	kg/m3	---	787.50	813.74	813.27	811.86	812.33	---	820.69	815.92	815.22	813.84	814.31	819.41	819.38	---	819.51	---	---	---	753.22	821.21
Surface Tension	dyne/cm	---	12.91	14.73	14.88	14.57	14.61	---	15.18	14.92	14.86	14.75	14.78	15.11	15.10	---	15.13	---	---	---	16.73	15.41
AQUEOUS PHASE																						
Mass Flow	kg/h	---	9526.98	33443.69	7882.74	28580.29	10297.52	---	8445.29	33390.88	7874.25	28543.51	10285.38	89733.93	0.00	---	89716.95	---	---	---	1904.93	89708.25
Liquid Vol Flow @Std Cond	m3/h	---	9.33	32.56	7.77	28.19	10.15	---	9.31	32.50	7.76	28.13	10.14	88.42	0.00	---	88.41	---	---	---	1.89	88.40
Liquid Vol Flow @Std Cond	bbl/day	---	1417	4975	1173	4251	1532	---	1405	4967	1171	4246	1536	13348	0	---	13345	---	---	---	164	13344
Actual Volume Flow	m3/h	---	9.83	34.40	8.12	29.50	10.62	---	9.70	34.33	8.10	29.45	10.60	92.26	0.00	---	92.26	---	---	---	1.12	92.26
Molecular Weight		---	18.9	18.9	18.9	18.9	18.9	---	18.9	18.9	18.9	18.9	18.9	18.9	18.9	---	18.9	---	---	---	18.9	18.9
Mass Heat Capacity	kJ/kg-C	---	4.34	4.34	4.34	4.35	4.35	---	4.34	4.34	4.34	4.35	4.34	4.34	4.34	---	4.34	---	---	---	4.32	4.34
Thermal Conductivity	W/m-K	---	0.666	0.663	0.664	0.666	0.665	---	0.662	0.663	0.663	0.666	0.665	0.663	0.663	---	0.663	---	---	---	0.666	0.662
Viscosity	cP	---	0.37	0.39	0.39	0.37	0.38	---	0.41	0.40	0.39	0.38	0.38	0.40	0.40	---	0.40	---	---	---	0.53	0.40
Mass Density	kg/m3	---	969.63	972.09	971.28	968.88	969.68	---	973.51	972.66	971.73	969.38	970.15	972.59	972.46	---	972.44	---	---	---	966.88	972.93
MIXTURE COMPOSITION (Mole Fraction)																						
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0055	0.0025	0.0031	0.0023	0.0022	0.0021	0.0055	0.0025	0.0031	0.0022	0.0022	0.0021	0.0026	0.0064	0.0064	0.0000	0.0069	0.0089	0.0089	0.0068	0.0000
CO2		0.0031	0.0040	0.0056	0.0038	0.0040	0.0039	0.0031	0.0040	0.0055	0.0038	0.0040	0.0039	0.0044	0.0105	0.0105	0.0001	0.0093	0.0093	0.0093	0.0105	0.0001
Methane		0.8527	0.2283	0.2991	0.2016	0.2112	0.2026	0.8527	0.2283	0.2991	0.2016	0.2112	0.2026	0.3611	0.7225	0.7225	0.0023	0.8082	0.8082	0.8082	0.7225	0.0023
Ethane		0.0353	0.0283	0.0393	0.0276	0.0286	0.0278	0.0353	0.0283	0.0393	0.0278	0.0290	0.0278	0.0237	0.0799	0.0799	0.0010	0.0735	0.0735	0.0735	0.0799	0.0010
Propane		0.0292	0.0236	0.0361	0.0260	0.0274	0.0263	0.0292	0.0236	0.0361	0.0260	0.0274	0.0263	0.0297	0.0684	0.0684	0.0022	0.0574	0.0574	0.0574	0.0684	0.0022
i-Butane		0.0072	0.0065	0.0104	0.0078	0.0082	0.0078	0.0072	0.0065	0.0104	0.0078	0.0082	0.0079	0.0087	0.0190	0.0190	0.0011	0.0151	0.0151	0.0151	0.0190	0.0013
n-Butane		0.0081	0.0084	0.0135	0.0100	0.0105	0.0101	0.0081	0.0084	0.0135	0.0100	0.0105	0.0101	0.0112	0.0240	0.0240	0.0014	0.0178	0.0178	0.0178	0.0240	0.0021
i-Pentane		0.0038	0.0049	0.0082	0.0060	0.0053	0.0051	0.0038	0.0049	0.0082	0.0060	0.0053	0.0051	0.0053	0.0101	0.0101	0.0018	0.0051	0.0051	0.0051	0.0101	0.0018
n-Pentane		0.0025	0.0034	0.0058	0.0042	0.0044	0.0043	0.0025	0.0034	0.0058	0.0042	0.0044	0.0043	0.0043	0.0078	0.0078	0.0016	0.0032	0.0032	0.0032	0.0078	0.0016
Cyclopentan		0.0007	0.0012	0.0015	0.0014	0.0014	0.0014	0.0007	0.0012	0.0015	0.0014	0.0014	0.0014	0.0014	0.0017	0.0017	0.0011	0.0002	0.0002	0.0002	0.0017	0.0011
Benzene		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cyclohexane		0.0004	0.0012	0.0014	0.0014	0.0014	0.0014	0.0004	0.0012	0.0014	0.0014	0.0014	0.0014	0.0013	0.0015	0.0015	0.0012	0.0001	0.0001	0.0001	0.0015	0.0012
Methylcyclohexane		0.0006	0.0021	0.0023	0.0024	0.0024	0.0024	0.0006	0.0021	0.0023	0.0024	0.0024	0.0024	0.0022	0.0017	0.0017	0.0025	0.0000	0.0000	0.0000	0.0017	0.0025
Toluene		0.0000	0.0006	0.0006	0.0006	0.0006	0.0006	0.0000	0.0005	0.0006	0.0006	0.0006	0.0006	0.0001	0.0004	0.0004	0.0007	0.0000	0.0000	0.0000	0.0004	0.0007
Ethylbenzene		0.0000	0.0000	0.0002	0.0000	0.0002	0.0000	0.0000	0.0000	0.0002	0.0000	0.0003	0.0003	0.0002	0.0001	0.0001	0.0004	0.0000	0.0000	0.0000	0.0001	0.0004
p-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0001	0.0001	0.0004	0.0000	0.0000	0.0000	0.0001	0.0004
m-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
o-Xylene		0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0003	0.0000	0.0000	0.0000	0.0001	0.0003
n-Nonane		0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0005
124-Mthenzene		0.0000	0.0000	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0006
C6*		0.0024	0.0045	0.0056	0.0053	0.0055	0.0054	0.0024	0.0045	0.0058	0.0053	0.0055	0.0054	0.0053	0.0067	0.0067	0.0008	0.0067	0.0067	0.0067	0.0067	0.0040
C7*		0.0000	0.0035	0.0038	0.0039	0.0040	0.0040	0.0000	0.0035	0.0038	0.0039	0.0040	0.0040	0.0035	0.0034	0.0034	0.0037	0.0002	0.0002	0.0002	0.0034	0.0037
C8*		0.0000	0.0036	0.0035	0.0039	0.0039	0.0040	0.0000	0.0036	0.0035	0.0039	0.0039	0.0040	0.0034	0.0018	0.0018	0.0045	0.0000	0.0000	0.0000	0.0018	0.0045
C9*		0.0000	0.0028	0.0020	0.0031	0.0030	0.0031	0.0000	0.0028	0.0020	0.0031	0.0030	0.0031	0.0027	0.0008	0.0008	0.0040	0.0000	0.0000	0.0000	0.0008	0.0040
C10-C15*		0.0000	0.0150	0.0134	0.0164	0.0160	0.0163	0.0000	0.0154	0.0134	0.0164	0.0160	0.0163	0.0143	0.0031	0.0031	0.0238	0.0000	0.0000	0.0000	0.0031	0.0238
C16 C19*		0.0000	0.0057	0.0058	0.0071	0.0070	0.0071	0.0000	0.0057	0.0058	0.0071	0.0070	0.0071	0.0061	0.0000	0.0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0104
C20-C27*		0.0000	0.0073	0.0063	0.0078	0.0076	0.0077	0.0000	0.0073	0.0063	0.0078	0.0076	0.0077	0.0067	0.0000	0.0000	0.0113	0.0000	0.0000	0.0000	0.0000	0.0113
C28-C37*		0.0000	0.0043	0.0037	0.0045	0.0044	0.0045	0.0000	0.0043	0.0037	0.0045	0.0044	0.0045	0.0039	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0066
C38-C80*		0.0000	0.0031	0.0027	0.0033	0.0032	0.0033	0.0000	0.0031	0.0027	0.0033	0.0032	0.0033	0.0028	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0048
H2O		0.0115	0.0328	0.0354	0.0329	0.0351	0.0358	0.0115	0.0328	0.0354	0.0329	0.0351	0.0358	0.0343	0.0316	0.0316	0.0070	0.0000	0.0000	0.0000	0.0316	0.0055
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

PSEUDO COMPONENT	LIQUID DENSITY (g/cm3)	Tc (°C)	Pc (bara)	ACENTRIC FACTOR	NBP (°C)	MOLECULAR WEIGHT (g/mol)	Vc (cm³/mol)
C6*	0.66	234.2	29.7	0.3	68.7	86.2	370.0
C7*	0.74	241.4	24.5	0.4	103.1	96.0	524.1
C8*	0.77	268.2	21.7	0.4	126.8	107.0	527.9
C9*	0.78	298.1	20.0	0.4	143.6	121.0	527.8
C10-C15*	0.82	419.6	16.1	0.6	220.7	171.6	716.7
C16-C19*	0.85	539.9	14.1	0.8	304.8	242.0	1019.3
C20-C27*	0.88	658.6	12.3	0.9	376.9	318.6	1381.5
C28-C37*	0.90	831.8	10.8	1.1	462.2	441.2	1879.7
C38-C80*	0.94	1084.1	9.7	1.0	579.2	669.1	3271.6

Approved For Construction

MASTER

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.1 :

PROBABILITY OF FAILURE TO OPEN CALCULATION

PSV-1020A/B

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.1 = Probabilty Of Failure To Open

PART 1 : CALCULATION OF PROBABILITY OF FAILURE TO OPEN

The fundamental calculation applied to PRDs for the fail to open case is the product of an estimated overpressure demand case frequency (or demand rate), the probability of the PRD failing to open on demand, and the probability that the protected equipment at higher overpressures will lose containment.

$$P_{f,j}^{prd} = P_{fod,j} \cdot DR_j . P_{f,j}$$ equation (1)

Dimana :

$P_{f,j}^{prd}$ = POF of a PRD overpressure demand case, (failures/year)

$P_{fod,j}$ = POFOD of a PRD (failures/demand)

DR_j = demand rate (demands/year)

$P_{f,j}$ = POF (loss of containment) (failures/year)

The subscript j in the above equation indicates that the POF for the PRD,P prd f , j. needs to be calculated for each of the applicable overpressure demand cases associated with the PRD

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 tahun see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service	:	Methane
Typical Temperature	:	473.2 ^{o}F
Fluid Severity	:	Mild See Table 7.4
Design Type PRD	:	Conventional
Discharge Location	:	discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fc,for conventional valves discharging to closed system or to flare

F_C = 0.75 for conventional valves discharging to closed system or flare

F_C = 1.00 for all other cases

STEP 4 Determine the environment adjustment factor, Fenv using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 1.0 (see data process condition)

STEP 5 The result of the procedure outlined above will be a modified characteristic life, ηmod, as defined in equation (2)

F_C = 0.75 see step 3

F_C = 1.00 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_C x F_{env} x η_{def} equation (2)

= 0.75 x 1.00 x 37.88

= 28.41

STEP 6 Assemble the PRD's inspection history, Grade each record using the inspection effectiveness table, part 2, Annex 2.c, Table 2.C.3.1. Record the result of each inspection record; PASS/FAIL and NO LEAK/LEAK and determine the confidence factors, Cfi, as applicable, for each inspection history based on the results of the test Determine the time duration, tdur,i of each inspection cycle

STEP 6.1 Each inspection record must be graded using the PRD inspection effectifeness table, part 2, annex 2.C, table 2.C.3.1

- Inspection effectiveness : part 2, annex 2.C, Table 2.C.3.1

Tabel 2.C.3.1- Inspeksi dan pengujian keefektifan untuk PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

STEP 6.2 Record the PASS/FAIL and NO LEAK/LEAK in order to determine the confidence factors, Cfi , as applicable , for each inspection history where a test was conducted

- Inspection Record = No Leak / Leak

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i = 0.5 see table 7.8

STEP 6.3 Determine the time duration , tdur,I ,between each inspection cycle

a. RBI Date $t_{dur,}i$ = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date $t_{dur,}i$ = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 6.4 Determine if the PRD was overhauled

- refer to section 7.7.2 and 7.7.3 ,as well as figure 7.7, for more information

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{134.9}{512.7}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - 0.237}{0.90}\right)$$

= 0.2924

P_S = 134.9

P_{Set} = 512.7

$\frac{P_s}{P_{set}}$ = 0.2631

STEP 7 Starting at the earliest inspection record, update the modifierd characteristic life ηmod ,determine in step 5 as follows

STEP 7.1 Calculate the prior POF using equation (3) . The time prior for use in equation (3) . Is the time duration of the inspection cycle , tdur,I as determine in step 6 . Note that for the first inspection record ,the modified characteristic life, ηmod, is used . sub sequent inspection record will use the update ed characteristic life ,ηupd,from step 7.5

$$P_{fod}=1-\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

a. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892051

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.09714382

STEP 7.2 Calculate the prior probability of passing using Equation (4)

$$P_{p,Prior}^{prd}= 1- P_{f,prior}^{prd}$$ equation (4)

a. RBI Date

$P_{p,Prior}^{prd}= 1- P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0289

= 0.97107949

B. RBI Plan Date

$P_{p,Prior}^{prd}= 1- P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0971

= 0.90285618

STEP 7.3 Determine the condition POF and the conditional probability of pass using Equations (5)

$$P_{f,cond}^{prd}= (1-CF_{pass}).P_{p,prior}^{prd}$$ equation (5)

CF_{noleak} = 0.5 step 6.2

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (BRI Plan Date) step 7.2

a. RBI Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48554

B. RBI Plan Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45143

step 7.4 Calculatethe weighted POF, $P_{f,wgt}^{prd}$ using the appropriate equation from table 7.9

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass Usually Effective Pass Fairly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Highly Effective Fail Usually Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{f,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

a. RBI Date

$P_{f,wgt}^{prd}$ = 0.4855

B. RBI Plan Date

$P_{f,wgt}^{prd}$ = 0.4514

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (6) and the weighted POF

$$\eta_{upd} = \frac{t}{\left(-ln\left[1 - P_{f,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}} \qquad \text{equation (6)}$$

η_{upd} = 10.62

STEP 7.6 Repeat step 7 for each of the inspection record available for the PRD until a final updated value for the characteristic life, η_{upd}, is determined

$$P_{f,Prior}^{prd} = 1 - \exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right] \qquad \text{equation (3)}$$

t	=	4	(RBI Date)		see step 6
t	=	8	(RBI Plan Date)		see step 6
ηupd	=	28.406	= η_{mod}	(RBI Date)	see step 5
ηupd	=	10.621		(RBI Plan Date)	see step 7.5
β	=	1.80			see step 2

a. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.45143

STEP 8 The POFOD should be adjusted based on the overpressure scenario, The overpressure factor Fop,j, is an adjustment for overpressure scenarios higher than 1.3 times the set pressure

$F_{op,j}$ = 1.0 for $\frac{F_{op,j}}{P_{set}} < 1.3$

$F_{op,j}$ = 0.2 for $\frac{F_{op,j}}{P_{set}} > 4$

$F_{op,j}$ = $1 - \frac{1}{3.375} \cdot \left(\frac{F_{op,j}}{P_{set}} - 1.3 \right)$ for all other cases

$F_{op,j}$: overpressure likelyto accur as a result of a PRD failling to open upon demand ,associated with the J overprssure demand case,kPa(psig) = 163.23 psig (see data process condition)

P_{set} : The set pressure of the PRD,kPa (psig) = 512.7 psig (see data process condition)

$\frac{F_{op,j}}{P_{set}}$: $\frac{163.23}{512.7}$: 0.3184

$F_{op,j}$: 0.2

$P_{fod,j} = P_{fod} \; x \; F_{op,j}$ equation (7)

P_{fod} = 0.029 (RBI Date) see step 7.1

P_{fod} = 0.451 (RBI Plan Date) see step 7.1

$F_{op,j}$ = 0.2 see step 7

a. RBI Date

$P_{fod,j}$ = 0.029 x 0.2

= 0.00578

B. RBI Plan Date

$P_{fod,j}$ = 0.451 x 0.2

= 0.09029

STEP 9 Estimates for the PRD initiating event frequencies, Efj, based on the various relief overpressure demand cases that the device is providing protection Examples of the initiating event frequencies are provided in Table 7.2 Additional background on the default initiating event frequencies is provided in Table 7. 3

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	EF_j (event/year)
Fire	1 per 250 years	0.004
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 10 Determine Credit for Other Layers of Protection. The concept of a demand rate reduction factor, DRRFj , is introduced here to account for the difference in the overpressure demand case event frequency and the demand rate on the PRD. demand rate reduction factor are provide in Table 7.2

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	$DRRF_f$
Fire	1 per 250 years	0.10
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 11 for each overpressure demand case, determine the demand rate placed on the PRD,DRj.The demand rate (DR) on the PRD is calculated as the product of the initiating event frequency and the DRRFj in accordance with Equation (1.12)

$$DR_j = EF_{j.} \; . DRRF_j$$ Equation (8)

EF (fire) = initiating fire frequencies = 0.004

DRRF (fire) = demand rate reduction factor = 0.10

DR (fire) = EF (fire) x DRRF (fire)

= 0.004 x 0.10

= 0.0004

EF (overfill) = initiating overfill frequencies = 0.10

DRRF (overfill) = demand rate reduction factor = 0.10

DR (overfill) = EF (overfill) x DRRF (overfill)

= 0.10 x 0.10

= 0.01

step 12 Determine the MAWP of the protected equipment

set pressure	=	512.7 psig	see data
% Allowable Overpressure	=	21%	process
MAWP	=	620.4 psig	

STEP 13 If an RBI Study has been completed for protected equipment, calculate its damage adjustment POF, Pf, using equation (1.1) since the DF for the protected equipment is a function of time ,the DF must be determined at the PRD inspection interval, t insp, specifide in step 1 . if a risk analysis for fix equipment has not been complated , a DF can be estimated using the values in table 7.10

Table 7. 10 – DF Classes for Protected Equipment

DF Class	DF	Description
None	1	New vessel or inspection shows little if any damage
Minimal	20	equipment has been in service for a reasonable amount of time and inspection shows evidence of minor damage . Damage mechanism have been identified and inspecton data is available.
Minor	200	One or more damage mechanisms have been identified, limited inspection data available and fairly moderate evidence of damage. Single damage mechanism identified, recent inspection indicates moderate evidence of damage.
Moderate	750	Moderate damage found during recent inspection. Low susceptible to one or more damage mechanisms, and limited inspection exists.
Severe	2000	One or more active damage mechanisms present without any recent inspection history. Limited inspection indicating high damage susceptibility

D_f = 20.0

STEP 14 Calculate the POF of the protected equipment at the elevated overpressure,Pf,j using equation (9).

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{(3.464837..\frac{Po,j}{MAWP})}$$ equation (9)

gff_{total}	=	0.0000306	see part 2 table 3.1
D_f	=	20.0	see step 13
F_{MS}	=	0.5	see part 2 section 3.5.4
$P_{o,j}$	=	163.229	data process condition
MAWP	=	620.367	see step 12

$$Pf,j = (0.0312881x0.0000306x20x0.5)e^{3.464837..\frac{163.229}{620.367}}$$

Pf,j = 2.E-05

STEP 15 Calculate the POF, ,using Equation (10)

A. RBI Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.00578 x 0.0004 x 2.38E-05

= 5.51219E-11

OVEFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.00578 x 0.01 x 2.38E-05

= 1.37805E-09

B. RBI Plan Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.09029 x 0.0004 x 2.3825E-05

= 8.60413E-10

OVEFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.09029 x 0.01 x 2.3825E-05

= 2.15103E-08

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.2 :
PROBABILITY OF FAILURE TO LEAKAGE CALCULATION

PSV-1020A/B

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

PART 2 : Calculation Procedure - POL at Specified Inspection Interval

The leakage case is different than the fail to open case since the POF is not a function of demand rate but rather is based on failure during continuous operation. The industry data associated with the probability of leakage,Pl , data is in per year units (failure/year). no multiplication by any demand rate is necessary

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 years see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service : Methane

Typical Temperature : 473.2 °F

Fluid Severity : Mild See Table 7.4

Design Type PRD : Conventional

Discharge Location : discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fs using section 7.3.2.g

F_s = 1.25 for soft seated design

F_s = 1.00 for all other cases

STEP 4 Determine the environmenta adjustment factor, Fenv.using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 0.8 (see data process condition)

STEP 5 calculate the modified characteristic life, ηmod, using equation (11) and the factors obtain in step 3 and 4.

F_s = 1.25 see step 3

F_{env} = 0.80 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_s . F_{env} . η_{def} equation (11)

= 1.25 x 0.80 x 37.88

= 37.88

STEP 6 Assemble the the PRDs inspection history, grade each record using the inspection effectiveness table, part 2,annex 2.C, Table 2.C.3.1. Record the result of each inspection record.; NO LEAK/LEAK and determine the confidance factors, Cfi, as applicable, for each inspection history based on the result of the test . Determine the time duration, tdur.i. of each inspection cycle.

- Inspection effectiveness : part 2,annex 2.C, Table 2.C.3.1

Table 2.C.3.1- Inspection and testing efectiveness for PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

- Inspection Record : No LEAK/ LEAK

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

  CF_i : 0.5

- Determine the time duration, tdur,j. of each inspection cycle

  A. RBI Date

  $t_{dur,}i$ = RBI date - Last Inspection

  = 15/03/2020 - 17/06/2016

  = 4 year

  B. RBI Plan Date

  $t_{dur,}i$ = Plan date - Last Inspection

  = 15/03/2024 - 17/06/2016

  = 8 year

STEP 7 Starting at the earliest inspection record , update the modified characteristic life, ηmod, determine in step 5 as follows

STEP 7.1 Calculate the prior probability of leakage using equation (12). Note that for the first inspection record , the modified characteristic life,ηmod,is used subsequent inspection record will use the updated characteristic from STEP 7.5 below.

$$P_{l,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (12)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	37.88	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{l,Prior}^{prd}$ = 0.01733

B. RBI Plan Date

$P_{l,Prior}^{prd}$ = 0.05907

STEP 7.2 Calculate the prior probability of passing using equation (13)

$$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$$ equation (13)

A. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0173

= 0.98267

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.05907

= 0.94093

STEP 7.3 Determine the conditional probability of leakage and conditional probability of pass using equation (14)

$$P_{l,cond}^{prd} = (1\text{-}CF_{pass}).P_{p,prior}^{prd}$$ equation (14)

CF_{pass} : 0.5 step 6

$P_{p,Prior}^{prd}$ = 0.98267 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.94093 (RBI Plan Date) step 7.2

a. RBI Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.98267

= 0.49133

B. RBI Plan Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.94093

= 0.47046

STEP 7.4 calculate the weighted probability of leakage, using the appropriate equation from table 7.9.

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.P_{f,prior}^{prd} + 0.5.P_{f,cond}^{prd}$

$P_{l,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

a. RBI Date

$P_{l,wgt}^{prd}$ = 0.49133

B. RBI Plan Date

$P_{l,wgt}^{prd}$ = 0.47046

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (15) and the weighted probability of leakage, establish in step 7.4

$$\eta upd = \frac{t}{(-\ln\left[1 - P_{l,wgt}^{prd}\right])^{\frac{1}{\beta}}}$$ equation (15)

η_{upd} = 10.29

STEP 8 Calculate the probability of leakage for the specific PRD in accordance with Equation (16)

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (16)

t	=	4	year	see step 6
t	=	8	year	see step 6
β	=	1.80		see step 2
η_{upd}	=	37.88	= η_{mod}	see step 5
η_{upd}	=	10.29		see step 7.5

a. RBI Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{4}{37.88}\right)^{1.80}\right]$

P_l^{prd} = 0.01733

B. RBI Plan Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{8}{10.29}\right)^{1.80}\right]$

P_l^{prd} = 0.47046

STEP 9

The Probability of leakage needs to be adjusted based on the closedness the system is operating near the set pressure with equation (17). The set pressure factor , F_{set} , is dependent on the PRD type.

$$P_{l,j}^{prd} = P_l^{prd} . F_{set}$$ equation (17)

PRD Type = Conventional see data general

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{134.9}{512.7}\right)}{0.90}\right)$$

$P_S =$ 134.9 see data

$P_{Set} =$ 512.7 process

$= 1 - \left(\frac{0.90 - \min(0.237)}{0.90}\right)$

$= 0.2924$

A. RBI Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

$P_l^{prd} =$ 0.01733 step 8

$F_{set} =$ 0.2924 Table 7.7

$P_{l,j}^{prd} =$ 0.0173 x 0.2924

$=$ 0.0051

B. RBI Plan Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

$P_l^{prd} =$ 0.47046 step 8

$F_{set} =$ 0.2924 Table 7.7

$P_{l,j}^{prd} =$ 0.4705 x 0.2924

$=$ 0.1375

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 3 :
CONSEQUENCE OF FAILURE CALCULATION

PSV-1020A/B

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
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PART 3 CONSEQUENCE CALCULATION of FAILURE to OPEN

STEP 1 Determine the list of overpressure scenarios applicable to the piece of equipment being protected by the PRD under evaluation. Table 7.2 provides a list of overpressure demand cases specific covered.

Overpressure Demand Case for PSV-1020A/B

1 Fire see table 7.3

2 Liquid Overfillling without administrative controls in place

step 2 For each overpressure demand case, estimate the amount of overpressure, $p_{o,j}$, likely to occur during the overpressure event if the PRD were to fail to open.

Table 7.3 - Overpressure Scenario Project					
Initiating Event	Equipment Type	PRD Demand rate reduction factor	Qualifier	over pressure potential	Background and comment
1. Overpressure Scenario					
1 per 250 years	All Equipment Type	0.1 industry experience justifies this value	N/A	4.0 x MAWP (RUPTURE)	see table 7.3
2. Overpressure scenario - liquid Overfilling					
1 per 100 years (admin control)	All Equipment including process tower	1.00	downsteam of positif displacement type rotating equipment	4.0 x MAWP	see table 7.3

$P_{0,fire}$ = 4 x MAWP
= 4 x 620.4
= 2481.6 psig

$P_{o,overfilling}$ = 4 x MAWP
= 4 x 620.4
= 2481.6 psig

STEP 3 For instalations that have multiple PRDs, determine the total amount of installed PRD orifice area , A_{total}^{prd}, including the area of the PRD being evaluated. Calculate the overpressure adjustment factor, F_a, in accordance with equation (1.37)

$$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \qquad \text{equation (1.37)}$$

A^{prd} = is the orifice area of the PRD, mm2
= 1 (asumsi)

A_{total}^{prd} = is the total installed orifice area of a multiple device installation,mm2
= 2 (asumsi)

multiple PRD ? Yes

F_a = 0.7071068

STEP 4 Reduce the overpressures determined in step 3 by the overpressure adjustment factor accordance with equation (1.38)

$$P_{o,j} = F_a \,.\, P_{o,j} \qquad \text{equation (1.38)}$$

F_a = 0.7071 see step 3

$P_{0,fire}$	=	2481.6	$P_{o,overfilling}$	=	2481.6
$P_{0,fire}$	=	2481.6 x 0.7	$P_{o,overfilling}$	=	2481.6 x 0.7
	=	1754.8 psig		=	1754.8 psig

STEP 5 for each overpressure demand case, calculate the financial consequence ,....., C_{prd} of loss containment from protected equipment using procedures developed in part 3. use the overpressure for demand cases as determine in STEP 4 in lieu of the operating pressure, P_s

STEP 1 Determine the Representative Fluid and Associated Properties

Fluid Properties

Sifat-sifat fluida yang dibutuhkan yang diperkirakan untuk masing-masing fluida representatif disediakan dalam Tabel 4.2 API 581 Bagian 3 COF dan tergantung pada fase simpanan fluida di bawah ini:

A). Stored Liquid	
1. Normal Boiling Point	(NBP)
2. Density	(ρt)
3. Auto-iIgnition Temperature	(AIT)
B). Stored Vapor or Gas	
1. Normal Boiling Point	(NBP)
2. Morcular Weight	(MW)
3. Ideal Gas Specific Heat Capacity Ratio	(k)
4. Constant Pressure Specific Heat	(Cp)
5. Auto-iIgnition Temperature	(AIT)

STEP 1.1 Select Representative fluid group Table 4.1

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

Fluid Composition Table

Well	Composition	Symbol	Amount	Unit
	Nitrogen	N_2	0.68	% mole
	Carbon Dioxide	CO_2	1.05	% mole
	Methane	CH_4	72.25	% mole
	Ethane	C_2H_6	7.9	% mole
	Propane	C_3H_8	6.84	% mole
`	i-Butane	i-C_4H_{10}	1.9	% mole
	n-Butane	n-C_4H_{10}	2.4	% mole
	i-Pentane	i-C_5H_{12}	5.01	% mole
	n-Pentane	n-C_5H_{12}	0.47	% mole
	Hexane Plus	C_6^+	1.5	% mole
		TOTAL	100.000	% mole

Chosen Representative Fluid : C1-C2

STEP 1.2 Determine the store fluid phase, liquid or vapor, if two phase , a level 2 consequence analysis should be performed

Stored fluid phase : Gas

Step 1.3 Determine the stored fluid properties

For a stored liquid

MW – Molecular weight, kg/kg-mol (lb/lb-mol), can be estimated from Table 4.2

k – Ideal gas specific heat ratio, can be estimated using Equation (3.1) and the C P values as determined using Table 4.2

AIT – Auto-ignition temperature, K (°R), can be estimated from Table 4.2

Table 4.2 - Properties of the Representative Fluids Used in Level 1 Consequence Analysis

Fluid	MW	Liquid Density (lb/ft^3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	CP				Auto ignition Temperature (°F)
						Ideal Gas Constant A	Ideal Gas Constant B	Ideal Gas Constant C	Ideal Gas Constant D	
C1-C2	23	15.64	-193	Gas	Note 1	12.3	1.15E-01	-2.87E-03	-1.30E-09	1036
C2-C3	51	33.61	-6.3	Gas	Note 1	2.632	0.3188	-1.35E-04	1.47E-08	696
C25+	422	56.19	981	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	396

1). Molecular Weight (MW), kg/kg-mol (lb/lb-mol)

The stored vapor Molecular Weight (MW) can be estimated from Table 4.2

MW = 23.00 (kg/kg-mol)

2). Auto-Ignition Temperature, K (^oR)

The stored liquid Auto-Ignition Temperature (AIT) can be estimated from Table 4.2 of API 581 Part 3 of COF.

AIT = 1036 (^oF)

AIT = 830.927778 (K)

AIT = 446.222222 (^oR)

3). Ideal gas specific heat ratio, k

Cp_A = 12.3 J/kmol-K

Cp_B = 1.15E-01 J/kmol-K

Cp_C = -2.87E-03 J/kmol-K

Cp_D = -1.30E-09 J/kmol-K

T = 70 C

T = 158 F

T = 343.15 K

R = 8.314 J/kg-mol-K

Cp $= A + BT + CT^2 + DT^3$ equation (19)

= 12.3 + (0.015 x 343.15) + (-0.0000287 x 343.15)^2 + (-1.3^{-9} x 343.15)^3

= 52.7321608 J/kmol-K

k = $\frac{Cp}{Cp - R}$ ..... equation (20)

= $\frac{52.732}{52.732 - 8.314}$

= 1.18717569

STEP 1.4 Determine the steady state phase of the fluid after release to the atmosphere, using Table 4.3 and the phase of the fluid stored in the equipment as determine in STEP 1.2.

Table 4.3 - Level 1 Guidelines for Determining the phase of a fluid

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (After release) Condition	Determine of Final Phase for Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	model as gas usless the fluid boilling point at ambient condiitions is greater than 80 F , than model as liquid
Liquid	Liquid	Model as Liquid

The fluid is Gas in the vessel, its post release is Gas

STEP 2 Release Hole Size Selection

STEP 2.1 Based on component type and table 4.4, determine the release hole size diameters, d_n.

Table 4.4 - Release Hole Sizes and Areas Used in Level 1 and 2 Consequences Analysis

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	$d_1 = 0.25$
2	Medium	> 1/4 - 2	$d_2 = 1$
3	Large	> 2 - 6	$d_3 = 4$
4	Rupture	. 6	d_4 = min[D,16]

STEP 2.2 Determine the failure frequency, gff_n, for the nth release hole size from part 2, table 3.1, and the total generic failure frequency from this table or from equation (3.2)

$$gff_{total} = \sum_{n=1}^{4} gff_n \qquad (3.2)$$

Table 3.1 part 2, suggested component generic failure frequencies

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Vessel/FinFan	KODRUM	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
	COLBTM					
	FINFAN					
	FILTER					
	DRUM					
	REACTOR					
	COLTOP					
	COLMID					

gff_{total} = 3.06E-05 failures/year

gff_{small} = 8.00E-06 failures/year

gff_{medium} = 2.00E-05 failures/year

gff_{large} = 2.00E-06 failures/year

$gff_{rupture}$ = 6.00E-07 failures/year

STEP 3 Release Rate Calculation

There are two regimes for flow gases through an orifice: aonic (choked) for higher internal pressure, and subssonic flow for lower pressure (nominally 15 psig (103.4 kPa) or less). The transition pressure at which the flow regime changes from sonic to subsonic is determined using below equation.

P_{atm} = 14.69 psi

k = 1.1872

$$P_{trans} = P_{atm}\left(\frac{k+1}{2}\right)^{\frac{k}{k-1}} \quad \text{..... equation (21)}$$

$$P_{trans} = 14.69\left(\frac{1.187+1}{2}\right)^{\frac{1.187}{0.187}}$$

= 18.0310985 psi

STEP 3.1 Select the appropriate release rate equation

$$W_n = \frac{Cd}{C2}\, x\, An \text{ x } Ps \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad \text{..... (equation 60)}$$

Abbreviation list :

C_d = Discharge coefficient, for turbulent liquid flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$

= 0.9

A_n = Release hole sized area

P_s	=	Storage operating pressure	=	1754.8	psi
P_{atm}	=	Atmosphere pressure	=	14.69	psi
k	=	Ideal gas specific heat capacity ratio	=	1.1872	
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	70	C
			=	158	F
			=	343.15	K

STEP 3.2 For every release hole size, calculate the release hole size area based on d_n

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

The release hole size area can be determined by formulating below equation:

$$An = \frac{\pi dn^2}{4} \quad \text{.....} \quad \text{equation (22)}$$

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch
= 0.0064 m
π = 3.14

$$A1 = \frac{\pi d1^2}{4}$$

$$= \frac{3.14\ x\ (0.25)^2}{4}$$

= 0.0491 inch^2
= 3E-05 m^2

2). MEDIUM RELEASE HOLE SIZE AREA

d_1 = 1 inch
= 0.0254 m
π = 3.14

$$A2 = \frac{\pi d2^2}{4}$$

$$= \frac{3.14\ x\ (1)^2}{4}$$

= 0.785 inch^2
= 0.0005 m^2

3). LARGE RELEASE HOLE SIZE AREA

d_1 = 4 inch

= 0.1016 m

π = 3.14

$$A3 = \frac{\pi d3^2}{4}$$

= 12.56 $inch^2$

= 0.0081 m^2

4). RUPTURE RELEASE HOLE SIZE AREA

d_1 = 16 inch

= 0.4064 m

π = 3.14

$$A4 = \frac{\pi d4^2}{4}$$

$$= \frac{3.14\ x\ (16)^2}{4}$$

= 200.96 $inch^2$

= 0.1296 m^2

STEP 3.3 For liquid releases, for each release hole size, calculate the viscosity correction factor ($K_{v,n}$)

$$K_{v,n} = \left(0.9935 + \frac{2.878}{Ren^{0.5}} + \frac{342.75}{Ren^{1.5}}\right)^{-1} \quad \text{.....} \quad \text{equation (23)}$$

Because the store fluid phase determined in STEP 1.2 is gaseous or vapor phase, then, this step is no neeed to be considered.

STEP 3.4 For each hole size, calculate the release rate, W_n , for each release area A_n

$$W_n = \frac{Cd}{C2}\ x\ An\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Abbreviation List:

C_d = 0.9

k = 1.18717569

ρl = 250.51 kg/m^3

= 2.5051E-07 kg/mm^3

A_{n1} = 3.1645E-05 m^2

A_{n2} = 0.00050645 m^2

A_{n3} = 0.00810321 m^2

A_{n4}	=	0.1296192	m^2
gc	=	1	kgm/Ns^2
	=	32.2	$lb_m ft/lb_f S^2$
Ps	=	12099.346	Kpa
P_{atm}	=	101.28755	KPa
C_2	=	1	
R	=	8.314	J/(kg-mol-K)
g_c	=	9.8	m/s^2
T_s	=	343.15	K
MW	=	23.00	(kg/kg-mol)

1). SMALL RELEASE HOLE SIZE AREA

$$W_1 = \frac{Cd}{C2} x\ A1 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_1 = \frac{0.9}{C2} x\ 0.000031645 \text{ x } 12099.35\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 343.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1..187+1}{1.187-1}}}$$

= 0.06257427 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$W_2 = \frac{Cd}{C2} x\ A2 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_2 = \frac{0.9}{C2} x\ 0.000506451 \text{ x } 12099.35\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 343.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1..187+1}{1.187-1}}}$$

= 1.00143661 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$W_3 = \frac{Cd}{C2} x\ A3 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_3 = \frac{0.9}{C2} x\ 0.00810321 \text{ x } 12099.35\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 343.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1..187+1}{1.187-1}}}$$

= 5.11835505 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$W_4 = \frac{Cd}{C2} x\ A4 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_4 = \frac{0.9}{C2} x\ 0.1296192 \text{ x } 12099.35\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 343.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1..187+1}{1.187-1}}}$$

= 256.304193 kg/s

STEP 4 Estimate the Fluid Inventory Available for Release

STEP 4.1 Group Component and equipment items into inventory groups (see annex 3.A)

only one component is given, and total inventory for the group

STEP 4.2 Calculate the fluid mass ,$mass_{comp}$, in the component being evaluated

OD	=	3006 mm	V_{vap}	=	31.111 m^3
	=	3.006 m	ρ_{vap}	=	8.87 kg/m^3
L	=	8800 mm			
	=	8.8 m	V_{liq}	=	31.111 m^3
V_{tot}	=	62.222 m^3	ρ_{liq}	=	819.38 kg/m^3
$Mass_{comp}$	=	275.96 kg			

STEP 4.3 Calculate the fluid mass in each of the other components that are included in the inventory group, $mass_{comp,i}$

There are no other component, only an inventory group mass

STEP 4.4 Calculate the fluid mass in the inventory group, $mass_{inv}$, using equation (3.9)

$$mass_{inv} = \sum_{i=1}^{n} mass_{comp,i} \qquad (3.9)$$

Where

$Mass_{co}$ = is the inventory fluid mass for the component or piece of equipment being evaluated, kgs [lbs]

$Mass_{inv}$ = is the inventory group fluid mass, kgs [lbs]

= 275.96 kg

STEP 4.5

Calculate the flow rate from a 203mm (8 inch) diameter hole, W_{max8}, using equation (3.3),(3.6)or (3.7) , as aplicable ,with A_n ,A8=32450 mm2 (50.3 inch2). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Where

C_d	=	Discharge coefficient, for turbulent gas flow from the sharp-edge orifices in the range of $0.85 \leq C_d \leq 1.00$	=	0.9	
A_n	=	Release hole sized area	=	50.3	$inch^2$
			=	32444	mm^2
			=	0.0324	m^2
P_s	=	Storage operating pressure	=	1754.8	psi
			=	12099	Kpa
P_{atm}	=	Atmosphere pressure	=	14.69	psi
			=	101.29	Kpa
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperature	=	70	C
			=	158	F
			=	343.15	K
C_2	=	SI and US customary conversion factors	=	1	
k	=	Ideal gas specific heat ratio	=	1.1872	

So,

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_{max8} = \frac{0.9}{1}\ x\ 0.0324 \text{ x } 12099.35 \sqrt{\left(\frac{1.1872\ x\ 23\ x\ 9.8}{8.314\ x\ 343.15}\right)\left(\frac{2}{1.1872+1}\right)^{\frac{1.1872+1}{1.1872-1}}}$$

$$= 64.1525721 \text{ kg/s}$$

STEP 4.6 For each release hole size, calculate the added fluid mass, $mass_{add,n}$, resulting from 3 (three) minutes of flow from the inventory group using equation (3.10) where Wn is the leakage rate for the release hole size being evaluated and W_{max8}, is from step 4.5

$$mass_{add,n} = 180.\min\left[W_n, W_{\max 8}\right] \quad (3.10)$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[\text{W}_1 \,, \text{W}_{\text{max8}}\,]$$
$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[0.0626, 64.15257\,]$$
$$= \quad 11.263 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 2}} = 180 \,.\, min[\text{W}_2 \,, \text{W}_{\text{max8}}\,]$$
$$\text{Mass}_{\text{add 2}} = 180 \,.\, min[1.0014, 64.15257\,]$$
$$= \quad 180.26 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min[\text{W}_3 \,, \text{W}_{\text{max8}}\,]$$
$$\text{Mass}_{\text{add 3}} = 180 \,.\, min\,[5.1184, 64.15257\,]$$
$$= \quad 921.3 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[\text{W}_4 \,, \text{W}_{\text{max8}}\,]$$
$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[256.3, 64.15257\,]$$
$$= \quad 11547 \text{ kgs}$$

STEP 4.7 For each release hole size, calculate the available mass for release using equation (3.11)

$$mass_{avail,n} = \min\left[\{mass_{comp} + \ mass_{add,n}\}, mass_{inv}\right]$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ 1} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,1}}\,\}, \text{Mass}_{\text{inv}}\,]$$
$$\text{Mass}_{avail\ 1} = min\,.\,[\{275.96 + 11.263\,\},\}, 275.96\,]$$
$$= \quad 275.96 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ 2} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,2}}\,\}, \text{Mass}_{\text{inv}}\,]$$
$$\text{Mass}_{avail\ 2} = min\,.\,[\{275.96 + 180.26\,\}, 275.96\,]$$
$$= \quad 275.96 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_{avail\ 3} = min.[\{Mass_{comp} + Mass_{add,3}\}, Mass_{inv}]$$

$$Mass_{avail\ 3} = min.[\{275.96 + 921.3\},, 275.96]$$

$$= 275.96 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_{avail\ 4} = min.[\{Mass_{comp} + Mass_{add,}\}, Mass_{inv}]$$

$$Mass_{avail\ 4} = min.[\{275.96 + 11547\},, 275.96]$$

$$= 275.96 \text{ kgs}$$

STEP 5 Determine the release type (continues or instantaneous)

STEP 5.1 For each release hole size, calculate the time required to release 4536kgs (10000 lbs) of fluid

$$t_n = \frac{C3}{W_n} \quad \text{..... equation (24)}$$

Where

t_n = time required to release 4536 kgs (10000 lbs) of fluid

C_3 = SI and US customary conversion factors

= 4536 kgs

= 10000 lbs

W_n = Theoretical release rate associated with the nth release hole size, kg/s [lb/s]

W_1 = 0.06257 kg/s

W_2 = 1.00144 kg/s

W_3 = 5.11836 kg/s

W_4 = 256.304193 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_1 = \frac{4536}{0.06257}$$

$$= 72489.8637 \text{ s}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_2 = \frac{4536}{1.00144}$$

$= 4529.49289$ s

3). LARGE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_3 = \frac{4536}{5.11836}$$

$= 886.222225$ s

4). RUPTURE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_4 = \frac{4536}{256.30419}$$

$= 17.6977206$ s

STEP 5.2 Determine the release type for each release hole size

For each release hole size, determine the release type either instataneous or continous using this following criteria:

a. If the release hole size is 6.35 mm(0.25 inch) or less, then the release type is continou

b. If t_n<180 sec and the releaase mass is gretaer than 4536 kgs (100000 lbs), then the release is instataneous; otherwise the release is continous

1). SMALL RELEASE HOLE SIZE AREA

$d_1 = 0.25$ inch

$t_1 = 72490$ s (Continous)

2). MEDIUM RELEASE HOLE SIZE AREA

$d_2 = 1$ inch

$t_2 = 4529.5$ s (Continous)

3). LARGE RELEASE HOLE SIZE AREA

$d_3 = 4$ inch

$t_3 = 886.22$ s (Continous)

4). RUPTURE RELEASE HOLE SIZE AREA

$d_4 = 16$ inch

$t_4 = 17.698$ s (Instataneous)

STEP6 Estimate The Impact of Detection and Isolation Systems on Release Magnitude

STEP 6.1 Determine the detection and isolation systems presents in the unit

STEP 6.2 Using table 4.5, select the appropriate classification (A,B,C) for the detection system.

Table 4.5 - Detection and Isolation system rating Guide

Type of Detection System	Detection Clssification
Instrumentation designed specifically to detect material losses by changes In operating conditions (i.e., loss of pressure or flow) in the system.	A
Suitable located detectors to determine when the material is present outside the pressure-containing envelope	B
Visual detection, cameras, or detectors with marginal coverage	C
Type of Isolation Sytem	**Isolation Classification**
Isolation or shutdown system activated directly process instrumentation or detection, with no operator intervention	A
Isolation or shutdown system activated by operators in the control room or other suitable locations remote from the leak	B
isolation dependent on manually-operated valves	C

Detection Is A

STEP 6.3 Using table 4.5, select the appropriate classification (a,b,c) for the isolation system

Isolation Is A

STEP 6.4 Determine the release reduction factor factdi using Table 4.6

Table 4.6 - Adjustment to Release Based on Detection and Isolation Systems

System Classification		Release Magnitude Adjustment	luction Factor, *fa*
Detection	Isolation		
A	A	Reduce release rate or mass by 25%	0.25
A	B	Reduce release rate or mass by 20%	0.20
A or B	C	Reduce release rate or mass by 10%	0.10
B	B	Reduce release rate or mass by 15%	0.15
C	C	No adjustment to release rate or mass	0.00

Release Magnitude Adjustment = Reduce release rate or mass by 25%

Reduction Factor, $fact_{di}$ = **0.25**

STEP 6.5 Determine the total leak durations for each release hole sizes using Table 4.7

Table 4.7 - Leak Durations Based on detection and Isolation Systems

Detection System Rating	Isolation System Rating	Maximum Leak Duration, ld_{max}
A	A	20 minutes for 1/4 inch leaks
		10 minutes for 1 inch leaks
		5 minutes for 4 inch leaks
A	B	30 minutes for 1/4 inch leaks
		20 minutes for 1 inch leaks
		10 minutes for 4 inch leaks
A	C	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	A or B	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	C	1 hour for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
C	A, B, or C	1 hour for 1/4 inch leaks
		40 minutes for 1 inch leaks
		20 minutes for 4 inch leaks

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 72490 s (Continous)

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 4529.5 s (Continous)

$ld_{max,2}$ = 10 minutes for 1 inch leaks

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 886.22 s (Continous)

$ld_{max,3}$ = 5 minutes for 4 inch leaks

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 17.698 s (Instataneous)

$ld_{max,4}$ = 5 minutes for 4 inch leaks

STEP7 Determine The Release Rate And Mass For Consequence of Failure

STEP 7.1 Calculate the adjusted release rate, raten for each release hole size

Reduction Factor, $fact_{di}$ = 0.25

W_1 = 0.0626 kg/s

W_2 = 1.0014 kg/s

W_3 = 5.1184 kg/s

W_4 = 256.3042 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$Rate_1 = W_n (1 - fact_{di})$$

$$Rate_1 = 0.0626 (1 - 0.25)$$

$$= 0.0469 \text{ kg/s}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$Rate_2 = W_n (1 - fact_{di})$$

$$Rate_2 = 1.0014 (1 - 0.25)$$

$$= 0.7511 \text{ kg/s}$$

3). LARGE RELEASE HOLE SIZE AREA

$$Rate_3 = W_n\,(1 - fact_{di})$$

$$Rate_3 = 5.1184\,(1 - 0.25)$$

$$= 3.8388 \text{ kg/s}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Rate_4 = W_n\,(1 - fact_{di})$$

$$Rate_4 = 256.3042\,(1 - 0.25)$$

$$= 192.23 \text{ kg/s}$$

STEP7.2 Calculate the leak duration, ldn, for each release hole size

$$ld_n = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\,.\,ld_{max,n}\}] \quad \text{.....equation (25)}$$

$ld_{max,1}$	=	20 minutes for 1/4 inch leaks	20	$Mass_{avail,1}$	=	275.96	kgs
$ld_{max,2}$	=	10 minutes for 1 inch leaks	10	$Mass_{avail,2}$	=	275.96	kgs
$ld_{max,3}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,3}$	=	275.96	kgs
$ld_{max,4}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,4}$	=	275.96	kgs

$Rate_1$ = 0.0469 kg/s
$Rate_2$ = 0.7511 kg/s
$Rate_3$ = 3.8388 kg/s
$Rate_4$ = 192.23 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$ld_1 = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_1}\},\{60\,.\,ld_{max,1}\}]$$

$$ld_1 = min\,.\,[\{\frac{275.96}{0.047}\},\{60\,.\,20\}]$$

$$= 1200 \text{ s}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2 = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_2}\},\{60\,.\,ld_{max,2}\}]$$

$$ld_2 = min\,.\,[\{\frac{275.96}{0.751}\},\{60\,.\,10\}]$$

$$= 367.41 \text{ s}$$

3). LARGE RELEASE HOLE SIZE AREA

$$ld_3 = min\ .\ [\{\frac{Mass_{avail,n}}{Rate_3}\},\{60\ .\ ld_{max,3}\ ]$$

$$ld_3 = min\ .\ [\{\frac{275.96}{3.839}\},\{60\ .\ 5\}]$$

$$= \quad 71.886\ s$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$ld_4 = min\ .\ [\{\frac{Mass_{avail,n}}{Rate_4}\},\{60\ .\ ld_{max,4}\ ]$$

$$ld_4 = min\ .\ [\{\frac{275.96}{192.2}\},\{60\ .\ 5\}]$$

$$= \quad 1.4356\ s$$

STEP 7. Calculate the release mass, $mass_n$, for each release hole size

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_1 = min\ .\ [\{Rate_1\ .\ ld_1\ \},Mass_{avail,n}\ ]$$

$$Mass_1 = min\ .\ [\{0.047\ .\ 1200\ \},275.96\ ]$$

$$= \quad 56.3168392\ kgs$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$Mass_2 = min\ .\ [\{Rate_2\ .\ ld_2\ \},Mass_{avail,n}\ ]$$

$$Mass_2 = min\ .\ [\{0.751\ .\ 367.4\ \},275.96\ ]$$

$$= \quad 275.955208\ kgs$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_3 = min\ .\ [\{Rate_3\ .\ ld_3\ \},Mass_{avail,n}\ ]$$

$$Mass_3 = min\ .\ [\{3.839\ .\ 71.89\ \},275.96\ ]$$

$$= \quad 275.955208\ kgs$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_4 = min\ .\ [\{Rate_4\ .\ ld_4\ \},Mass_{avail,n}\ ]$$

$$Mass_4 = min\ .\ [\{192.2\ .\ 1.436\ \},275.96\ ]$$

$$= \quad 275.955208\ kgs$$

PART 8 : DETERMINE FLAMMABLE AND EXPLOSIVE CONSEQUENCE

8.1 CONSEQUENCE AREA EQUATIONS

1). CONTINOUS RELEASE

$CA_n^{CONT} = \alpha(rate_n)^b$ ..... equation (26)

2). INSTATANEOUS RELEASE

$CA_n^{CONT} = \alpha(mass_n)^b$ ..... equation (27)

STEP 8.1 Select the consequence area mitigation reduction factor, $fact_{mit}$, from Table 4.10

Mitigation System	Consequence Area Adjustemnet	Consequence Area Reduction Factor, factor mit
Inventory blowdown , couple with isolation system classification B or higher	Reduce consequence area by 25%	0.25
Fire water deluge system and monitors	Reduce consequence area by 20%	0.2
Fire water monitor only	Reduce consequence area by 5%	0.05
Foam spray system	Reduce consequence area by 15%	0.15

Mitigation system = Inventory blowdown , couple with isolation system classification B or higher *

Consequence Area = Reducer consequence area by 25 % *

$fact_{mit}$ = 0.25

STEP 8.2 Calculate the energy efficiency, $eneff_n$, for each hole size using equation mentioned below.

C_{4A} = 2205 1/kg

$eneff_n = 4.\ log_{10}[C_4\ .mass_n] - 15$ ..... equation (28)

$Mass_1$ = 56.32 kgs

$Mass_2$ = 275.96 kgs

$Mass_3$ = 275.96 kgs

$Mass_4$ = 275.96 kgs

1. SMALL RELEASE HOLE SIZE AREA

$eneff_1 = 4\ .log_{10}\ [C_{4A}\ .mass_1] - 15$

$eneff_1 = 4\ .log_{10}\ [2205\ .56.32] - 15$

$eneff_1$ = 5.376187

2. MEDIUM RELEASE HOLE SIZE AREA

$$eneff_2 = 4 . log_{10} [C_{4A} . mass_2] - 15$$
$$eneff_2 = 4 . log_{10} [2205 . 275.96] - 15$$
$$eneff_2 = 8.136989$$

3. LARGE RELEASE HOLE SIZE AREA

$$eneff_3 = 4 . log_{10} [C_{4A} . mass_3] - 15$$
$$eneff_3 = 4 . log_{10} [2205 . 275.96] - 15$$
$$eneff_3 = 8.136989$$

4. RUPTURE RELEASE HOLE SIZE AREA

$$eneff_4 = 4 . log_{10} [C_{4A} . mass_4] - 15$$
$$eneff_4 = 4 . log_{10} [275.96] - 15$$
$$eneff_4 = 8.13699$$

STEP 8.3 Determine the fluid type

Determine the fluid type, either TYPE 0 or TYPE 1 based on Table 4.1 of API RP 581 Part 3 of COF.

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

C_1-C_2	=	TYPE 0	AIT	=	446.22222 ($^{\circ}$R)
MW	=	23 (kg/kg-mol)	T	=	70 (^{o}C)
AIT	=	1036 (^{o}F)	T	=	158 (^{o}F)
AIT	=	830.92778 (K)	T	=	343.15 (K)

STEP 8.4 For each release hole size, calculate the component damage consequence areas for Auto-Ignition Not Likely, Continous Release (AINT-CONT), $CA^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

Table 4.8 - Component Damage Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	8.7	0.98			55	0.95			6.5	0.67			164	0.62		
C3-C4	10.1	1.0			64	1.0			4.6	0.7			80	0.63		

α = $\alpha_{cmd,n}^{AINL-CONT}$ = 8.7 b = $b_{cmd}^{AINL-CONT}$ = 0.98

2). Calculate the consequence of area using equation below

$Rate_1$ = 0.047 kg/s

$Rate_2$ = 0.751 kg/s

$Rate_3$ = 3.839 kg/s

Rate4 = 192.2 kg/s

$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$ ..... equation (29)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-CONT} = \alpha(rate_1)^b \cdot (1 - fact_{mit})$

= 0.325 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-CONT} = \alpha(rate_2)^b \cdot (1 - fact_{mit})$

= 4.911 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-CONT} = \alpha(rate_3)^b \cdot (1 - fact_{mit})$

= 24.3 m^2

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$

= 1125.0 m^2

STEP 8.5 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Continous Release (AIL-CONT), $CA^{AIL\text{-}CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

α = $\alpha_{cmd,n}^{AIL-CONT}$ = 55.0 b = $b_{cmd}^{AIL-CONT}$ = 0.95

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$ ..... equation (30)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-CONT} = \alpha(rate_1)^b \cdot (1 - fact_{mit})$

= 2.259 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-CONT} = \alpha(rate_2)^b \cdot (1 - fact_{mit})$

= 31.43 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-CONT} = \alpha(rate_3)^b \cdot (1 - fact_{mit})$

= 148.1 m^2

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$

= 6095.2 m^2

STEP 8.6 For each release hole size, calculate the component damage consequence areas for Auto-ignition Not Likely, Instaneous Release, (AINL-INST), $CA^{AINL\text{-}INST}$

1). Determine the appropriate constant a and b from the Table 4.8

α = $\alpha_{cmd,n}^{AINL-INST}$ = 6.5 b = $b_{cmd}^{AINL-INST}$ = 0.67

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right)$ ..... equation (31)

From step 7, know that :

$Mass_1$	=	56.32	kgs	$eneff_1$	=	5.376
$Mass_2$	=	275.96	kgs	$eneff_2$	=	8.137
$Mass_3$	=	275.96	kgs	$eneff_3$	=	8.137
$Mass_4$	=	275.96	kgs	$eneff_4$	=	8.137

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 6.5\,(56.32)^{0,67}.\left(\frac{1-0,25}{5.376}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 13.50\ m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 6.5(275.96)^{0,67}.\left(\frac{1-0,25}{8.136989}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 25.87\ m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 6.5\,(275.96)^{0,67}.\left(\frac{1-0,25}{8.136989}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 25.87\ m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 6.5\,(275.96)^{0,67}.\left(\frac{1-0,25}{8.136989}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 25.87\ m^2$$

STEP 8.7 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Instataneous Release (AIL-INST), $CA^{AIL-INST}$

1). Determine the appropriate constant a and b from the Table 4.8

α = $\alpha_{cmd,n}^{AIL-INST}$ = 163.7 b = $b_{cmd}^{AIL-INST}$ = 0.62

2). Calculate the consequence of area using equation below

$$CA_{cmd,n}^{AIL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (32)}$$

From step 7, know that :

$Mass_1$	=	56.32	kgs	$eneff_1$	=	5.376
$Mass_2$	=	275.96	kgs	$eneff_2$	=	8.137
$Mass_3$	=	275.96	kgs	$eneff_3$	=	8.137
$Mass_4$	=	275.96	kgs	$eneff_4$	=	8.137

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AIL-INST} = \alpha\,(mass_1)^b \cdot \left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 163.7\,(56.32)^{0,62} \cdot \left(\frac{1-0,25}{5.376}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 277.99\ m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AIL-INST} = \alpha\,(mass_2)^b \cdot \left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 163.7\,(275.96)^{0,62} \cdot \left(\frac{1-0,25}{8.137}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 492.00\ m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AIL-INST} = \alpha\,(mass_3)^b \cdot \left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 163.7\,(275.96)^{0,62} \cdot \left(\frac{1-0,25}{8.137}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 492.00\ m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AIL-INST} = \alpha\,(mass_4)^b \cdot \left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 163.7\,(275.96)^{0,62} \cdot \left(\frac{1-0,25}{8.137}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 492.00\ m^2$$

STEP 8.8 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Continous Release (AINL-CONT), $CA_{inj,n}^{AIL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

Table 4.9 - Personnel Injury Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	21.8	1.00			143	0.92			12.5	0.67			474	0.63		
C3-C4	25.6	1.0			171	1.0			9.7	0.7			270	0.63		

α = $\alpha_{inj,n}^{AINL-CONT}$ = 21.8 b = $b_{inj,n}^{AINL-CONT}$ = 1.00

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1 - fact_{mit}) \quad \text{..... equation (33)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-CONT} = \left[\alpha.\left(rate_1^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 0.7695 \ m^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-CONT} = \left[\alpha.\left(rate_2^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 12.296 \ m^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-CONT} = \left[\alpha.\left(rate_3^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 62.854 \ m^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-CONT} = \left[\alpha.\left(rate_4^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 3146.8 \ m^2$$

STEP 8.9 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Continous Release (AIL-CONT), $CA_{inj,n}^{AIL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

α = $\alpha_{inj,n}^{AIL-CONT}$ = 143.0 b = $b_{inj,n}^{AIL-CONT}$ = 0.92

2). Calculate the consequence of area using equation below

$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1 - fact_{mit})$ ..... equation (34)

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-CONT} = \left[\alpha.\left(rate_1^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 6.4376 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-CONT} = \left[\alpha.\left(rate_2^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 82.411 m^2

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-CONT} = \left[\alpha.\left(rate_3^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 369.72 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-CONT} = \left[\alpha.\left(rate_4^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 13535 m^2

STEP 8.10 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Instataneous Release (AINL-INST), $CA_{inj,n}^{AINL-INST}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

α = $\alpha_{inj,n}^{AINL-INST}$ = 12.5 b = $b_{inj,n}^{AINL-INST}$ = 0.67

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (35)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-INST} = \left[a.\left(mass_1^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AINL-INST} = [79.(56.32)^{0,67}].\left(\frac{1-0,25}{5.376}\right)$$

$$CA_{inj,1}^{AINL-INST} = 25.88 \text{ m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-INST} = \left[a.\left(mass_2^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AINL-INST} = [79.(275.96)^{0,67}].\left(\frac{1-0,25}{8.137}\right)$$

$$CA_{inj,2}^{AINL-INST} = 49.60 \text{ m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-INST} = \left[a.\left(mass_3^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AINL-INST} = [79.(275.96)^{0,67}].\left(\frac{1-0,25}{8.137}\right)$$

$$CA_{inj,3}^{AINL-INST} = 49.60 \text{ m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-INST} = \left[a.\left(mass_4^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AINL-INST} = [79.(275.96)^{0,67}].\left(\frac{1-0,25}{8.137}\right)$$

$$CA_{inj,4}^{AINL-INST} = 49.60 \text{ m}^2$$

STEP 8.11 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Instataneous Release (AIL-INST),

$$CA_{inj,n}^{AIL-INST}$$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

α = $\alpha_{inj,n}^{AIL-INST}$ = 474.0 b = $b_{inj,n}^{AIL-INST}$ = 0.63

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{.....} \quad \text{equation (36)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-INST} = \left[a\,.\left(mass_1^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AIL-INST} = [3100\,.(56.32)^{0,63}].\left(\frac{1-0,25}{5.376}\right)$$

$$CA_{inj,1}^{AIL-INST} = 838.04 \quad m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-INST} = \left[a\,.\left(mass_2^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AIL-INST} = [3100\,.(275.96\,)^{0,63}].\left(\frac{1-0,25}{8.137}\right)$$

$$CA_{inj,2}^{AIL-INST} = 1506.97 \quad m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-INST} = \left[a\,.\left(mass_3^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AIL-INST} = [3100\,.(275.96)^{0,63}].\left(\frac{1-0,25}{8.137}\right)$$

$$CA_{inj,3}^{AIL-INST} = 1506.97 \quad m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-INST} = \left[a\,.\left(mass_4^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AIL-INST} = [3100\,.(275.96\,)^{0,63}].\left(\frac{1-0,25}{8.137}\right)$$

$$CA_{inj,4}^{AIL-INST} = 1506.97 \quad m^2$$

8.12 STEP 8.12 For each release hole size, calculate the instataneous / continous blending factor, $factn^{IC}$.

1). FOR CONTINOUS RELEASE

C_5 = 25.2 kg/s

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad \text{equation (37)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$fact_1^{IC} = \min\left[\left\{\frac{rate_1}{C_5}\right\}, 1.0\right]$$

= 0.00186508

B). MEDIUM RELEASE HOLE SIZE AREA

$$fact_2^{IC} = \min\left[\left\{\frac{rate_2}{C_5}\right\}, 1.0\right]$$

= 0.02980159

C). LARGE RELEASE HOLE SIZE AREA

$$fact_3^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$

= 0.15234127

D). RUPTURE RELEASE HOLE SIZE AREA

$$fact_4^{IC} = \min\left[\left\{\frac{rate_4}{C_5}\right\}, 1.0\right]$$

= 1

2). FOR INSTATANEOUS RELEASE

$$fact_4^{IC} = 1$$

8.13 Calculate the AIT blending factor, $fact^{AIT}$, using these optional equation below.

$$fact^{AIT} = 0 \quad \text{for } T_S + C_6 \leq AIT \quad \text{equation (38)}$$

$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2 \,.\, C_6} \quad \text{for } T_S + C_6 > AIT > T_S - C_6$$

$$fact^{AIT} = 1 \quad \text{for } T_S - C_6 \geq AIT \quad \text{equation (39)}$$

Ts	=	70 (^{o}C)	AIT	=	1036 (^{o}F)
Ts	=	158 (^{o}F)	AIT	=	830.927778 (K)
Ts	=	343.15 (K)	AIT	=	446.222222 (^{o}R)
C_6	=	55.6 (K)			

$T_s + C_6$	=	398.75 (K)
$T_s - C_6$	=	287.55 (K)
$\frac{(T_s - AIT + C_6)}{2 \,.\, C_6}$		-3.8865 (K)

$fact^{AIT}$ = 0

STEP 8.14 Calculate the continuous/instantaneous blended consequence area for the component using equation (3.53) through (3.56) based on the consequence areas calculated in previous steps $fact_n^{IC}$

` A. Componen demage for auto-ignition Likely, Continous - Instataneous release

$$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} . fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} . (1 - fact_n^{IC})$$ equation (40)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-INST}$	=	277.99	m^2
$fact_1^{IC}$	=	0.0019	
$CA_{cmd,1}^{AIL-CONT}$	=	2.2590036	m^2
$CA_{cmd,1}^{AIL}$	=	2.7732663	m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-INST}$	=	492.00	m^2
$fact_2^{IC}$	=	0.029802	
$CA_{cmd,2}^{AIL-CONT}$	=	31.425478	m^2
$CA_{cmd,2}^{AIL}$	=	45.151365	m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-INST}$	=	492.00	m^2
$fact_3^{IC}$	=	0.152341	
$CA_{cmd,3}^{AIL-CONT}$	=	148.05775	m^2
$CA_{cmd,3}^{AIL}$	=	200.45453	m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-INST}$ = 492.00 m^2

$fact_4^{IC}$ = 1.000000

$CA_{cmd,4}^{AIL-CONT}$ = 6095.2 m^2

$CA_{cmd,4}^{AIL}$ = 492.00119 m^2

B. Personal Injury for auto-ignition Likely, Continous - Instataneous release

$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} . fact_n^{IC} + CA_{inj,n}^{AIL-CONT} . (1 - fact_n^{IC})$.... equation (41)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AIL-INST}$ = 838.04 m^2

$fact_1^{IC}$ = 0.0019

$CA_{inj,1}^{AIL-CONT}$ = 6.4376495 m^2

$CA_{inj,1}^{AIL}$ = 7.9886631 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AIL-INST}$ = 1506.97 m^2

$fact_2^{IC}$ = 0.029802

$CA_{inj,2}^{AIL-CONT}$ = 82.411163 m^2

$CA_{inj,2}^{AIL}$ = 124.86524 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AIL-INST}$ = 1506.97 m^2

$fact_3^{IC}$ = 0.152341

$CA_{inj,3}^{AIL-CONT}$ = 369.72427 m^2

$CA_{inj,3}^{AIL}$ = 542.97352 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AIL-INST}$ = 1506.97 m^2

$fact_4^{IC}$ = 1.000000

$CA_{inj,4}^{AIL-CONT}$ = 13534.755 m^2

$CA_{inj,4}^{AIL}$ = 1506.9686 m^2

C. Componen demage for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST} . fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (42)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-INST}$ = 13.50 m^2

$fact_1^{IC}$ = 0.0019

$CA_{cmd,1}^{AINL-CONT}$ = 0.3248899 m^2

$CA_{cmd,1}^{AINL}$ = 0.349468 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-INST}$ = 25.87 m^2

$fact_2^{IC}$ = 0.029802

$CA_{cmd,2}^{AINL-CONT}$ = 4.9114248 m^2

$CA_{cmd,2}^{AINL}$ = 5.5361591 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-INST}$ = 25.87 m^2

$fact_3^{IC}$ = 0.1523

$CA_{cmd,3}^{AINL-CONT}$ = 24.300439 m^2

$CA_{cmd,3}^{AINL}$ = 24.54024 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-INST}$ = 25.87 m^2

$fact_4^{IC}$ = 1.0000

$CA_{cmd,4}^{AINL-CONT}$ = 1125.0 m^2

$CA_{cmd,4}^{AINL}$ = 25.874547 m^2

D. Personal Injury for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} . fact_n^{IC} + CA_{inj,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (43)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AINL-INST}$ = 25.88 m^2

$fact_1^{IC}$ = 0.0019

$CA_{inj,1}^{AINL-CONT}$. = 0.7695075 m^2

$CA_{inj,1}^{AINL}$ = 0.8163481 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AINL-INST}$ = 49.60 m^2

$fact_2^{IC}$ = 0.029802

$CA_{inj,2}^{AINL-CONT}$ = 12.295748 m^2

$CA_{inj,2}^{AINL}$ = 13.407459 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AINL-INST}$ = 49.60 m^2

$fact_3^{IC}$ = 0.1523

$CA_{inj,3}^{AINL-CONT}$ = 62.854028 m^2

$CA_{inj,3}^{AINL}$ = 60.834819 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AINL-INST}$ = 49.60 m^2

$fact_4^{IC}$ = 1.0000

$CA_{inj,4}^{AINL-CONT}$ = 3146.7945 m^2

$CA_{inj,4}^{AINL}$ = 49.599517 m^2

STEP 8.15 Calculate the AIT blended consequence areas for the component using equations (3.57) and (3.58) based on the consequence areas determined in step 8.14 and the AIT blending factors, , calculate in step 8.13. the resulting consequence areas are the component damage and personnel injury flammable consequence areas, and for each release hole size selected in step 2.2 $CA_{cmd,n}^{flam}$ $CA_{inj,n}^{flam}$

A. Componen Demage

$CA_{cmd,n}^{flam} = CA_{smd,n}^{AIL} . fact^{AIT} + CA_{cmd,n}^{AINL} . (1 - fact^{AIT})$ ..... equation (44)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL}$ = 2.7732663 m^2

$fact^{AIT}$ = 0

$CA_{cmd,1}^{AINL}$ = 0.349468 m^2

$CA_{cmd,1}^{flam}$ = 0.349468 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL}$ = 45.151365 m^2

$fact^{AIT}$ = 0

$CA_{cmd,2}^{AINL}$ = 5.5361591 m^2

$CA_{cmd,2}^{flam}$ = 5.5361591 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL}$ = 200.45453 m^2

$fact^{AIT}$ = 0

$CA_{cmd,3}^{AINL}$ = 24.54024 m^2

$CA_{cmd,3}^{flam}$ = 24.54024 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL}$ = 492.00119 m^2

$fact^{AIT}$ = 0

$CA_{cmd,4}^{AINL}$ = 25.874547 m^2

$CA_{cmd,4}^{flam}$ = 25.874547 m^2

B. Personal Injury

$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} . fact^{AIT} + CA_{inj,n}^{AINL} . (1 - fact^{AIT})$..... equation (45)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{flam-AIL}$ = 7.9886631 m^2

$fact^{AIT}$ = 0

$CA_{inj,1}^{AINL}$ = 0.8163481 m^2

$CA_{inj,1}^{flam}$ = 0.8163481 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{flam-AIL}$ = 124.86524 m^2

$fact^{AIT}$ = 0

$CA_{inj,2}^{AINL}$ = 13.407459 m^2

$CA_{inj,2}^{flam}$ = 13.407459 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{flam-ALL}$ = 542.97352 m^2

$fact^{AIT}$ = 0

$CA_{inj,3}^{AINL}$ = 60.834819 m^2

CA_{inj3}^{flam} = 60.834819 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{flam-ALL}$ = 1506.9686 m^2

$fact^{AIT}$ = 0

$CA_{inj,4}^{AINL}$ = 49.599517 m^2

CA_{inj4}^{flam} = 49.599517 m^2

STEP 8.16 Determine the consequence areas (probability weighted on release hole size) for component damage and personnel injury using equations (3.59) and (3.60) based on the consequence area from step 8.15

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		Small	Medium	Large	Rupture	
Vessel/ FinFan	KODRUM	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
	COLBTM					
	FINFAN					
	FILTER					
	DRUM					
	REACTOR					
	COLTOP					
	COLMID					

CONSEQUENCE AREA FOR COMPONENT DAMAGE

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad \text{..... equation (46)}$$

$$CA_{cmd}^{flam} = \left(\frac{(gff_{1.}\, CA_{cmd,1}^{flam}) + (gff_{2.}\, CA_{cmd,2}^{flam}) + (gff_{3.}\, CA_{cmd,3}^{flam}) + (gff_{4.}\, CA_{cmd,4}^{flam})}{gff_{total}} \right)$$

$$= 5.82\ m^2$$

CONSEQUENCE AREA FOR PERSONNEL INJURY

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad \text{..... equation (47)}$$

$$CA_{inj}^{flam} = \left(\frac{\left(gff_1 \cdot CA_{inj,1}^{flam}\right) + \left(gff_2 \cdot CA_{inj,2}^{flam}\right) + \left(gff_3 \cdot CA_{inj,3}^{flam}\right) + \left(gff_4 \cdot CA_{inj,4}^{flam}\right)}{gff_{total}} \right.$$

$$= \left. 13.925\ m^2 \right.$$

PART 9 : CALCULATE THE TOXIC CONSEQUENCES AREA

Table 4.113 Continuous Gas and Liquid Release Toxic Consequence Equation Constantsfor Miscellaneous Chemicals

Chemical	Release Duration (minutes)	Gas Release Constants		Liquid Release Constants	
		e	f	e	f
Aluminum Chloride (Alcl3)	ALL	17.663	0.9411	N/A	N/A
Carbon Monoxide (CO)	3	41.412	1.15	N/A	N/A
	5	279.79	1.06	N/A	N/A
	10	834.48	1.13	N/A	N/A
	20	2915.9	1.11	N/A	N/A
	40	5346.8	1.17	N/A	N/A
	60	6293.7	1.21	N/A	N/A
Hydrogen Chloride (HCL)	3	215.48	1.09	N/A	N/A
	5	536.28	1.15	N/A	N/A
	10	2397.5	1.1	N/A	N/A
	20	4027	1.18	N/A	N/A
	40	7534.5	1.2	N/A	N/A
	60	8625.1	1.23	N/A	N/A
Nitric Acid	3	53.013	1.25	5110	1.08
	5	68.7	1.25	9640.8	1.02
	10	96.325	1.24	12.453	1.06
	20	126.942	1.23	19.149	1.06
	40	146.941	1.22	31.145	1.06
	60	156.345	1.22	41.999	1.12
Nitrogen Dioxide (NO2)	3	6633.1	0.7	2132.9	0.98
	5	9221.4	0.68	2887	1.04
	10	11.965	0.68	6194.4	1.07
	20	14.248	0.72	13.843	1.08
	40	22.411	0.7	27.134	1.12
	60	24.994	0.71	41.657	1.13

Phosgene	3	12.902	1.2	3414.8	1.06
	5	22.976	1.29	6857.1	1.1
	10	48.985	1.24	21.215	1.12
	20	108.298	1.27	63.361	1.16
	40	244.67	1.3	178.841	1.2
	60	367.877	1.31	314.608	1.23
Toluene Diisocyanate (TDI)	3	N/A	N/A	3692.5	1.06
	5	N/A	N/A	3849.2	1.09
	10	N/A	N/A	4564.9	1.1
	20	N/A	N/A	4777.5	1.06
	40	N/A	N/A	4953.2	1.06
	60	N/A	N/A	5972.1	1.03
Ethylene Glycol Monoethyl Ether (EE)	1.5	3.819	1.171	N/A	N/A
	3	7.438	1.181	N/A	N/A
	5	17.735	1.122	N/A	N/A
	10	33.721	1.111	3.081	1.105
	20	122.68	0.971	16.877	1.065
	40	153.03	0.995	43.292	1.132
	60	315.57	0.899	105.74	1.104

Because of no chemical toxic in this equipment, so this step not calculate.

PART 10 : CALCULATE THE NON-FLAMMABLE, NON-TOXIC CA

Step 10.1 For each release hole size, calculate the non-flammable , non-toxic

For steam-calculate $CA_{inj,N}^{CONT}$ using equation (43) and $CA_{inj,N}^{INST}$

1). FOR STEAM

Steam represents a hazard to personnel who are exposed to it at high temperatures. In general, steam is at 100oC (212oF) immediately after exiting a hole in an equipment item. Within a few feet, the steam will begin to mix with air cool, and condensed. The approach used here is that injury occurs above 60oC (140oF). In this case of Production Separator, the temperatur inside the presssure vessel is maximally working at 100oC (212oF). So, steam leaks is potentially occur at this situation.

$Mass_1$ = 56.3168 kgs

$Mass_2$ = 275.9552 kgs

$Mass_3$ = 275.9552 kgs

$Mass_4$ = 275.9552 kgs

$Rate_1$ = 0.0470 kg/s

$Rate_2$ = 0.7510 kg/s

$Rate_3$ = 3.8390 kg/s

$Rate_4$ = 192.2000 kg/s

C_9 = 0.123 m^2.sec/kg

C_{10} = 9.744 $m^2/kg^{0.06384}$

$fact_1^{IC}$ = 0.0018651

$fact_2^{IC}$ = 0.0298016

$fact_3^{IC}$ = 0.15234127

$fact_4^{IC}$ = 1

$CA_{inj,n}^{CONT} = C_9 . Rate_n)$ ……. equation (48)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{CONT} = C_9 . Rate_1)$

= 0.00578 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{CONT} = C_9 . Rate_2)$

= 0.09237 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{CONT} = C_9 . Rate_3)$

= 0.47220 m^2

$CA_{inj,n}^{INST} = C_{10} . Mass_n)^{0.6384}$ ……. equation (49)

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{INST} = C_{10} . Mass_4)^{0.6384}$

= 154.68252 m^2

2). FOR ACIDS AND CAUSTIC

For Acids or caustics- compute, $CA_{inj,N}^{CONT}$ using equation (3.72), (3.73), (3.74). Note that the data is not provided for an instantaneous release ; therefore,

No acid or caustic, thus value are 0.

Step 10.2 For each release hole size, calculate the instantaneous/continuous blending factor, $fact_n^{IC}$ for steam, use equation (3.71).
for acids or caustics, $fact_n^{IC}$ =0.0

Step 10.3 For each release hole size , compute the blended non-flammable , non-toxic personnel injury consequence area for steam or acid leaks , , using equation (3.76) based on the consequence are from step 10.1 and the blending factor , , from step 10.2, $CA_{inj,n}^{leak}$ $fact_n^{IC}$ note that there is no need to calculate component damage area for the level 1 non-flammable release (steam or acid/caustic) :

$CA_{cmd,n}^{leak}$ = 0 m^2

$CA_{inj,n}^{leak} = CA_{inj,n}^{INST}.\ fact_n^{IC} + CA_{inj,n}^{CONT}.(1 - fact_n^{IC})$ ..... equation (50)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{leak} = CA_{inj,1}^{INST}.\ fact_1^{IC} + CA_{inj,1}^{CONT}.(1 - fact_1^{IC})$

= 0.0057702 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{leak} = CA_{inj,2}^{INST}.\ fact_2^{IC} + CA_{inj,2}^{CONT}.(1 - fact_2^{IC})$

= 0.0896201 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{leak} = CA_{inj,3}^{INST}.\ fact_3^{IC} + CA_{inj,3}^{CONT}.(1 - fact_3^{IC})$

= 0.40026191 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{leak} = CA_{inj,4}^{INST}.\ fact_4^{IC} + CA_{inj,4}^{CONT}.(1 - fact_4^{IC})$

= 154.68252 m^2

Step 10.4 Determine the final non-flammable, non toxic consequence areas for personnil injury, CA_{icmd}^{nfnt} using equation (3.80) based on consequence areas calculated for each release hole size in step 10.3 . Note that there is no need to calculate a final-flammable, non-toxic consequence area for component damage area for the level 1 non-flammable release (steam or acid/caustic, or :

$CA_{cmd,n}^{lnfnt}$ = 0 m^2

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}} \right) \quad \text{..... equation (51)}$$

$$CA_{inj}^{nfnt} = \left(\frac{(gff_1 \cdot CA_{inj,1}^{leak}) + (gff_2 \cdot CA_{inj,2}^{leak}) + (gff_3 \cdot CA_{inj,3}^{leak}) + (gff_4 \cdot CA_{inj,4}^{leak})}{gff_{total}} \right)$$

= 3.11924 m^2

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		Small	Medium	Large	Rupture	
Vessel/ FinFan	KODRUM	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
	COLBTM					
	FINFAN					
	FILTER					
	DRUM					
	REACTOR					
	COLTOP					
	COLMID					

PART 11 : CALCULATION OF FINAL CONSEQUENCE AREA

Step 11.1 Calculate the final component damage consequence area, Cacmd

Note that since the component damage consequence areas for toxic releases, CAcmd^{tox}, and non-flammable, non-toxic releases, CAcmd^{nfnt}, are both equal to zero. Then, the final component damage consequence area is equal to the consequence area calculated for flammable releases, CAcmd^{flam}.

$$CA_{cmd} = CA_{cmd}^{flam} \quad \text{..... equation (52)}$$

= 5.82 m^2

Step 11.2 Calculate the final personnel injury consequence area, CA_{inj}

$$CA_{inj} = \max \left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt} \right] \quad \text{..... equation (53)}$$

CA_{inj}^{flam} = 13.925 m^2

CA_{inj}^{tox} = 0.00 m^2

CA_{inj}^{nfnt} = 3.11924 m^2

CA_{inj} = max $\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$

= 13.925141 m^2

Step 11.3 Calculate the final consequence area, CA, using equation below:

CA=max$\left[CA_{cmd}, CA_{inj}\right]$

= 13.93 m^2

= 149.88897 ft^2

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 4 :

INSPECTION PLANNING AND RECOMMENDATION

PSV-1020A/B

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 4 = Inspection Planning and Recommendation

STEP 1 CALCULATION OF RISK ANALYSIS

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (54)

dimana :

$Risk^{prd}$ = total risiko PRD

$Risk_f^{prd}$ = risiko PRD gagal membuka

$Risk_l^{prd}$ = risiko PRD bocor

STEP 1.1 Menghitung resiko dari peluang kegagalan PRD untuk gagal membuka $Risk_f^{prd}$

A. RBI Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 5.5122E-11 $Risk_{f.j}^{prd}$ = 6E-11 . 13.925

$C_{f,j}^{prd}$ = 13.93 m^2 = CA = 7.6758E-10

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 1.378E-09 $Risk_{f.j}^{prd}$ = 1E-09 x 13.925

$C_{f,j}^{prd}$ = 13.93 m^2 = CA = 1.919E-08

B. RBI Plan Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 8.6041E-10 $Risk_{f.j}^{prd}$ = 9E-10 . 13.925

$C_{f,j}^{prd}$ = 13.93 m^2 = CA = 1.1981E-08

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 2.151E-08 $Risk_{f.j}^{prd}$ = 2E-08 x 13.925

$C_{f,j}^{prd}$ = 13.93 m^2 = CA = 2.9953E-07

$$Risk_f^{prd} = \sum_{j=1}^{ndc} P_{f,j}^{prd} . C_{f,j}^{prd}$$

A. RBI Date

$Risk_f^{prd}$ = 8E-10 + 2E-08

= 1.9957E-08

B. RBI Plan Date

$Risk_f^{prd}$ = 1E-08 + 3E-07

= 3.1152E-07

STEP 1.2 Hitung risiko untuk kasus kebocoran PRD, $Risk_l^{prd}$

$$Risk_l^{prd} = P_l^{prd} . C_l^{prd}$$ equation (56)

Dimana :

P_l^{prd} = 0.0051 (RBI Date)

P_l^{prd} = 0.1375 (RBI Plan Date)

C_l^{prd} = 13.93 m^2

A. RBI Date

$Risk_l^{prd}$ = 0.0051 x 13.925

= 0.071

B. RBI Plan Date

$Risk_l^{prd}$ = 0.1375 x 13.93

= 1.9147

STEP 1.3 Menghitung total risiko menggunakan persamaan (57)

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (57)

A. Risk at RBI Date

$Risk^{prd}$ = 0.071 $m^2/year$

= 0.7644 $ft^2/year$

B. Risk at RBI Plan Date

$Risk^{prd}$ = 1.9147 $m^2/year$

= 20.61 $ft^2/year$

STEP 2 Risk Matrix

Probabilty Score at RBI Date = 6E-11 + 1E-09 + 0.0051

= 5.10E-03

Probabilty Score at Plan Date = 9E-10 + 2E-08 + 0.1375

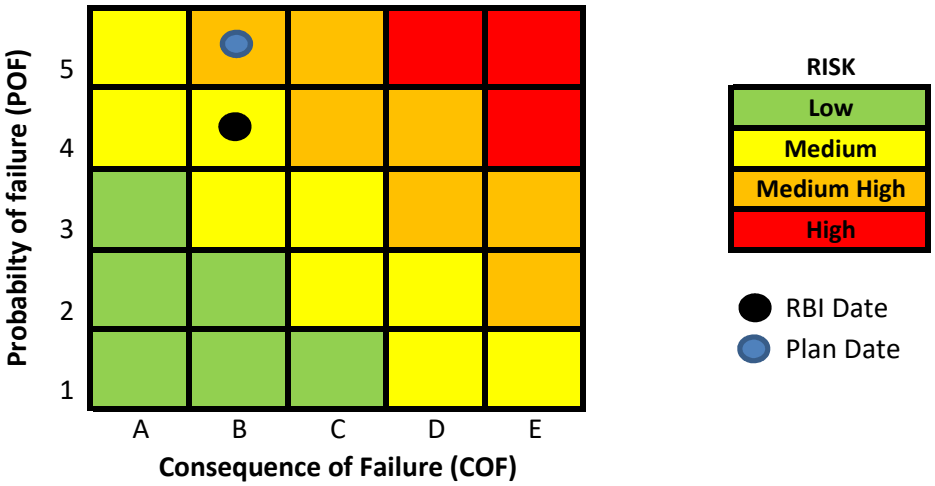
= 1.38E-01

Consequence Score = 13.93 m^2

= 149.89 ft^2

Table 4.1 Numerical Values Associated with POF and Area-Based COF Categories

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t,I_E) \leq 3.06E-05$	$D_{ftotal} \leq 1$	A	$CA \leq 100$
2	$3.06E-05 < P_f(t,I_E) \leq 3.06E-04$	$1 < D_{ftotal} \leq 10$	B	$100 < CA \leq 1.000$
3	$3.06E-04 < P_f(t,I_E) \leq 3.06E-03$	$10 < D_{ftotal} \leq 100$	C	$1.000 < CA \leq 10.000$
4	$3.06E-03 < P_f(t,I_E) \leq 3.06E-02$	$100 < D_{ftotal} \leq 1000$	D	$10.000 < CA \leq 100.000$
5	$P_f(t,I_E) > 3.06E-02$	$D_{ftotal} > 1000$	E	$CA > 100.000$



STEP 3 Inspection Date

Target date dapat dihitung dengan cara melakukan interpolasi nilai RBI Date dan PRBI Plan Date

Dalam menentukan target date, digunakan nilai risk target sebesar 40ft^2 (3.71 m^2) untuk menentukan tahun inspection date.

Data	Date	Age	Risk (m^2/yr)
RBI Date	15/03/2020	0	0.071
Risk Target	?	?	3.71
Plan Date	15/3/2024	11	1.9147

$$\frac{Y - Y_1}{Y_2 - Y_1} = \frac{X - X_1}{X_2 - X_1}$$

$$Y = Y_1 + \left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)$$

$$Y = 0 + \left(\frac{3.71 - 0.071}{1.9147 - 0.071}\right)(11 - 0)$$

Y = 21.711254 Year

Y = 7924.6077 Hari

= 24/11/2041

Berdasarkan standart API 510 memberikan rekomendasi interval inspeksi maksimal untuk *Pressure Reliev Device* yaitu 10 tahun dari inspeksi terakhir. Sehingga untuk jadwal inspeksi selanjutnya yaitu pada tanggal 17 juni 2026.

STEP 4 Recommendation

1 Inspection Category

Inspection Effectiveness	Description of Inspection	Date
C	Inspeksi visual telah dilakukan tanpa tes pop, di mana dokumentasi terperinci tentang kondisi internal PRD komponen dibuat.	17/06/2026
Fairly Effective	Tes trevitest atau in-situ telah dilakukan di tempat yang sebenarnya cairan proses tidak digunakan untuk memberi tekanan pada sistem.	

Berdasarkan standart API 581 Direkomendasikan menggunakan inspection effectiveness kategori C dengan mengaplikasikan Visual on-stream inspection

2 Inspection Strategy

Berdasarkan Standart API 576 berikut rekomendasi record visual inspeksi Pressure Relief Device

Unit	Location		Set Pressure	Test Interval
Make		:		
Style		:		
Body and bonnet material		:		
Nozzle and disk material		:		
Trim material		:		
Spring material		:		
Spring no		:		
Flange sizes				
	Inlet	:		
	Outlet	:		
Spring set pressure		:		
Relieving pressure		:		
normal operating temp		:		
Remark				

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 1:

DATA PRESSURE RELIEF DEVICE

PSV-1311

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

Lampiran 1 = Data Pressure Relief Device

1 GENERAL

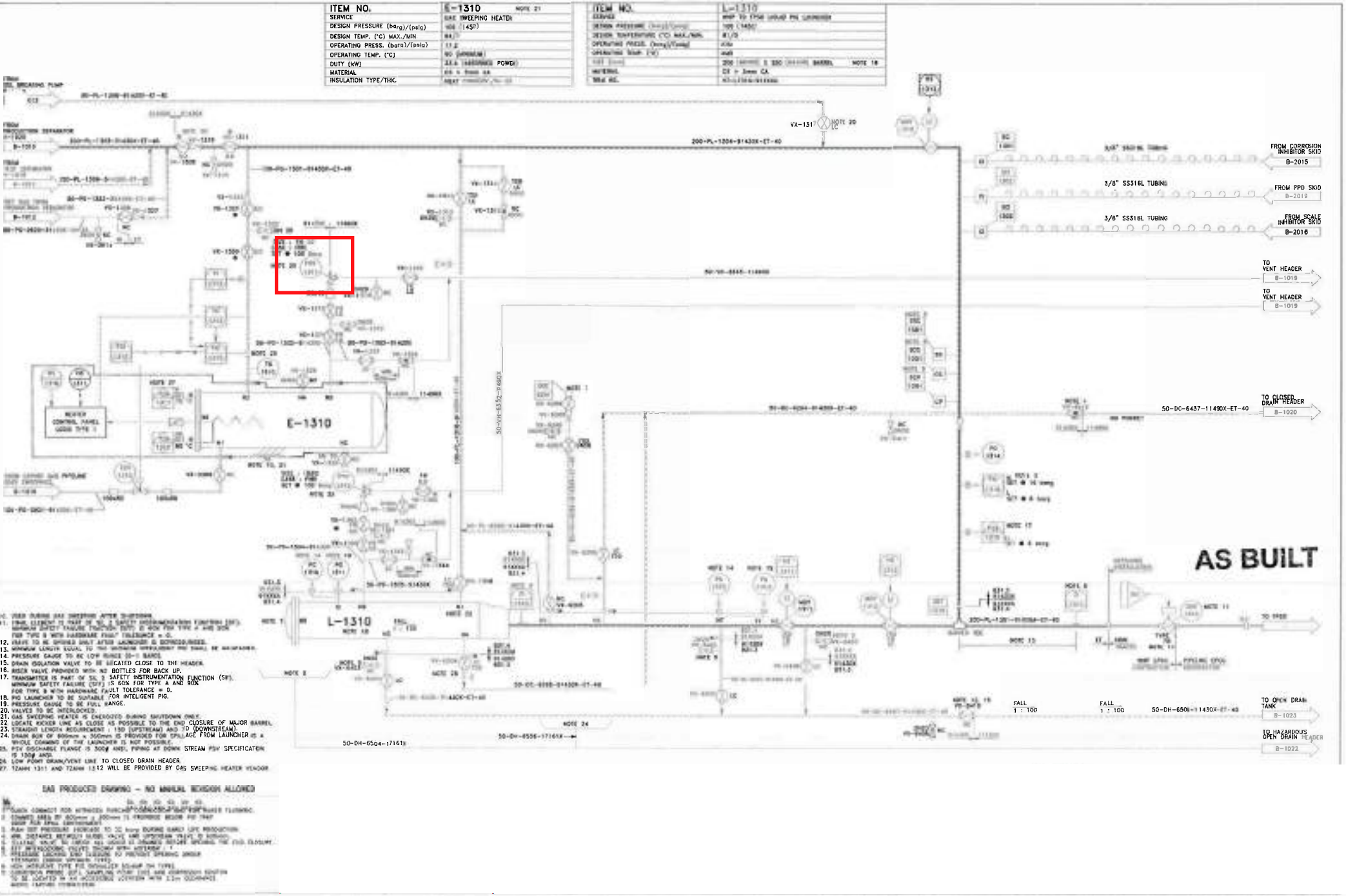
Tag Number	:	PSV-1311	
Service	:	WHP to FPSO Gas Sweeping Heater	
Noozle (full/semi)	:	FULL	
PID No.	:	BTJT-A-B-1011	
Design	:	SAFETY-RELIEF	
Type	:	Conventional	
Bonnet Type	:	Closed	
Nace Requirement	:	Yes	

2 PROCESS CONDITIONS

Fluid		:	Hydrocarbon	
State		:	Gas	
Required Capacity		:	42.77	lb/h
Molecular Weight		:	21	
Operating Pressure		:	162.4	psig
Set Pressure		:	1450	psig
Operating Temperatur		:	990	^{o}F
Reliefing Temperatur		:	990	^{o}F
Back Pressure	Constant	:	0	psig
	Variable	:	0	psi
	Total	:	94.3	psig
% Allowable Overpressure		:	21%	
Overpressure Factor		:	-	
Compressible Factor		:	1.028	
Laten Heat of Vaporation		:	-	Btu/lb
Ratio of Specific Heats (Cp/C		:	1.134	
Relief Density		:	3.78	Lb/ft^2
Relief Viscosity		:	-	cP
Barometric Pressure		:	14.69	psia

3 DESIGN CONDITION

Design Pressure	:	1450	psig
Design Temperatur	:	1000	^{o}F


ITEM NO.
E-1310
SERVICE
DESIGN PRESSURE (barg)/(psig)
DESIGN TEMP. (°C) MAX./MIN
OPERATING PRESS. (barg)/(psig)
OPERATING TEMP. (°C)
DUTY (kW)
MATERIAL
INSULATION TYPE/THK.
ITEM NO.
L-1310
VX-1317
NOTE 20
200-PL-1204-91430X-ET-40
FROM CORROSION INHIBITOR SKID
B-2015
3/8" SS316L TUBING
FROM PPD SKID
B-2019
3/8" SS316L TUBING
FROM SCALE INHIBITOR SKID
B-2016
TO VENT HEADER
B-1019
TO VENT HEADER
B-1019
TO CLOSED DRAIN HEADER
B-1020
50-DC-6437-11490X-ET-40
E-1310
L-1310
AS BUILT
FALL 1 : 100
FALL 1 : 100
50-DH-6504-17161X
50-DH-6556-17161X
TO OPEN DRAIN TANK
B-1023
TO HAZARDOUS OPEN DRAIN HEADER
B-1022
GAS PRODUCED DRAWING – NO MANUAL REVISION ALLOWED

CASE 1 : MAXIMUM GAS FLOW RATE (AUGUST 2016)

Stream Name		1	1A	1B	1C	1D	1E	2	2A	2B	2C
Description		Wellhead Flowline U/S of choke - NAG	Wellhead Flowline (BT2_A_P) U/S of choke - Long String	Wellhead Flowline (BT4_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_D_P) U/S of choke - Long String	Wellhead Flowline (BT2_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_E_P) U/S of choke - Long String	Wellhead Flowline D/S of choke - Short String (NAG)	Wellhead Flowline (BT2_A_P) D/S of choke - Long String	Wellhead Flowline (BT4_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_D_P) D/S of choke - Long String
MIXTURE											
Vapour Fraction		1.0000	0.2955	0.4203	0.2920	0.3095	0.2950	1.0000	0.3159	0.4223	0.2840
Temperature	C	75.0	75.0	71.0	72.0	75.0	74.0	66.4	69.2	70.2	71.4
Pressure	kPag	2959	2959	1034	1034	1034	1034	930	930	930	930
Pressure	bar_g	29.6	29.6	10.3	10.3	10.3	10.3	9.3	9.2	9.2	9.3
Mass Flow	kg/h	8478.39	26300.60	110228.76	22227.17	83356.85	29194.58	8478.39	26300.60	110228.76	22227.17
Molar Flow	kgmole/h	449.11	841.38	3550.51	685.08	2545.47	899.18	449.11	841.38	3550.51	685.08
Molecular Weight		18.9	31.3	31.0	32.4	32.4	32.5	18.9	31.3	31.0	32.4
Heat Flow	kW	-3821	-53720	-205650	-44662	-163516	-58456	-3821	-53720	-205650	-44662
Mass Heat Capacity	kJ/kg C	2.40	2.88	2.80	2.91	2.91	2.92	2.27	2.92	2.79	2.91
Mass Density	kg/m3	21.04	108.95	29.76	43.88	41.06	43.17	7.04	35.86	29.34	39.70
GAS PHASE											
Std Gas Flow	kNm3/h	10.05	5.56	33.39	4.46	17.62	5.95	10.05	5.95	33.54	4.51
Std Gas Flow	MMSCFD	9.00	4.98	29.91	4.01	15.79	5.33	9.00	5.33	30.05	4.04
Molar Flow	kgmole/h	449.11	248.67	1492.34	200.05	787.71	265.75	449.11	265.81	1499.40	201.38
Actual Gas Flow	ACT m3/h	403.02	217.58	3621.21	488.87	1934.34	650.66	1205.17	710.89	4009.69	540.38
Mass Flow	kg/h	8478.39	5617.70	37106.46	4989.82	15634.55	6670.73	8478.39	6309.08	37411.64	5048.85
Molecular Weight		18.9	22.6	24.9	24.9	25.2	25.1	18.9	23.7	25.0	25.1
Mass Heat Capacity	kJ/kg-C	2.40	2.30	2.13	2.13	2.14	2.14	2.27	2.13	2.12	2.12
Z Factor		0.95	0.93	0.96	0.96	0.96	0.96	0.98	0.97	0.97	0.97
Thermal Conductivity	W/m-K	0.041	0.038	0.034	0.034	0.035	0.035	0.038	0.035	0.034	0.034
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mass Density	kg/m3	21.04	26.82	10.25	10.25	10.25	10.25	7.04	6.86	9.33	9.34
Cp/Cv (Gamma)		1.32	1.30	1.23	1.23	1.22	1.22	1.27	1.23	1.22	1.22
OIL PHASE											
Mass Flow	kg/h	—	11155.91	39678.59	9354.61	33942.01	12226.33	—	10545.33	39426.24	9304.07
Liquid Vol Flow @Std Cond	m3/h	—	13.25	46.51	10.96	39.75	14.32	—	12.29	46.14	10.89
Liquid Vol Flow @Std Cond	barrel/day	—	2088	7021	1656	6000	2162	—	1855	6965	1643
Actual Volume Flow	m3/h	—	13.99	48.76	11.50	41.81	15.05	—	12.85	48.32	11.41
Molecular Weight		—	174.5	196.6	197.0	198.1	197.7	—	205.6	198.4	199.5
Mass Heat Capacity	kJ/kg-C	—	2.10	2.13	2.13	2.14	2.14	—	2.11	2.12	2.13
Thermal Conductivity	W/m K	—	0.103	0.109	0.109	0.109	0.109	—	0.111	0.110	0.110
Viscosity	cP	—	1.20	1.56	1.54	1.50	1.51	—	1.76	1.62	1.60
Mass Density	kg/m3	—	787.80	813.74	813.27	811.86	812.33	—	820.69	815.97	815.22
Surface Tension	dyne/cm	—	12.91	14.73	14.88	14.57	14.61	—	15.18	14.92	14.80
AQUEOUS PHASE											
Mass Flow	kg/h	—	9526.98	33443.69	7882.74	28580.29	10297.52	—	9445.29	33390.88	7874.25
Liquid Vol Flow @Std Cond	m3/h	—	9.38	32.98	7.77	28.19	10.15	—	9.31	32.90	7.76
Liquid Vol Flow @Std Cond	barrel/day	—	1417	4975	1173	4251	1532	—	1406	4967	1171
Actual Volume Flow	m3/h	—	9.83	34.40	8.12	29.50	10.62	—	9.70	34.33	8.10
Molecular Weight		—	18.0	18.0	18.0	18.0	18.0	—	18.0	18.0	18.0
Mass Heat Capacity	kJ/kg-C	—	4.34	4.34	4.34	4.35	4.35	—	4.34	4.34	4.34
Thermal Conductivity	W/m-K	—	0.666	0.663	0.664	0.666	0.665	—	0.662	0.663	0.663
Viscosity	cP	—	0.37	0.39	0.39	0.37	0.38	—	0.41	0.40	0.39
Mass Density	kg/m3	—	969.63	972.09	971.29	968.88	969.68	—	973.51	972.66	971.73
MIXTURE COMPOSITION (Mole Fraction)											
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005
Nitrogen		0.0055	0.0025	0.0031	0.0021	0.0022	0.0021	0.0055	0.0025	0.0031	0.0021
CO2		0.0031	0.0040	0.0056	0.0038	0.0040	0.0039	0.0031	0.0040	0.0055	0.0038
Methane		0.8627	0.2283	0.2901	0.2016	0.2112	0.2026	0.8627	0.2283	0.2901	0.2016
Ethane		0.0453	0.0283	0.0393	0.0276	0.0290	0.0278	0.0453	0.0283	0.0393	0.0276
Propane		0.0262	0.0236	0.0361	0.0260	0.0274	0.0263	0.0262	0.0236	0.0361	0.0260
i-Butane		0.0072	0.0065	0.0104	0.0078	0.0082	0.0078	0.0072	0.0065	0.0104	0.0078
n-Butane		0.0081	0.0084	0.0135	0.0103	0.0109	0.0105	0.0081	0.0084	0.0135	0.0103
i-Pentane		0.0038	0.0040	0.0062	0.0050	0.0053	0.0051	0.0038	0.0040	0.0062	0.0050
n-Pentane		0.0025	0.0034	0.0050	0.0042	0.0044	0.0043	0.0025	0.0034	0.0050	0.0042
Mcyclopentan		0.0007	0.0012	0.0015	0.0014	0.0014	0.0014	0.0007	0.0012	0.0015	0.0014
Benzene		0.0000	0.0003	0.0004	0.0004	0.0004	0.0004	0.0000	0.0003	0.0004	0.0004
Cyclohexane		0.0004	0.0012	0.0014	0.0014	0.0014	0.0014	0.0004	0.0012	0.0014	0.0014
Mcyclohexane		0.0006	0.0021	0.0023	0.0024	0.0024	0.0024	0.0000	0.0021	0.0023	0.0024
Toluene		0.0000	0.0006	0.0006	0.0006	0.0006	0.0006	0.0000	0.0005	0.0006	0.0006
E-Benzene		0.0000	0.0003	0.0002	0.0003	0.0003	0.0003	0.0000	0.0003	0.0002	0.0003
p-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
m-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
o-Xylene		0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002	0.0002
n-Pbenzene		0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0003	0.0003
124-MBenzene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
C6*		0.0024	0.0045	0.0056	0.0053	0.0055	0.0054	0.0024	0.0045	0.0056	0.0053
C7*		0.0000	0.0035	0.0038	0.0039	0.0040	0.0040	0.0000	0.0035	0.0038	0.0039
C8*		0.0000	0.0036	0.0035	0.0039	0.0039	0.0040	0.0000	0.0036	0.0035	0.0039
C9*		0.0000	0.0026	0.0020	0.0031	0.0030	0.0031	0.0000	0.0026	0.0026	0.0031
C10-C15*		0.0000	0.0154	0.0134	0.0164	0.0160	0.0163	0.0000	0.0154	0.0134	0.0164
C16-C19*		0.0000	0.0057	0.0056	0.0071	0.0070	0.0071	0.0000	0.0057	0.0056	0.0071
C20-C27*		0.0000	0.0073	0.0063	0.0078	0.0076	0.0077	0.0000	0.0073	0.0063	0.0078
C28-C37*		0.0000	0.0043	0.0037	0.0045	0.0044	0.0045	0.0000	0.0043	0.0037	0.0045
C38-C80*		0.0000	0.0031	0.0027	0.0033	0.0032	0.0033	0.0000	0.0031	0.0027	0.0033
H2O		0.0115	0.6328	0.5354	0.6479	0.6343	0.6456	0.0115	0.6328	0.5354	0.6479
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Stream Name	2D	2E	3	4	4A	5	6	7	8	9	10
Description	Wellhead Flowline (BT2_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_E_P) D/S of choke - Long String	Inlet to Production Separator	Production Separator Gas Outlet	Gas Pipeline to FPSO	Liquid Pipeline to FPSO	Export Gas from FPSO to WHP (Note 7)	Export Gas from WHP to ORF (Note 6)	Gas Lift	Gas Inlet to FPSO (Note 6)	Liquid Inlet to FPSO (Note 6)
MIXTURE											
Vapour Fraction	0.3115	0.2976	0.4147	1.0000	1.0000	0.0002	1.0000	1.0000	1.0000	0.0841	0.0019
Temperature	74.3	73.4	70.3	70.5	70.2	70.5	65.8	22.9	85.8	32.1	69.7
Pressure	930	930	930	930	880	880	9101	7120	9101	755	522
Pressure	9.3	9.3	9.3	9.3	8.8	8.8	91.0	71.2	91.0	7.6	5.2
Mass Flow	82356.85	29194.58	289534.68	92836.71	92836.71	196698.17	80517.40	72509.32	7845.62	92836.71	196698.17
Molar Flow	2545.47	899.18	9400.90	3899.75	3899.75	5501.15	3833.67	3452.38	373.55	3899.75	5501.15
Molecular Weight	32.4	32.5	30.8	23.8	23.8	35.8	21.0	21.0	21.0	23.8	35.8
Heat Flow	-163516	-58456	-547951	-96398	-96338	-451503	-86559	-78265	-8434	-98081	-451835
Mass Heat Capacity	2.90	2.91	2.81	2.14	2.14	3.13	2.72	2.61	2.72	2.11	3.13
Mass Density	37.14	39.04	27.10	8.87	8.43	870.51	75.42	61.13	75.42	7.80	731.73
GAS PHASE											
Std Gas Flow	17.74	5.99	87.21	87.24	87.24	0.01	85.76	77.23	8.36	85.80	0.23
Std Gas Flow	15.89	5.36	78.12	78.15	78.15	0.02	76.83	69.19	7.49	76.91	0.21
Molar Flow	792.94	267.56	3898.54	3899.75	3899.75	1.13	3833.67	3452.38	373.55	3837.74	10.47
Actual Gas Flow	2148.41	722.19	10461.79	10470.75	11011.23	3.10	1067.56	1186.11	104.02	11747.65	46.67
Mass Flow	20061.87	6749.84	92780.89	92836.71	92836.71	27.22	80517.40	72509.32	7845.62	91452.63	286.14
Molecular Weight	25.3	25.2	23.8	23.8	23.8	24.1	21.0	21.0	21.0	23.8	27.3
Mass Heat Capacity	2.13	2.12	2.14	2.14	2.14	2.14	2.72	2.61	2.72	2.06	2.06
Z Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.86	0.86	0.86	0.97	0.97
Thermal Conductivity	0.034	0.034	0.035	0.035	0.035	0.035	0.047	0.043	0.047	0.033	0.037
Viscosity	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Mass Density	9.35	9.35	8.87	8.87	8.43	8.54	75.42	61.13	75.42	7.80	6.13
Cp/Cv (Gamma)	1.22	1.22	1.23	1.23	1.23	1.23	1.46	1.44	1.46	1.24	1.20
OIL PHASE											
Mass Flow	33751.47	12159.37	107020.65	0.00	—	106954.00	—	—	—	80.05	106703.77
Liquid Vol Flow @Std Cond	39.46	14.22	124.70	0.00	—	124.69	—	—	—	0.10	124.26
Liquid Vol Flow @Std Cond	5957	2147	18838	0	—	18823	—	—	—	16	18758
Actual Volume Flow	41.47	14.93	130.61	0.00	—	130.51	—	—	—	0.11	129.94
Molecular Weight	200.7	200.3	205.1	205.3	—	205.6	—	—	—	110.1	206.7
Mass Heat Capacity	2.14	2.13	2.12	2.12	—	2.12	—	—	—	2.09	2.11
Thermal Conductivity	0.110	0.110	0.111	0.111	—	0.111	—	—	—	0.107	0.112
Viscosity	1.55	1.56	1.72	1.72	—	1.72	—	—	—	0.49	1.79
Mass Density	813.88	814.31	819.41	819.38	—	819.51	—	—	—	733.22	821.21
Surface Tension	14.75	14.78	15.11	15.10	—	15.13	—	—	—	16.73	15.41
AQUEOUS PHASE											
Mass Flow	28543.51	10285.38	89733.93	0.00	—	89710.95	—	—	—	1101.03	89708.25
Liquid Vol Flow @Std Cond	28.13	10.14	88.42	0.00	—	88.41	—	—	—	1.09	88.40
Liquid Vol Flow @Std Cond	4246	1530	13348	0	—	13345	—	—	—	164	13344
Actual Volume Flow	29.45	10.60	92.26	0.00	—	92.26	—	—	—	1.12	92.20
Molecular Weight	18.0	18.0	18.0	18.0	—	18.0	—	—	—	18.0	18.0
Mass Heat Capacity	4.35	4.34	4.34	4.34	—	4.34	—	—	—	4.32	4.34
Thermal Conductivity	0.666	0.665	0.663	0.663	—	0.663	—	—	—	0.646	0.662
Viscosity	0.38	0.38	0.40	0.40	—	0.40	—	—	—	0.53	0.40
Mass Density	969.38	970.15	972.59	972.46	—	972.44	—	—	—	966.88	972.93
MIXTURE COMPOSITION (Mole Fraction)											
H2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0022	0.0021	0.0026	0.0068	0.0068	0.0000	0.0089	0.0089	0.0089	0.0068	0.0000
CO2	0.0040	0.0039	0.0044	0.0105	0.0105	0.0001	0.0093	0.0093	0.0093	0.0105	0.0001
Methane	0.2112	0.2026	0.3011	0.7225	0.7225	0.0023	0.8082	0.8082	0.8082	0.7225	0.0023
Ethane	0.0290	0.0278	0.0337	0.0799	0.0799	0.0010	0.0735	0.0735	0.0735	0.0799	0.0010
Propane	0.0274	0.0263	0.0297	0.0684	0.0684	0.0022	0.0574	0.0574	0.0574	0.0684	0.0022
i-Butane	0.0082	0.0079	0.0087	0.0190	0.0190	0.0013	0.0151	0.0151	0.0151	0.0190	0.0013
n-Butane	0.0109	0.0105	0.0112	0.0240	0.0240	0.0021	0.0178	0.0178	0.0178	0.0240	0.0021
i-Pentane	0.0053	0.0051	0.0053	0.0101	0.0101	0.0019	0.0051	0.0051	0.0051	0.0101	0.0019
n-Pentane	0.0044	0.0043	0.0043	0.0078	0.0078	0.0016	0.0032	0.0032	0.0032	0.0078	0.0016
Mcyclopentan	0.0014	0.0014	0.0014	0.0017	0.0017	0.0011	0.0007	0.0007	0.0007	0.0017	0.0011
Benzene	0.0004	0.0004	0.0003	0.0004	0.0004	0.0003	0.0000	0.0000	0.0000	0.0004	0.0003
Cyclohexane	0.0014	0.0014	0.0013	0.0015	0.0015	0.0012	0.0001	0.0001	0.0001	0.0015	0.0012
Mcyclohexane	0.0024	0.0024	0.0022	0.0017	0.0017	0.0025	0.0000	0.0000	0.0000	0.0017	0.0025
Toluene	0.0006	0.0006	0.0000	0.0004	0.0004	0.0007	0.0000	0.0000	0.0000	0.0004	0.0007
E-Benzene	0.0003	0.0003	0.0002	0.0001	0.0001	0.0004	0.0000	0.0000	0.0000	0.0001	0.0004
p-Xylene	0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
m-Xylene	0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
o-Xylene	0.0002	0.0002	0.0002	0.0001	0.0001	0.0003	0.0000	0.0000	0.0000	0.0001	0.0003
n-Pbenzene	0.0003	0.0003	0.0003	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0005
124-MBenzene	0.0004	0.0004	0.0004	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0006
C6*	0.0055	0.0054	0.0051	0.0007	0.0007	0.0040	0.0008	0.0008	0.0008	0.0007	0.0040
C7*	0.0040	0.0040	0.0035	0.0034	0.0034	0.0037	0.0002	0.0002	0.0002	0.0034	0.0037
C8*	0.0039	0.0040	0.0034	0.0018	0.0018	0.0046	0.0000	0.0000	0.0000	0.0018	0.0046
C9*	0.0030	0.0031	0.0027	0.0008	0.0008	0.0040	0.0000	0.0000	0.0000	0.0008	0.0040
C10-C15*	0.0160	0.0163	0.0140	0.0001	0.0001	0.0238	0.0000	0.0000	0.0000	0.0001	0.0238
C16-C19*	0.0070	0.0071	0.0061	0.0000	0.0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0104
C20-C27*	0.0076	0.0077	0.0066	0.0000	0.0000	0.0113	0.0000	0.0000	0.0000	0.0000	0.0113
C28-C37*	0.0044	0.0045	0.0039	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0066
C38-C80*	0.0032	0.0033	0.0028	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0048
H2O	0.6343	0.6456	0.5431	0.0318	0.0318	0.9055	0.0000	0.0000	0.0000	0.0318	0.9055
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

PSEUDO COMPONENT	LIQUID DENSITY (g/cm3)	Tc (°C)	Pc (bara)	ACENTRIC FACTOR	NBP (°C)	MOLECULAR WEIGHT (g/mol)	Vc (cm³/mol)
C6*	0.66	234.2	29.7	0.3	68.7	86.2	370.0
C7*	0.74	241.4	24.5	0.4	103.1	96.0	524.1
C8*	0.77	268.2	21.7	0.4	126.8	107.0	527.9
C9*	0.78	298.1	20.0	0.4	143.6	121.0	527.8
C10-C15*	0.82	419.6	18.1	0.6	220.7	171.6	716.7
C16-C19*	0.85	539.9	14.1	0.8	304.8	242.0	1019.3
C20-C27*	0.88	658.6	12.3	0.9	376.9	318.6	1381.5
C28-C37*	0.90	831.8	10.8	1.1	462.2	441.2	1979.7
C38-C80*	0.94	1084.1	0.7	1.0	579.2	669.1	3271.8

Approved For Construction

MASTER

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.1:
PROBABILITY OF FAILURE TO OPEN CALCULATION

PSV-1311

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.1 = Probabilty Of Failure To Open

PART 1 : CALCULATION OF PROBABILITY OF FAILURE TO OPEN

The fundamental calculation applied to PRDs for the fail to open case is the product of an estimated overpressure demand case frequency (or demand rate), the probability of the PRD failing to open on demand, and the probability that the protected equipment at higher overpressures will lose containment.

$$P_{f,j}^{prd} = P_{fod,j} \cdot DR_j . P_{f,j}$$ equation (1)

Dimana :

$P_{f,j}^{prd}$ = POF of a PRD overpressure demand case, (failures/year)

$P_{fod,j}$ = POFOD of a PRD (failures/demand)

DR_j = demand rate (demands/year)

$P_{f,j}$ = POF (loss of containment) (failures/year)

The subscript j in the above equation indicates that the POF for the PRD,P prd f , j. needs to be calculated for each of the applicable overpressure demand cases associated with the PRD

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 tahun see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service	:	Methane	
Typical Temperature	:	990 ^{o}F	
Fluid Severity	:	Mild	See Table 7.4
Design Type PRD	:	Conventional	
Discharge Location	:	discharge to flare with flare recovery system	

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fc,for conventional valves discharging to closed system or to flare

F_C = 0.75 for conventional valves discharging to closed system or flare

F_C = 1.00 for all other cases

STEP 4 Determine the environment adjustment factor, Fenv using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 1.0 (see data process condition)

STEP 5 The result of the procedure outlined above will be a modified characteristic life, ηmod, as defined in equation (2)

F_C = 0.75 see step 3

F_C = 1.00 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_C x F_{env} x η_{def} equation (2)

= 0.75 x 1.00 x 37.88

= 28.41

STEP 6 Assemble the PRD's inspection history, Grade each record using the inspection effectiveness table, part 2, Annex 2.c, Table 2.C.3.1. Record the result of each inspection record; PASS/FAIL and NO LEAK/LEAK and determine the confidence factors, Cfi, as applicable, for each inspection history based on the results of the test Determine the time duration, tdur,i of each inspection cycle

STEP 6.1 Each inspection record must be graded using the PRD inspection effectifeness table, part 2, annex 2.C, table 2.C.3.1

- Inspection effectiveness : part 2, annex 2.C, Table 2.C.3.1

Tabel 2.C.3.1- Inspeksi dan pengujian keefektifan untuk PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

STEP 6.2 Record the PASS/FAIL and NO LEAK/LEAK in order to determine the confidence factors, Cfi , as applicable , for each inspection history where a test was conducted

- Inspection Record = No Leak / Leak

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i = 0.5 see table 7.8

STEP 6.3 Determine the time duration , tdur,I ,between each inspection cycle

a. RBI Date $t_{dur,}i$ = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date $t_{dur,}i$ = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 6.4 Determine if the PRD was overhauled

- refer to section 7.7.2 and 7.7.3 ,as well as figure 7.7, for more information

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{162.4}{1450}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.1)}{0.90}\right)$$

= 0.2111

P_S = 162.4

P_{Set} = 1450

$\frac{P_s}{P_{set}}$ = 0.112

STEP 7 Starting at the earliest inspection record, update the modifierd characteristic life ηmod ,determine in step 5 as follows

STEP 7.1 Calculate the prior POF using equation (3) . The time prior for use in equation (3) . Is the time duration of the inspection cycle , tdur,I as determine in step 6 . Note that for the first inspection record ,the modified characteristic life, ηmod, is used . sub sequent inspection record will use the update ed characteristic life ,ηupd,from step 7.5

$$P_{f,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.09714

STEP 7.2 Calculate the prior probability of passing using Equation (4)

$$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$$ equation (4)

a. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0289

= 0.97108

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0971

= 0.90286

STEP 7.3 Determine the condition POF and the conditional probability of pass using Equations (5)

$$P_{f,cond}^{prd} = (1\text{-}CF_{pass}).P_{p,prior}^{prd}$$ equation (5)

CF_{pass} = 0.5 step 6.2

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (BRI Plan Date) step 7.2

a. RBI Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48554

B. RBI Plan Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45143

step 7.4 Calculatethe weighted POF, $P_{f,wgt}^{prd}$ using the appropriate equation from table 7.9

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{f,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

a. RBI Date

$P_{f,wgt}^{prd}$ = 0.4855

B. RBI Plan Date

$P_{f,wgt}^{prd}$ = 0.4514

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (6) and the weighted POF

$$\eta_{upd} = \frac{t}{\left(-ln\left[1 - P_{f,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}}$$ equation (6)

η_{upd} = 10.62

STEP 7.6 Repeat step 7 for each of the inspection record available for the PRD until a final updated value for the characteristic life, η_{upd}, is determined.

$$P_{f,Prior}^{prd} = 1 - \exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
ηupd	=	28.406	$= \eta_{mod}$	see step 5
ηupd	=	10.621		see step 7.5
β	=	1.80		see step 2

a. RBI Date

$P_{f,Prior}^{prd}$ = 0.15838

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.45143

STEP 8 The POFOD should be adjusted based on the overpressure scenario, The overpressure factor Fop,j, is an adjustment for overpressure scenarios higher than 1.3 times the set pressure

$F_{op,j}$ = 1.0 for $\frac{F_{op,j}}{P_{set}} < 1.3$

$F_{op,j}$ = 0.2 for $\frac{F_{op,j}}{P_{set}} > 4$

$F_{op,j}$ = $1 - \frac{1}{3.375} \cdot \left(\frac{F_{op,j}}{P_{set}} - 1.3 \right)$ for all other cases

$F_{op,j}$: overpressure likelyto accur as a result of a PRD failling to open upon demand ,associated with the J overprssure demand case,kPa(psig) = 196.5 psig (see data process condition)

P_{set} : The set pressure of the PRD,kPa (psig) = 1450 psig (see data process condition)

$\frac{F_{op,j}}{P_{set}}$: $\frac{196.5}{1450}$: 0.1355

$F_{op,j}$: 0.2

$P_{fod,j} = P_{fod} \cdot F_{op,j}$ equation (7)

P_{fod} = 0.158 (RBI Date) see step 7.1

P_{fod} = 0.451 (RBI Plan Date) see step 7.1

$F_{op,j}$ = 0.2 see step 7

a. RBI Date

$P_{fod,j}$ = 0.15838 x 0.2

= 0.03168

B. RBI Plan Date

$P_{fod,j}$ = 0.45143 x 0.2

= 0.09029

STEP 9 Estimates for the PRD initiating event frequencies, Efj, based on the various relief overpressure demand cases that the device is providing protection Examples of the initiating event frequencies are provided in Table 7.2 Additional background on the default initiating event frequencies is provided in Table 7. 3

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	EF_j (event/year)
Fire	1 per 250 years	0.004
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 10 Determine Credit for Other Layers of Protection. The concept of a demand rate reduction factor, DRRFj , is introduced here to account for the difference in the overpressure demand case event frequency and the demand rate on the PRD. demand rate reduction factor are provide in Table 7.2

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	$DRRF_f$
Fire	1 per 250 years	0.10
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 11 for each overpressure demand case, determine the demand rate placed on the PRD,DRj.The demand rate (DR) on the PRD is calculated as the product of the initiating event frequency and the DRRFj in accordance with Equation (1.12)

$$DR_j = EF_{j.} \; . DRRF_j$$ Equation (8)

EF (fire) = initiating fire frequencies = 0.004

DRRF (fire) = demand rate reduction factor = 0.10

DR (fire) = EF (fire) x DRRF (fire)

= 0.004 x 0.10

= 0.0004

EF (overfill) = initiating overfill frequencies = 0.10

DRRF (overfill) = demand rate reduction factor = 0.10

DR (overfill) = EF (overfill) x DRRF (overfill)

= 0.10 x 0.10

= 0.01

step 12 Determine the MAWP of the protected equipment

set pressure	=	1450 psig	see data
% Allowable Overpressure	=	21%	process
MAWP	=	1755 psig	

STEP 13 If an RBI Study has been completed for protected equipment, calculate its damage adjustment POF, Pf, using equation (1.1) since the DF for the protected equipment is a function of time ,the DF must be determined at the PRD inspection interval, t insp, specifide in step 1 . if a risk analysis for fix equipment has not been complated , a DF can be estimated using the values in table 7.10

Table 7. 10 – DF Classes for Protected Equipment

DF Class	DF	Description
None	1	New vessel or inspection shows little if any damage
Minimal	20	equipment has been in service for a reasonable amount of time and inspection shows evidence of minor damage . Damage mechanism have been identified and inspecton data is available.
Minor	200	One or more damage mechanisms have been identified, limited inspection data available and fairly moderate evidence of damage. Single damage mechanism identified, recent inspection indicates moderate evidence of damage.
Moderate	750	Moderate damage found during recent inspection. Low susceptible to one or more damage mechanisms, and limited inspection exists.
Severe	2000	One or more active damage mechanisms present without any recent inspection history. Limited inspection indicating high damage susceptibility

D_f = 20.0

STEP 14 Calculate the POF of the protected equipment at the elevated overpressure,Pf,j using equation (9).

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{(3.464837.\frac{Po,j}{MAWP})}$$ equation (9)

gff_{total}	=	0.0000306	see part 2 table 3.1
D_f	=	20.0	see step 13
F_{MS}	=	0.5	see part 2 section 3.5.4
$P_{o,j}$	=	162.4	data process condition
MAWP	=	1754.5	see step 12

$$Pf,j = (0.0312881x0.0000306x20x0.5)e^{3.464837.\frac{162.4}{1754.5}}$$

Pf,j = 0.0000131942

STEP 15 Calculate the POF, ,using Equation (1.11)

A. RBI Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.0316766 x 0.0004 x 1.32E-05

$P_{f,j}^{prd}$ = 1.67E-10

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.0316766 x 0.01 x 1.32E-05

$P_{f,j}^{prd}$ = 4.18E-09

A. RBI Plan Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.09029 x 0.0004 x 1.32E-05

$P_{f,j}^{prd}$ = 4.76E-10

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.01 x 1.32E-05

$P_{f,j}^{prd}$ = 5.96E-08

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.2:
PROBABILITY OF FAILURE TO LEAKAGE CALCULATION

PSV-1311

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

PART 2 : Calculation Procedure - POL at Specified Inspection Interval

The leakage case is different than the fail to open case since the POF is not a function of demand rate but rather is based on failure during continuous operation. The industry data associated with the probability of leakage,Pl , data is in per year units (failure/year). no multiplication by any demand rate is necessary

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 years see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service : Methane

Typical Temperature : 990 °F

Fluid Severity : Mild See Table 7.4

Design Type PRD : Conventional

Discharge Location : discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fs using section 7.3.2.g).

F_s = 1.25 for soft seated design see data material

F_s = 1.00 for all other cases

STEP 4 Determine the environmenta adjustment factor, Fenv.using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 0.6 (see data process condition)

STEP 5 calculate the modified characteristic life, ηmod, using equation (11) and the factors obtain in step 3 and 4.

F_s = 1.25 see step 3

F_{env} = 0.60 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_s x F_{env} x η_{def} equation (11)

= 1.25 x 0.60 x 37.88

= 28.41

STEP 6 Assemble the the PRDs inspection history, grade each record using the inspection effectiveness table, part 2,annex 2.C, Table 2.C.3.1. Record the result of each inspection record.; NO LEAK/LEAK and determine the confidance factors, Cfi, as applicable, for each inspection history based on the result of the test . Determine the time duration, tdur.i. of each inspection cycle.

- Inspection effectiveness : part 2,annex 2.C, Table 2.C.3.1

Table 2.C.3.1- Inspection and testing efectiveness for PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

- Inspection Record : No LEAK/ LEAK

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i : 0.5

- Determine the time duration, tdur,j. of each inspection cycle

A. RBI Date

t_{dur},i = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date

t_{dur},i = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 7 Starting at the earliest inspection record , update the modified characteristic life, ηmod, determine in step 5 as follows

STEP 7.1 Calculate the prior probability of leakage using equation (12). Note that for the first inspection record , the modified characteristic life,ηmod,is used subsequent inspection record will use the updated characteristic from STEP 7.5 below.

$$P_{l,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (12)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{l,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{l,Prior}^{prd}$ = 0.09714

STEP 7.2 Calculate the prior probability of passing using equation (13)

$$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$$ equation (13)

A. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd} = 1 - 0.0289$

$P_{p,Prior}^{prd} = 0.97108$

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd} = 1 - 0.0971$

$P_{p,Prior}^{prd} = 0.90286$

STEP 7.3 Determine the conditional probability of leakage and conditional probability of pass using equation (14)

$$P_{l,cond}^{prd} = (1\text{-}CF_{pass}).P_{p,prior}^{prd}$$ equation (14)

CF_{pass} : 0.5 step 6

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (RBI Plan Date) step 7.2

A. RBI Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48554

B. RBI Plan Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45143

STEP 7.4 calculate the weighted probability of leakage, $P_{l,wgt}^{prd}$, using the appropriate equation from table 7.9.

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.P_{f,prior}^{prd} + 0.5.P_{f,cond}^{prd}$

$P_{l,wgt}^{prd} = P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{l,wgt}^{prd}$ = 0.48554

B. RBI Plan Date

$P_{l,wgt}^{prd}$ = 0.45143

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (15) and the weighted probability of leakage, $P_{l,wgt}^{prd}$ established in step 7.4

$$\eta upd = \frac{t}{(-\ln\left[1 - P_{f,wgt}^{prd}\right])^{\frac{1}{\beta}}}$$ equation (15)

η_{upd} = 10.62

STEP 8 Calculate the probability of leakage for the specific PRD in accordance with Equation (16)

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (16)

t = 4 year see step 6

t = 8 year see step 6

β = 1.80 see step 2

η_{upd} = 28.41 = η_{mod} see step 5

η_{upd} = 10.62 see step 7.5

a. RBI Date

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{4}{28.41}\right)^{1.80}\right]$$

P_l^{prd} = 0.02892

B. RBI Plan Date

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{8}{10.62}\right)^{1.80}\right]$$

P_l^{prd} = 0.45143

STEP 9

The Probability of leakage needs to be adjusted based on the closedness the system is operating near the set pressure with equation (17). The set pressure factor , F_{set} , is dependent on the PRD type.

$$P_{l,j}^{prd} = P_l^{prd} . F_{set}$$ equation (17)

PRD Type = Conventional see data general

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{162.4}{1450}\right)}{0.90}\right)$$

$P_S =$ 162.4 see data

$P_{Set} =$ 1450 process

$= 1 - \left(\frac{0.90 - \min(0.1)}{0.90}\right)$

$= 0.2111$

A. RBI Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

$P_l^{prd} =$ 0.0289 step 8

$F_{set} =$ 0.2111 Table 7.7

$P_{l,j}^{prd} =$ 0.0289 x 0.2111

$=$ 0.0061

B. RBI Plan Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

$P_l^{prd} =$ 0.45143 step 8

$F_{set} =$ 0.2111 Table 7.7

$P_{l,j}^{prd} =$ 0.4514 x 0.2111

$=$ 0.0953

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 3 :
CONSEQUENCE OF FAILURE CALCULATION

PSV-1311

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
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			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
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PART 3 CONSEQUENCE CALCULATION of FAILURE to OPEN

STEP 1 Determine the list of overpressure scenarios applicable to the piece of equipment being protected by the PRD under evaluation. Table 7.2 provides a list of overpressure demand cases specific covered.

Overpressure Demand Case for PSV-1311

1 Fire see table 7.3

2 Liquid Overfillling without administrative controls in place

step 2 For each overpressure demand case, estimate the amount of overpressure, $p_{o,j}$ likely to occur during the overpressure event if the PRD were to fail to open.

Table 7.3 - Overpressure Scenario Project

Initiating Event	Equipment Type	PRD Demand rate reduction factor	Qualifier	over pressure potential	Background and comment
1. Overpressure Scenario					
1 per 250 years	All Equipment Type	0.1 industry experience justifies this value	N/A	4.0 x MAWP (RUPTURE)	see table 7.3
2. Overpressure scenario - liquid Overfilling					
1 per 100 years (admin control)	All Equipment including process tower	1.00	downsteam of positif displacement type rotating equipment	4.0 x MAWP	see table 7.3

$P_{0,fire}$ = 4 x MAWP
= 4 x 1755
= 7020 psig

$P_{o,overfilling}$ = 4 x MAWP
= 4 x 1755
= 7020 psig

STEP 3 For instalations that have multiple PRDs, determine the total amount of installed PRD orifice area , A_{total}^{prd}, including the area of the PRD being evaluated. Calculate the overpressure adjustment factor, , in accordance with equation (1.37) F_a

$$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \qquad \text{equation (1.37)}$$

A^{prd} = is the orifice area of the PRD, mm2

A_{total}^{prd} = is the total installed orifice area of a multiple device installation,mm2

multiple PRD ? no

F_a = 1

STEP 4 Reduce the overpressures determined in step 3 by the overpressure adjustment factor accordance with equation (1.38)

$$P_{o,j} = F_a \,.\, P_{o,j} \qquad \text{equation (1.38)}$$

F_a = 1 see step 3

$P_{0,fire}$	=	7020.0		$P_{o,overfilling}$	=	7020.0	
$P_{0,fire}$	=	7020.0 x	1	$P_{o,overfilling}$	=	7020.0 x	1
	=	7020.0 psig			=	7020.0 psig	

STEP 5 for each overpressure demand case, calculate the financial consequence ,....., C_{rla}^{prd} of loss containment from protected equipment using procedures developed in part 3. use the overpressure for demand cases as determine in STEP 4 in lieu of the operating pressure, P_s

STEP 1 Determine the Representative Fluid and Associated Properties

Fluid Properties

Sifat-sifat fluida yang dibutuhkan yang diperkirakan untuk masing-masing fluida representatif disediakan dalam Tabel 4.2 API 581 Bagian 3 COF dan tergantung pada fase simpanan fluida di bawah ini:

A). Stored Liquid	
1. Normal Boiling Point	(NBP)
2. Density	(ρt)
3. Auto-iIgnition Temperature	(AIT)
B). Stored Vapor or Gas	
1. Normal Boiling Point	(NBP)
2. Morcular Weight	(MW)
3. Ideal Gas Specific Heat Capacity Ratio	(k)
4. Constant Pressure Specific Heat	(Cp)
5. Auto-iIgnition Temperature	(AIT)

STEP 1.1 Select Representative fluid group Table 4.1

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

Fluid Composition Table

Well	Composition	Symbol	Amount	Unit
	Nitrogen	N_2	0.68	% mole
	Carbon Dioxide	CO_2	1.05	% mole
	Methane	CH_4	72.25	% mole
	Ethane	C_2H_6	7.9	% mole
	Propane	C_3H_8	6.84	% mole
`	i-Butane	i-C_4H_{10}	1.9	% mole
	n-Butane	n-C_4H_{10}	2.4	% mole
	i-Pentane	i-C_5H_{12}	5.01	% mole
	n-Pentane	n-C_5H_{12}	0.47	% mole
	Hexane Plus	C_6^+	1.5	% mole
		TOTAL	100.000	% mole

Chosen Representative Fluid : C1-C2

STEP 1.2 Determine the store fluid phase, liquid or vapor, if two phase , a level 2 consequence analysis should be performed

Stored fluid phase : Gas

Step 1.3 Determine the stored fluid properties

For a stored liquid

MW – Molecular weight, kg/kg-mol (lb/lb-mol), can be estimated from Table 4.2

k – Ideal gas specific heat ratio, can be estimated using Equation (3.1) and the C P values as determined using Table 4.2

AIT – Auto-ignition temperature, K (°R), can be estimated from Table 4.2

Table 4.2 - Properties of the Representative Fluids Used in Level 1 Consequence Analysis

Fluid	MW	Liquid Density (lb/ft^3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	CP				Auto ignition Temperature (°F)
						Ideal Gas Constant A	Ideal Gas Constant B	Ideal Gas Constant C	Ideal Gas Constant D	
C1-C2	23	15.64	-193	Gas	Note 1	12.3	1.15E-01	-2.87E-03	-1.30E-09	1036
C2-C3	51	33.61	-6.3	Gas	Note 1	2.632	0.3188	-1.35E-04	1.47E-08	696
C25+	422	56.19	981	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	396

1). Molecular Weight (MW), kg/kg-mol (lb/lb-mol)

The stored vapor Molecular Weight (MW) can be estimated from Table 4.2

MW = 23.00 (kg/kg-mol)

2). Auto-Ignition Temperature, K (^oR)

The stored liquid Auto-Ignition Temperature (AIT) can be estimated from Table 4.2 of API 581 Part 3 of COF.

AIT = 1036 (^oF)

AIT = 830.927778 (K)

AIT = 446.222222 (^oR)

3). Ideal gas specific heat ratio, k

Cp_A = 12.3 J/kmol-K

Cp_B = 1.15E-01 J/kmol-K

Cp_C = -2.87E-03 J/kmol-K

Cp_D = -1.30E-09 J/kmol-K

T = 71 C
T = 159.8 F
T = 344.15 K
R = 8.314 J/kg-mol-K

$Cp = A + BT + CT^2 + DT^3$ ..... equation (19)

= 12.3 + (0.015 x 344.15) + (-0.0000287 x 344.15)^2 + (-1.3^{-9} x 344.15)^3

= 52.852822 J/kmol-K

$k = \frac{Cp}{Cp - R}$ ..... equation (20)

$= \frac{52.853}{52.853 - 8.314}$

= 1.18666861

STEP 1.4 Determine the steady state phase of the fluid after release to the atmosphere, using Table 4.3 and the phase of the fluid stored in the equipment as determine in STEP 1.2.

Table 4.3 - Level 1 Guidelines for Determining the phase of a fluid

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (After release) Condition	Determine of Final Phase for Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	model as gas usless the fluid boilling point at ambient condiitions is greater than 80 F , than model as liquid
Liquid	Liquid	Model as Liquid

The fluid is Gas in the vessel, its post release is Gas

STEP 2 Release Hole Size Selection

STEP 2.1 Based on component type and table 4.4, determine the release hole size diameters, d_n.

Table 4.4 - Release Hole Sizes and Areas Used in Level 1 and 2 Consequences Analysis

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	$d_1 = 0.25$
2	Medium	> 1/4 - 2	$d_2 = 1$
3	Large	> 2 - 6	$d_3 = 4$
4	Rupture	. 6	d_4 = min[D,16]

STEP 2.2 Determine the failure frequency, gff_n, for the nth release hole size from part 2, table 3.1, and the total generic failure frequency from this table or from equation (3.2)

$$gff_{total} = \sum_{n=1}^{4} gff_n \qquad (3.2)$$

Table 3.1 part 2, suggested component generic failure frequencies

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

Diameter = 100 mm = 3.94 inci

gff_{total} = 8.00E-06 failures/year

gff_{small} = 2.00E-05 failures/year

gff_{medium} = 0.00E+00 failures/year

gff_{large} = 2.60E-06 failures/year

$gff_{rupture}$ = 3.06E-05 failures/year

STEP 3 Release Rate Calculation

There are two regimes for flow gases through an orifice: aonic (choked) for higher internal pressure, and subssonic flow for lower pressure (nominally 15 psig (103.4 kPa) or less). The transition pressure at which the flow regime changes from sonic to subsonic is determined using below equation.

P_{atm} = 14.69 psi

k = 1.1867

$$P_{trans} = P_{atm}\left(\frac{k+1}{2}\right)^{\frac{k}{k-1}} \quad \text{..... equation (21)}$$

$$P_{trans} = 14.69\left(\frac{1.187+1}{2}\right)^{\frac{1.187}{0.187}}$$

= 18.0215241 psi

STEP 3.1 Select the appropriate release rate equation

$$W_n = \frac{Cd}{C2}\, x\, An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad \text{..... equation 22)}$$

Abbreviation list :

C_d	=	Discharge coefficient, for turbulent liquid flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$			
	=	0.9			
A_n	=	Release hole sized area			
P_s	=	Storage operating pressure	=	7020	psi
P_{atm}	=	Atmosphere pressure	=	14.69	psi
k	=	Ideal gas specific heat capacity ratio	=	1.1867	
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	71	C
			=	159.8	F
			=	344.15	K

STEP 3.2 For every release hole size, calculate the release hole size area based on d_n

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

The release hole size area can be determined by formulating below equation:

$$An = \frac{\pi dn^2}{4} \quad \text{.....} \quad \text{equation (22)}$$

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch
= 0.0064 m
π = 3.14

$$A1 = \frac{\pi d1^2}{4}$$

$$= \frac{3.14\ x\ (0.25)^2}{4}$$

= 0.0491 $inch^2$
= 3E-05 m^2

2). MEDIUM RELEASE HOLE SIZE AREA

d_1 = 1 inch
= 0.0254 m
π = 3.14

$$A2 = \frac{\pi d2^2}{4}$$

$$= \frac{3.14\ x\ (1)^2}{4}$$

= 0.785 $inch^2$
= 0.0005 m^2

3). LARGE RELEASE HOLE SIZE AREA

d_1 = 4 inch

= 0.1016 m

π = 3.14

$$A3 = \frac{\pi d3^2}{4}$$

= 12.56 $inch^2$

= 0.0081 m^2

4). RUPTURE RELEASE HOLE SIZE AREA

d_1 = 16 inch

= 0.4064 m

π = 3.14

$$A4 = \frac{\pi d4^2}{4}$$

$$= \frac{3.14\ x\ (16)^2}{4}$$

= 200.96 $inch^2$

= 0.1296 m^2

STEP 3.3 For liquid releases, for each release hole size, calculate the viscosity correction factor ($K_{v,n}$)

$$K_{v,n} = \left(0.9935 + \frac{2.878}{Ren^{0.5}} + \frac{342.75}{Ren^{1.5}}\right)^{-1} \quad \text{.....} \quad \text{equation (23)}$$

Because the store fluid phase determined in STEP 1.2 is gaseous or vapor phase, then, this step is no neeed to be considered.

STEP 3.4 For each hole size, calculate the release rate, W_n, for each release area A_n

$$W_n = \frac{Cd}{C2}\ x\ An\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Abbreviation List:

C_d = 0.9

k = 1.18666861

ρl = 250.51 kg/m^3

= 2.5051E-07 kg/mm^3

A_{n1} = 3.1645E-05 m^2

A_{n2} = 0.00050645 m^2

A_{n3} = 0.00810321 m^2

A_{n4}	=	0.1296192	m^2
gc	=	1	kgm/Ns^2
	=	32.2	$lb_m ft/lb_f S^2$
Ps	=	48402.90	Kpa
P_{atm}	=	101.288	KPa
C_2	=	1	
R	=	8.314	J/(kg-mol-K)
g_c	=	9.8	m/s^2
T_s	=	344.15	K
MW	=	23.00	(kg/kg-mol)

1). SMALL RELEASE HOLE SIZE AREA

$$W_1 = \frac{Cd}{C2}\ x\ A1\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_1 = \frac{0.9}{C2}\ x\ 0.000031645\ \text{x}\ 48402.9\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 0.24992317 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$W_2 = \frac{Cd}{C2}\ x\ A2\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_2 = \frac{0.9}{C2}\ x\ 0.000506451\ \text{x}\ 48402.9\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 3.99976263 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$W_3 = \frac{Cd}{C2}\ x\ A3\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_3 = \frac{0.9}{C2}\ x\ 0.00810321\ \text{x}\ 48402.9\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 20.4428369 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$W_4 = \frac{Cd}{C2}\ x\ A4\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_4 = \frac{0.9}{C2}\ x\ 0.1296192\ \text{x}\ 48402.9\sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 1023.6853 kg/s

STEP 4 Estimate the Fluid Inventory Available for Release

STEP 4.1 Group Component and equipment items into inventory groups (see annex 3.A)

only one component is given, and total inventory for the group

STEP 4.2 Calculate the fluid mass ,$mass_{comp}$, in the component being evaluated

ID	=	0.10	m
V_{tot}	=	0.785	m^3
	=	27.7220134	ft^3
ρ_{gas}	=	8.43	kg/m^3
	=	0.5262677	lb/ft^3
L	=	100	m
$Mass_{comp}$	=	6.61755	kg

STEP 4.3 Calculate the fluid mass in each of the other components that are included in the inventory group, $mass_{comp,i}$

There are no other component, only an inventory group mass

STEP 4.4 Calculate the fluid mass in the inventory group, $mass_{inv}$, using equation (3.9)

$$mass_{inv} = \sum_{i=1}^{n} mass_{comp,i}$$

Where

$Mass_{comp}$ = is the inventory fluid mass for the component or piece of equipment being evaluated, kgs [lbs]

$Mass_{inv}$ = is the inventory group fluid mass, kgs [lbs]

= 6.6176 kg

STEP 4.5

Calculate the flow rate from a 203mm (8 inch) diameter hole, W_{max8}, using equation (3.3),(3.6)or (3.7) , as aplicable ,with A_n ,A8=32450 mm2 (50.3 inch2). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Where

C_d	=	Discharge coefficient, for turbulent gas flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$	=	0.9	
A_n	=	Release hole sized area	=	5.1031	$inch^2$
			=	129619	mm^2
			=	0.1296	m^2
P_s	=	Storage operating pressure	=	7020	psi
			=	48403	Kpa
P_{atm}	=	Atmosphere pressure	=	14.69	psi
			=	101.29	Kpa
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	71	C
			=	159.8	F
			=	344.15	K
C_2	=	SI and US customary conversion factors	=	1	
k	=	Ideal gas specific heat ratio	=	1.1867	

So,

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_{max8} = \frac{0.9}{1}\ x\ 0.1296 \text{ x } 48402.9 \sqrt{\left(\frac{1.1867\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.1867+1}\right)^{\frac{1.1867+1}{1.1867-1}}}$$

= 1023.6853 kg/s

STEP 4.6 For each release hole size, calculate the added fluid mass, $mass_{add,n}$, resulting from 3 (three) minutes of flow from the inventory group using equation (3.10) where Wn is the leakage rate for the release hole size being evaluated and $W_{max8,}$ is from step 4.5

$$mass_{add,n} = 180.\min\left[W_n, W_{\max 8}\right] \quad (3.10)$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[\text{W}_1 \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[0.2499, 1023.69\,]$$

$$= \quad 44.986 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add n}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 2}} = 180 \,.\, min[3.9998, 46.1023.69\,]$$

$$= \quad 719.96 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min\,[20.4428, 1023.69\,]$$

$$= \quad 3679.7 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[1023.69, 1023.69\,]$$

$$= \quad 184263 \text{ kgs}$$

STEP 4.7 For each release hole size, calculate the available mass for release using equation (3.11)

$$mass_{avail,n} = \min\left[\{mass_{comp} + \ mass_{add,n}\}, mass_{inv}\right]$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 1} = min\,.\,[\{6.6176 + 44.99\}, 6.6176\,]$$

$$= \quad 6.62 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 2} = min\,.\,[\{6.6176 + 720\}, 6.6176\,]$$

$$= \quad 6.62 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 3} = min.[\{6.6176 + 3680\}, 6.6176]$$

= 6.62 kgs

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 4} = min.[\{6.6176 + 2E{+}05\}, 6.6176]$$

= 6.62 kgs

STEP 5 Determine the release type (continues or instantaneous)

STEP 5.1 For each release hole size, calculate the time required to release 4536kgs (10000 lbs) of fluid

$$t_n = \frac{C3}{W_n} \quad \text{.....} \quad \text{equation (24)}$$

Where

t_n = time required to release 4536 kgs (10000 lbs) of fluid

C_3 = SI and US customary conversion factors

= 4536 kgs

= 10000 lbs

W_n = Theoretical release rate associated with the nth release hole size, kg/s [lb/s]

W_1 = 0.2499 kg/s

W_2 = 3.9998 kg/s

W_3 = 20.4428 kg/s

W_4 = 1023.685 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_1 = \frac{4536}{0.2499}$$

= 18149.5779 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_2 = \frac{4536}{3.9998}$$

= 1134.0673 s

3). LARGE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_3 = \frac{4536}{20.4428}$$

= 221.887012 s

4). RUPTURE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_4 = \frac{4536}{1023.685}$$

= 4.43104928 s

STEP 5.2 Determine the release type for each release hole size

For each release hole size, determine the release type either instataneous or continous using this following criteria:

a. If the release hole size is 6.35 mm(0.25 inch) or less, then the release type is continous

b. If t_n<180 sec and the releaase mass is gretaer than 4536 kgs (100000 lbs), then the release is instataneous: otherwise the release is continous

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 18150 s (Continous)

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1134.1 s (Continous)

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 221.89 s (Continous)

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.431 s (Instataneous)

STEP6 Estimate The Impact of Detection and Isolation Systems on Release Magnitude

STEP 6.1 Determine the detection and isolation systems presents in the unit

STEP 6.2 Using table 4.5, select the appropriate classification (A,B,C) for the detection system.

Table 4.5 - Detection and Isolation system rating Guide

Type of Detection System	Detection Clssification
Instrumentation designed specifically to detect material losses by changes In operating conditions (i.e., loss of pressure or flow) in the system.	A
Suitable located detectors to determine when the material is present outside the pressure-containing envelope	B
Visual detection, cameras, or detectors with marginal coverage	C
Type of Isolation Sytem	**Isolation Classification**
Isolation or shutdown system activated directly process instrumentation or detection, with no operator intervention	A
Isolation or shutdown system activated by operators in the control room or other suitable locations remote from the leak	B
isolation dependent on manually-operated valves	C

Detection Is A

STEP 6.3 Using table 4.5, select the appropriate classification (a,b,c) for the isolation system

Isolation Is A

STEP 6.4 Determine the release reduction factor factdi using Table 4.6

Table 4.6 - Adjustment to Release Based on Detection and Isolation Systems

System Classification		Release Magnitude Adjustment	duction Factor, *fac*
Detection	**Isolation**		
A	A	Reduce release rate or mass by 25%	0.25
A	B	Reduce release rate or mass by 20%	0.20
A or B	C	Reduce release rate or mass by 10%	0.10
B	B	Reduce release rate or mass by 15%	0.15
C	C	No adjustment to release rate or mass	0.00

Release Magnitude Adjustment = Reduce release rate or mass by 25%

Reduction Factor, $fact_{di}$ = **0.25**

STEP 6.5 Determine the total leak durations for each release hole sizes using Table 4.7

Table 4.7 - Leak Durations Based on detection and Isolation Systems

Detection System Rating	Isolation System Rating	Maximum Leak Duration, ld_{max}
A	A	20 minutes for 1/4 inch leaks
		10 minutes for 1 inch leaks
		5 minutes for 4 inch leaks
A	B	30 minutes for 1/4 inch leaks
		20 minutes for 1 inch leaks
		10 minutes for 4 inch leaks
A	C	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	A or B	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	C	1 hour for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
C	A, B, or C	1 hour for 1/4 inch leaks
		40 minutes for 1 inch leaks
		20 minutes for 4 inch leaks

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 18150 s (Continous)

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1134.1 s (Continous)

$ld_{max,2}$ = 10 minutes for 1 inch leaks

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 221.89 s (Continous)

$ld_{max,3}$ = 5 minutes for 4 inch leaks

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.431 s (Instataneous)

$ld_{max,4}$ = 5 minutes for 4 inch leaks

STEP7 Determine The Release Rate And Mass For Consequence of Failure

STEP 7.1 Calculate the adjusted release rate, raten for each release hole size

Reduction Factor, $fact_{di}$ = 0.25

W_1 = 0.2499 kg/s

W_2 = 3.9998 kg/s

W_3 = 20.4428 kg/s

W_4 = 1023.685 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$Rate_1 = W_n\,(1 - fact_{di})$$

$$Rate_1 = 0.2499\,(1 - 0.25)$$

= 0.1874 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$Rate_2 = W_n\,(1 - fact_{di})$$

$$Rate_2 = 3.9998\,(1 - 0.25)$$

= 2.9998 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$Rate_3 = W_n\,(1 - fact_{di})$$

$$Rate_3 = 20.4428\,(1 - 0.25)$$

= 15.332 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$Rate_4 = W_n\,(1 - fact_{di})$$

$$Rate_4 = 1023.685\,(1 - 0.25)$$

= 767.76 kg/s

STEP7.2 Calculate the leak duration, ldn, for each release hole size

$$ld_n = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\,.\,ld_{max,n}\}] \quad \text{.....} \quad \text{equation (25)}$$

$ld_{max,1}$	=	20 minutes for 1/4 inch leaks	20	$Mass_{avail,1}$	=	6.62	kgs
$ld_{max,2}$	=	10 minutes for 1 inch leaks	10	$Mass_{avail,2}$	=	6.62	kgs
$ld_{max,3}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,3}$	=	6.62	kgs
$ld_{max,4}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,4}$	=	6.62	kgs

1). SMALL RELEASE HOLE SIZE AREA

$$ld_1 = min\,.\,[\{\frac{Mass_{avail,1}}{Rate_1}\},\{60\,.\,ld_{max,1}\}]$$

$$ld_1 = min\,.\,[\{\frac{6.62}{0.187}\},\{60\,.\,20\}]$$

= 35.304 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2 = min\,.\,[\{\frac{Mass_{avail,2}}{Rate_2}\},\{60\,.\,ld_{max,2}\}]$$

$$ld_2 = min\,.\,[\{\frac{6.62}{3}\},\{60\,.\,10\}]$$

= 2.206 s

3). LARGE RELEASE HOLE SIZE AREA

$$ld_3 = min\ .\ [\{\frac{Mass_{avail,3}}{Rate_3}\},\{60\ .\ ld_{max,3}\}]$$

$$ld_3 = min\ .\ [\{\frac{6.62}{15.33}\},\{60\ .\ 5\}]$$

$$= \quad 0.4316\ s$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$ld_4 = min\ .\ [\{\frac{Mass_{avail,4}}{Rate_4}\},\{60\ .\ ld_{max,4}\}]$$

$$ld_4 = min\ .\ [\{\frac{6.62}{767.8}\},\{60\ .\ 5\}]$$

$$= \quad 0.0086\ s$$

STEP 7.3 Calculate the release mass, $mass_n$, for each release hole size

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_1 = min\ .\ [\{Rate_1\ .\ ld_1\},Mass_{avail,n}]$$

$$Mass_1 = min\ .\ [\{0.187\ .\ 35.3\},6.62]$$

$$= \quad 6.61755\ kgs$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$Mass_2 = min\ .\ [\{Rate_2\ .\ ld_2\},Mass_{avail,n}]$$

$$Mass_2 = min\ .\ [\{3\ .\ 2.206\},6.62]$$

$$= \quad 6.61755\ kgs$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_3 = min\ .\ [\{Rate_3\ .\ ld_3\},Mass_{avail,n}]$$

$$Mass_3 = min\ .\ [\{15.33\ .\ 0.432\},6.62]$$

$$= \quad 6.61755\ kgs$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_4 = min\ .\ [\{Rate_4\ .\ ld_4\},Mass_{avail,n}]$$

$$Mass_4 = min\ .\ [\{767.8\ .\ 0.009\},6.62]$$

$$= \quad 6.61755\ kgs$$

PART 8 : DETERMINE FLAMMABLE AND EXPLOSIVE CONSEQUENCE

8.1 CONSEQUENCE AREA EQUATIONS

1). CONTINOUS RELEASE

$CA_n^{CONT} = \alpha(rate_n)^b$ ..... equation (26)

2). INSTATANEOUS RELEASE

$CA_n^{CONT} = \alpha(mass_n)^b$ ..... equation (27)

STEP 8.1 Select the consequence area mitigation reduction factor, $fact_{mit}$, from Table 4.10

Mitigation System	Consequence Area Adjustemnet	Consequence Area Reduction Factor, factor mit
Inventory blowdown , couple with isolation system classification B or higher	Reduce consequence area by 25%	0.25
Fire water deluge system and monitors	Reduce consequence area by 20%	0.2
Fire water monitor only	Reduce consequence area by 5%	0.05
Foam spray system	Reduce consequence area by 15%	0.15

Mitigation system = Inventory blowdown , couple with isolation system classification B or higher *

Consequence Area = Reducer consequence area by 25 % *

$fact_{mit}$ = 0.25

STEP 8.2 Calculate the energy efficiency, $eneff_n$, for each hole size using equation mentioned below.

C_4 = 2205 1/kg

$eneff_n = 4.log_{10}[C_4 . mass_n] - 15$ ..... equation (28)

$Mass_1$ = 6.62 kgs

$Mass_2$ = 6.62 kgs

$Mass_3$ = 6.62 kgs

$Mass_4$ = 6.62 kgs

1. SMALL RELEASE HOLE SIZE AREA

$eneff_1 = 4 . log_{10} [C_{4A} . mass_1] - 15$

$eneff_1 = 4 . log_{10} [2205 . 6.62] - 15$

$eneff_1 = 1.656423$

2. MEDIUM RELEASE HOLE SIZE AREA

$$eneff_2 = 4 . log_{10} [C_{4A} . mass_2] - 15$$
$$eneff_2 = 4 . log_{10} [2205 . 6.62] - 15$$
$$eneff_2 = 1.656423$$

3. LARGE RELEASE HOLE SIZE AREA

$$eneff_3 = 4 . log_{10} [C_{4A} . mass_3] - 15$$
$$eneff_3 = 4 . log_{10} [2205 . 6.62] - 15$$
$$eneff_3 = 1.656423$$

4. RUPTURE RELEASE HOLE SIZE AREA

$$eneff_4 = 4 . log_{10} [C_{4A} . mass_4] - 15$$
$$eneff_4 = 4 . log_{10} [2205 . 6.62] - 15$$
$$eneff_4 = 1.65642$$

STEP 8.3 Determine the fluid type

Determine the fluid type, either TYPE 0 or TYPE 1 based on Table 4.1 of API RP 581 Part 3 of COF.

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

C_1-C_2	=	TYPE 0	AIT	=	446.222222 (^oR)
MW	=	23 (kg/kg-mol)	T	=	71 (^oC)
AIT	=	1036 (^oF)	T	=	159.8 (^oF)
AIT	=	830.927778 (K)	T	=	344.15 (K)

STEP 8.4 For each release hole size, calculate the component damage consequence areas for Auto-Ignition Not Likely, Continous Release (AINT-CONT), $CA^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

Table 4.8 - Component Damage Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	8.7	0.98			55	0.95			6.5	0.67			164	0.62		
C3-C4	10.1	1.0			64	1.0			4.7	0.7			80	0.63		

$\alpha = \alpha_{cmd,n}^{AINL-CONT} =$ 8.7 $\quad$ $b = b_{cmd}^{AINL-CONT} =$ 0.98

2). Calculate the consequence of area using equation below

$Rate_1 = 0.187$ kg/s

$Rate_2 = 3$ kg/s

$Rate_3 = 15.33$ kg/s

$Rate4 = 767.8$ kg/s

$$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit}) \quad \text{..... equation (29)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-CONT} = \alpha(rate_1)^b \cdot (1 - fact_{mit})$$

$= 1.2618$ m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$$

$= 19.15$ m^2

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$$

$= 94.713$ m^2

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$$

$= 4386.56$ m^2

STEP 8.5 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Continous Release (AIL-CONT), $CA^{AIL\text{-}CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-CONT} =$ 55.0 b $= b_{cmd}^{AIL-CONT} =$ 0.95

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$ ..... equation (30)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 8.3883\ m^2$

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 117.14\ m^2$

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 551.68\ m^2$

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$

$= 22720.1\ m^2$

STEP 8.6 For each release hole size, calculate the component damage consequence areas for Auto-ignition Not Likely, Instaneous Release, (AINL-INST), $CA^{AINL\text{-}INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AINL-INST} =$ 6.5 b $= b_{cmd}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right)$ ..... equation (31)

From step 7, know that :

$Mass_1$	=	6.62	kgs	$eneff_1$	=	1.66
$Mass_2$	=	6.62	kgs	$eneff_2$	=	1.66
$Mass_3$	=	6.62	kgs	$eneff_3$	=	1.66
$Mass_4$	=	6.62	kgs	$eneff_4$	=	1.66

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 6{,}469\,(6.62)^{0{,}67}.\left(\frac{1-0{,}25}{1.66}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 10.44\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 6{,}469(6.62)^{0{,}67}.\left(\frac{1-0{,}25}{1.66}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 10.44\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 6{,}469\,(6.62)^{0{,}67}.\left(\frac{1-0{,}25}{1.66}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 10.44\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 6{,}469\,(6.62)^{0{,}67}.\left(\frac{1-0{,}25}{1.66}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 10.44\ \text{m}^2$$

STEP 8.7 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Instataneous Release (AIL-INST), $CA^{AIL-INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-INST} =$ 164.0 b = $b_{cmd}^{AIL-INST} =$ 0.62

2). Calculate the consequence of area using equation below

$$CA_{cmd,n}^{AIL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{.....} \quad \text{equation (32)}$$

From step 7, know that :

$Mass_1$	=	6.62	kgs	$eneff_1$	=	1.66
$Mass_2$	=	6.62	kgs	$eneff_2$	=	1.66
$Mass_3$	=	6.62	kgs	$eneff_3$	=	1.66
$Mass_4$	=	6.62	kgs	$eneff_4$	=	1.66

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AIL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 164\,(6.62)^{0,62}.\left(\frac{1-0,25}{1.66}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 239.64\ m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AIL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 164\,(6.62)^{0,62}.\left(\frac{1-0,25}{1.66}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 239.64\ m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AIL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 164\,(6.62)^{0,62}.\left(\frac{1-0,25}{1.66}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 239.64\ m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AIL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 164\,(6.62)^{0,62}.\left(\frac{1-0,25}{1.66}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 239.64\ m^2$$

STEP 8.8 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Continous Release (AINL-CONT), $CA_{inj,n}^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

Table 4.9 - Personnel Injury Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	21.8	1.00			143	0.92			12.5	0.67			474	0.63		
C3-C4	25.6	1.0			171	1.0			9.7	0.7			270	0.63		

$\alpha = \alpha_{inj,n}^{AINL-CONT} =$ **21.8** $\quad b = b_{inj,n}^{AINL-CONT} =$ **1.00**

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1 - fact_{mit}) \quad \text{..... equation (33)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-CONT} = \left[\alpha.\left(rate_1^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 3.0617 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-CONT} = \left[\alpha.\left(rate_2^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 49.118 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-CONT} = \left[\alpha.\left(rate_3^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 250.99 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-CONT} = \left[\alpha.\left(rate_4^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 12571 \text{ m}^2$$

STEP 8.9 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Continous Release (AIL-CONT), $CA_{inj,n}^{AIL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-CONT} =$ 143.2 b $= b_{inj,n}^{AIL-CONT} =$ 0.92

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1 - fact_{mit}) \quad \text{..... equation (34)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-CONT} = \left[\alpha.\left(rate_1^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 22.967 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-CONT} = \left[\alpha.\left(rate_2^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 295.09 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-CONT} = \left[\alpha.\left(rate_3^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 1323.4 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-CONT} = \left[\alpha.\left(rate_4^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 48465 \text{ m}^2$$

STEP 8.10 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Instataneous Release (AINL-INST), $CA_{inj,n}^{AINL-INST}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AINL-INST} =$ 12.5 b $= b_{inj,n}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (35)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-INST} = \left[a.\left(mass_1^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AINL-INST} = [12{,}46\ (6.62\ )^{0{,}67}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,1}^{AINL-INST} = 20.01\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-INST} = \left[a.\left(mass_2^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AINL-INST} = [12{,}46\ .(\ 6.62)^{0{,}67}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,2}^{AINL-INST} = 20.01\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-INST} = \left[a.\left(mass_3^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AINL-INST} = [12{,}46\ .(6.62\ )^{0{,}67}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,3}^{AINL-INST} = 20.01\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-INST} = \left[a.\left(mass_4^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AINL-INST} = [12{,}46\ .(\ 6.62\ )^{0{,}67}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,4}^{AINL-INST} = 20.01\ \text{m}^2$$

STEP 8.11 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Instataneous Release (AIL-INST),

$$CA_{inj,n}^{AIL-INST}$$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-INST} =$ 473.9 b $= b_{inj,n}^{AIL-INST} =$ 0.63

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \ldots\ldots\ldots \text{equation (36)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-INST} = \left[a.\left(mass_1^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AIL-INST} = [473{,}9.(6.62)^{0{,}63}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,1}^{AIL-INST} = 705.69 \quad m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-INST} = \left[a.\left(mass_2^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AIL-INST} = [473{,}9.(6.62)^{0{,}63}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,2}^{AIL-INST} = 705.69 \quad m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-INST} = \left[a.\left(mass_3^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AIL-INST} = [473{,}9.(6.62)^{0{,}63}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,3}^{AIL-INST} = 705.69 \quad m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-INST} = \left[a.\left(mass_4^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AIL-INST} = [473{,}9.(6.62)^{0{,}63}].\left(\frac{1-0{,}25}{1.65}\right)$$

$$CA_{inj,4}^{AIL-INST} = 705.69 \quad m^2$$

8.12 STEP 8.12 For each release hole size, calculate the instataneous / continous blending factor, factn^{IC}.

1). FOR CONTINOUS RELEASE

C_5 = 25.2 kg/s

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad \text{.....equation (37)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$fact_1^{IC} = \min\left[\left\{\frac{rate_1}{C_5}\right\}, 1.0\right]$$

$$= 0.00742063$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$fact_2^{IC} = \min\left[\left\{\frac{rate_2}{C_5}\right\}, 1.0\right]$$

$$= 0.11904762$$

C). LARGE RELEASE HOLE SIZE AREA

$$fact_3^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$

$$= 0.60833333$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$fact_4^{IC} = \min\left[\left\{\frac{rate_4}{C_5}\right\}, 1.0\right]$$

$$= 1$$

2). FOR INSTATANEOUS RELEASE

$$fact_4^{IC} = 1$$

8.13 Calculate the AIT blending factor, $fact^{AIT}$, using these optional equation below.

$$fact^{AIT} = 0 \quad \text{for } T_S + C_6 \leq AIT \quad \text{equation (38)}$$

$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2 \,.\, C_6} \quad \text{for } T_S + C_6 > AIT > T_S - C_6$$

$$fact^{AIT} = 1 \quad \text{for } T_S - C_6 \geq AIT \quad \text{equation (39)}$$

Ts	=	71 (^{o}C)	AIT	=	1036 (^{o}F)
Ts	=	159.8 (^{o}F)	AIT	=	830.927778 (K)
Ts	=	344.15 (K)	AIT	=	446.222222 (^{o}R)
C_6	=	55.6 (K)			

$T_s + C_6$	=	399.75 (K)
$T_s - C_6$	=	288.55 (K)
$\frac{(T_s - AIT + C_6)}{2 \,.\, C_6}$	=	-3.8775 (K)

$fact^{AIT}$ = 0

STEP 8.14 Calculate the continuous/instantaneous blended consequence area for the component using equation (3.53) through (3.56) based on the consequence areas calculated in previous steps $fact_n^{IC}$

A. Componen demage for auto-ignition Likely, Continous - Instataneous release

$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} . fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} . (1 - fact_n^{IC})$ equation (40)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-INST}$	=	10.44	m^2
$fact_1^{IC}$	=	0.0074	
$CA_{cmd,1}^{AIL-CONT}$	=	1.2617848	m^2
$CA_{cmd,1}^{AIL}$	=	1.3298876	m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-INST}$	=	10.44	m^2
$fact_2^{IC}$	=	0.119048	
$CA_{cmd,2}^{AIL-CONT}$	=	19.149584	m^2
$CA_{cmd,2}^{AIL}$	=	18.112643	m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-INST}$	=	10.44	m^2
$fact_3^{IC}$	=	0.608333	
$CA_{cmd,3}^{AIL-CONT}$	=	94.713487	m^2
$CA_{cmd,3}^{AIL}$	=	43.446676	m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-INST}$ = 10.44 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AIL-CONT}$ = 4386.56 m^2

$CA_{cmd,4}^{AIL}$ = 10.439277 m^2

B. Personal Injury for auto-ignition Likely, Continous - Instataneous release

$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} . fact_n^{IC} + CA_{inj,n}^{AIL-CONT} . (1 - fact_n^{IC})$ .....equation (41)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AIL-INST}$ = 705.69 m^2

$fact_{n1}^{IC}$ = 0.0074

$CA_{inj,1}^{AIL-CONT}$ = 22.966698 m^2

$CA_{inj,1}^{AIL}$ = 28.032962 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AIL-INST}$ = 705.69 m^2

$fact_{n2}^{IC}$ = 0.119048

$CA_{inj,2}^{AIL-CONT}$ = 295.09091 m^2

$CA_{inj,2}^{AIL}$ = 343.97213 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AIL-INST}$ = 705.69 m^2

$fact_{n3}^{IC}$ = 0.608333

$CA_{inj,3}^{AIL-CONT}$ = 1323.4364 m^2

$CA_{inj,3}^{AIL}$ = 947.64257 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AIL-INST}$ = 705.69 m^2

$fact_{n4}^{IC}$ = 1

$CA_{inj,4}^{AIL-CONT}$ = 48465.482 m^2

$CA_{inj,4}^{AIL}$ = 705.69314 m^2

C. Componen demage for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST} . fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (42)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-INST}$ = 10.44 m^2

$fact_1^{IC}$ = 0.0074

$CA_{cmd,1}^{AINL-CONT}$ = 1.2617848 m^2

$CA_{cmd,1}^{AINL}$ = 1.3298876 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-INST}$ = 10.44 m^2

$fact_2^{IC}$ = 0.119048

$CA_{cmd,2}^{AINL-CONT}$ = 19.149584 m^2

$CA_{cmd,2}^{AINL}$ = 18.112643 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-INST}$ = 10.44 m^2

$fact_3^{IC}$ = 0.6083

$CA_{cmd,3}^{AINL-CONT}$ = 94.713487 m^2

$CA_{cmd,3}^{AINL}$ = 43.446676 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-INST}$ = 10.44 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AINL-CONT}$ = 4386.56 m^2

$CA_{cmd,4}^{AINL}$ = 10.439277 m^2

D. Personal Injury for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} . fact_n^{IC} + CA_{inj,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (43)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AINL-INST}$ = 20.01 m^2

$fact_1^{IC}$ = 0.0074

$CA_{inj,1}^{AINL-CONT}$ = 3.0616575 m^2

$CA_{inj,1}^{AINL}$ = 3.1874345 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AINL-INST}$ = 20.01 m^2

$fact_2^{IC}$ = 0.119048

$CA_{inj,2}^{AINL-CONT}$ = 49.1175 m^2

$CA_{inj,2}^{AINL}$ = 45.652475 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AINL-INST}$ = 20.01 m^2

$fact_3^{IC}$ = 0.6083

$CA_{inj,3}^{AINL-CONT}$ = 250.99043 m^2

$CA_{inj,3}^{AINL}$ = 110.47812 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AINL-INST}$ = 20.01 m^2

$fact_4^{IC}$ = 1

$CA_{inj,4}^{AINL-CONT}$ = 12570.806 m^2

$CA_{inj,4}^{AINL}$ = 20.011292 m^2

STEP 8.15 Calculate the AIT blended consequence areas for the component using equations (3.57) and (3.58) based on the consequence areas determined in step 8.14 and the AIT blending factors, , calculate in step 8.13. the resulting consequence areas are the component damage and personnel injury flammable consequence areas, and for each release hole size selected in step 2.2

$CA_{cmd,n}^{flam}$ $CA_{inj,n}^{flam}$

A. Componen Demage

$CA_{cmd,n}^{flam} = CA_{smd,n}^{AIL} . fact^{AIT} + CA_{cmd,n}^{AINL} . (1 - fact^{AIT})$ .....equation (44)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL}$ = 1.3298876 m^2

$fact^{AIT}$ = 0

$CA_{cmd,1}^{AINL}$ = 1.3298876 m^2

$CA_{cmd,1}^{flam}$ = 1.3298876 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL}$ = 18.112643 m^2

$fact^{AIT}$ = 0

$CA_{cmd,2}^{AINL}$ = 18.112643 m^2

$CA_{cmd,2}^{flam}$ = 18.112643 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL}$ = 43.446676 m^2

$fact^{AIT}$ = 0

$CA_{cmd,3}^{AINL}$ = 43.446676 m^2

$CA_{cmd,3}^{flam}$ = 43.446676 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL}$ = 10.439277 m^2

$fact^{AIT}$ = 0

$CA_{cmd,4}^{AINL}$ = 10.439277 m^2

$CA_{cmd,4}^{flam}$ = 10.439277 m^2

B. Personal Injury

$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} . fact^{AIT} + CA_{inj,n}^{AINL} . (1 - fact^{AIT})$ …….. equation (45)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{flam-AIL}$ = 28.032962 m^2

$fact^{AIT}$ = 0

$CA_{inj,1}^{AINL}$ = 3.1874345 m^2

$CA_{inj,1}^{flam}$ = 3.1874345 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{flam-AIL}$ = 343.97213 m^2

$fact^{AIT}$ = 0

$CA_{inj,2}^{AINL}$ = 45.652475 m^2

$CA_{inj,2}^{flam}$ = 45.652475 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{flam-AIL}$ = 947.64257 m^2

$fact^{AIT}$ = 0

$CA_{inj,3}^{AINL}$ = 110.47812 m^2

CA_{inj3}^{flam} = 110.47812 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{flam-AIL}$ = 705.69314 m^2

$fact^{AIT}$ = 0

$CA_{inj,4}^{AINL}$ = 20.011292 m^2

CA_{inj4}^{flam} = 20.011292 m^2

STEP 8.16 Determine the consequence areas (probability weighted on release hole size) for component damage and personnel injury using equations (3.59) and (3.60) based on the consequence area from step 8.15

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

CONSEQUENCE AREA FOR COMPONENT DAMAGE

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad \text{.....(equation)}$$

$$CA_{cmd}^{flam} = \left(\frac{(gff_{1.}\, CA_{cmd,1}^{flam}) + (gff_{2.}\, CA_{cmd,2}^{flam}) + (gff_{3.}\, CA_{cmd,3}^{flam}) + (gff_{4.}\, CA_{cmd,4}^{flam})}{gff_{total}} \right)$$

$$= 13.07\ m^2$$

CONSEQUENCE AREA FOR PERSONNEL INJURY

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad \text{(equation 94)}$$

$$CA_{inj}^{flam} = \left(\frac{\left(gff_1 \cdot CA_{inj,1}^{flam}\right) + \left(gff_2 \cdot CA_{inj,2}^{flam}\right) + \left(gff_3 \cdot CA_{inj,3}^{flam}\right) + \left(gff_4 \cdot CA_{inj,4}^{flam}\right)}{gff_{total}} \right.$$

$$= \left. 32.372\ m^2 \right.$$

PART 9 : CALCULATE THE TOXIC CONSEQUENCES AREA

Table 4.113 Continuous Gas and Liquid Release Toxic Consequence Equation Constantsfor Miscellaneous Chemicals

Chemical	Release Duration (minutes)	Gas Release Constants		Liquid Release Constants	
		e	f	e	f
Aluminum Chloride (Alcl3)	ALL	17.663	0.9411	N/A	N/A
Carbon Monoxide (CO)	3	41.412	1.15	N/A	N/A
	5	279.79	1.06	N/A	N/A
	10	834.48	1.13	N/A	N/A
	20	2915.9	1.11	N/A	N/A
	40	5346.8	1.17	N/A	N/A
	60	6293.7	1.21	N/A	N/A
Hydrogen Chloride (HCL)	3	215.48	1.09	N/A	N/A
	5	536.28	1.15	N/A	N/A
	10	2397.5	1.1	N/A	N/A
	20	4027	1.18	N/A	N/A
	40	7534.5	1.2	N/A	N/A
	60	8625.1	1.23	N/A	N/A
Nitric Acid	3	53.013	1.25	5110	1.08
	5	68.7	1.25	9640.8	1.02
	10	96.325	1.24	12.453	1.06
	20	126.942	1.23	19.149	1.06
	40	146.941	1.22	31.145	1.06
	60	156.345	1.22	41.999	1.12
Nitrogen Dioxide (NO2)	3	6633.1	0.7	2132.9	0.98
	5	9221.4	0.68	2887	1.04
	10	11.965	0.68	6194.4	1.07
	20	14.248	0.72	13.843	1.08
	40	22.411	0.7	27.134	1.12
	60	24.994	0.71	41.657	1.13

Phosgene	3	12.902	1.2	3414.8	1.06
	5	22.976	1.29	6857.1	1.1
	10	48.985	1.24	21.215	1.12
	20	108.298	1.27	63.361	1.16
	40	244.67	1.3	178.841	1.2
	60	367.877	1.31	314.608	1.23
Toluene Diisocyanate (TDI)	3	N/A	N/A	3692.5	1.06
	5	N/A	N/A	3849.2	1.09
	10	N/A	N/A	4564.9	1.1
	20	N/A	N/A	4777.5	1.06
	40	N/A	N/A	4953.2	1.06
	60	N/A	N/A	5972.1	1.03
Ethylene Glycol Monoethyl Ether (EE)	1.5	3.819	1.171	N/A	N/A
	3	7.438	1.181	N/A	N/A
	5	17.735	1.122	N/A	N/A
	10	33.721	1.111	3.081	1.105
	20	122.68	0.971	16.877	1.065
	40	153.03	0.995	43.292	1.132
	60	315.57	0.899	105.74	1.104

Because of no chemical toxic in this equipment, so this step not calculate.

PART 10 : CALCULATE THE NON-FLAMMABLE, NON-TOXIC CA

Step 10.1 For each release hole size, calculate the non-flammable , non-toxic For steam-calculate $CA_{inj,N}^{CONT}$ using equation (43) and $CA_{inj,N}^{INST}$

1). FOR STEAM

Steam represents a hazard to personnel who are exposed to it at high temperatures. In general, steam is at 100oC (212oF) immediately after exiting a hole in an equipment item. Within a few feet, the steam will begin to mix with air cool, and condensed. The approach used here is that injury occurs above 60oC (140oF). In this case of Production Separator, the temperatur inside the presssure vessel is maximally working at 100oC (212oF). So, steam leaks is potentially occur at this situation.

$Mass_1$ = 6.617550 kgs
$Mass_2$ = 6.617550 kgs
$Mass_3$ = 6.617550 kgs
$Mass_4$ = 6.617550 kgs
$Rate_1$ = 0.1870 kg/s
$Rate_2$ = 3.0000 kg/s
$Rate_3$ = 15.3300 kg/s
$Rate_4$ = 767.8000 kg/s
C_9 = 0.123 m^2.sec/kg
C_{10} = 9.744 $m^2/kg^{0.06384}$
$fact_1^{IC}$ = 0.0074206
$fact_2^{IC}$ = 0.1190476
$fact_3^{IC}$ = 0.6083333
$fact_4^{IC}$ = 1

$CA_{inj,n}^{CONT} = C_9 . Rate_n)$ ..... equation (48)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{CONT} = C_9 . Rate_1)$
= 0.02300 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{CONT} = C_9 . Rate_2)$
= 0.36900 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{CONT} = C_9 . Rate_3)$
= 1.88559 m^2

$CA_{inj,n}^{INST} = C_{10} . Mass_n)^{0.6384}$ ..... equation (49)

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{INST} = C_{10} . Mass_4)^{0.6384}$
= 14.293645 m^2

2). FOR ACIDS AND CAUSTIC

For Acids or caustics- compute, $CA_{inj,n}^{CONT}$ using equation (3.72), (3.73), (3.74). Note that the data is not provided for an instantaneous release ; therefore,

No acid or caustic, thus value are 0.

Step 10.2 For each release hole size, calculate the instantaneous/continuous blending factor, $fact_n^{IC}$. For steam, use equation (3.71).

for acids or caustics, $fact_n^{IC}$ =0.0

Step 10.3 For each release hole size , compute the blended non-flammable , non-toxic personnel injury consequence area for steam or acid leaks, $CA_{inj,n}^{leak}$, using equation (3.76) based on the consequence are from step 10.1 and the blending factor , $fact_n^{IC}$, from step 10.2. Note that there is no need to calculate component damage area for the level 1 non-flammable release (steam or acid/caustic) :

$CA_{cmd,n}^{leak}$ = 0 m^2

$CA_{inj,n}^{leak} = CA_{inj,n}^{INST}.\ fact_n^{IC} + CA_{inj,n}^{CONT}.(1 - fact_n^{IC})$ ..... equation (50)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{leak} = CA_{inj,1}^{INST}.\ fact_1^{IC} + CA_{inj,1}^{CONT}.(1 - fact_1^{IC})$

= 0.0228303 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{leak} = CA_{inj,2}^{INST}.\ fact_2^{IC} + CA_{inj,2}^{CONT}.(1 - fact_2^{IC})$

= 0.3250714 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{leak} = CA_{inj,3}^{INST}.\ fact_3^{IC} + CA_{inj,3}^{CONT}.(1 - fact_3^{IC})$

= 0.73852275 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{leak} = CA_{inj,4}^{INST}.\ fact_4^{IC} + CA_{inj,4}^{CONT}.(1 - fact_4^{IC})$

= 14.293645 m^2

Step 10.4 Determine the final non-flammable, non toxic consequence areas for personnil injury, CA_{icmd}^{nfnt} using equation (3.80) based on consequence areas calculated for each release hole size in step 10.3 . Note that there is no need to calculate a final-flammable, non-toxic consequence area for component damage area for the level 1 non-flammable release (steam or acid/caustic, or :

$CA_{cmd,n}^{lnfnt} = 0 \ m^2$

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}} \right) \quad \text{..... (equation)}$$

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

$$CA_{inj}^{nfnt} = \left(\frac{(gff_1 \cdot CA_{inj,1}^{leak}) + (gff_2 \cdot CA_{inj,2}^{leak}) + (gff_3 \cdot CA_{inj,3}^{leak}) + (gff_4 \cdot CA_{inj,4}^{leak})}{gff_{total}} \right)$$

$= 1.43293 \ m^2$

PART 11 : CALCULATION OF FINAL CONSEQUENCE AREA

Step 11.1 Calculate the final component damage consequence area, Cacmd

Note that since the component damage consequence areas for toxic releases, CAcmd^{tox}, and non-flammable, non-toxic releases, CAcmd^{nfnt}, are both equal to zero. Then, the final component damage consequence area is equal to the consequence area calculated for flammable releases, CAcmd^{flam}.

$CA_{cmd} = CA_{cmd}^{flam}$ ..... equation (52)

$= 13.07 \ m^2$

Step 11.2 Calculate the final personnel injury consequence area, CA_{inj}

$CA_{inj} = \max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$ ..... equation (53)

$CA_{inj}^{flam} = 32.372 \ m^2$

$CA_{inj}^{tox} = 0.00 \ m^2$

$CA_{inj}^{nfnt} = 1.43293 \ m^2$

$CA_{inj} = \max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$

$= 32.3718411 \ m^2$

Step 11.3 Calculate the final consequence area, CA, using equation below:

$CA = \max\left[CA_{cmd}, CA_{inj}\right]$

$= 32.37 \ m^2$

$= 348.447598 \ ft^2$

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 4 :

INSPECTION PLANNING AND RECOMMENDATION

PSV-1311

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 4 = Inspection Planning and Recommendation

STEP 1 CALCULATION OF RISK ANALYSIS

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (54)

dimana :

$Risk^{prd}$ = total risiko PRD

$Risk_f^{prd}$ = risiko PRD gagal membuka

$Risk_l^{prd}$ = risiko PRD bocor

STEP 1 Menghitung resiko dari peluang kegagalan PRD untuk gagal membuka $Risk_{f.j}^{prd}$

A. RBI Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 1.67E-10 $Risk_{f.j}^{prd}$ = 2E-10 x 32.372

$C_{f,j}^{prd}$ = 32.37 m^2 = 5.4119E-09

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 4.18E-09 $Risk_{f.j}^{prd}$ = 4E-09 x 32.372

$C_{f,j}^{prd}$ = 32.37 m^2 = 1.353E-07

B. RBI Plan Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 4.76E-10 $Risk_{f.j}^{prd}$ = 5E-10 x 32.372

$C_{f,j}^{prd}$ = 32.37 m^2 = 1.5425E-08

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 5.96E-08 $Risk_{f.j}^{prd}$ = 6E-08 x 32.372

$C_{f,j}^{prd}$ = 32.37 m^2 = 1.9281E-06

$$Risk_f^{prd} = \sum_{j=1}^{ndc} P_{f,j}^{prd} . C_{f,j}^{prd}$$

A. RBI Date

$Risk_f^{prd}$ = 5E-09 + 1E-07

= 1.4071E-07

B. RBI Plan Date

$Risk_f^{prd}$ = 2E-08 + 2E-06

= 1.9436E-06

STEP 1.2 Hitung risiko untuk kasus kebocoran PRD, $Risk_l^{prd}$

$$Risk_l^{prd} = P_l^{prd} . C_l^{prd}$$ equation (56)

Dimana :

P_l^{prd} = 0.0061 (RBI Date)

P_l^{prd} = 0.0953 (RBI Plan Date)

C_l^{prd} = 32.37 m^2

A. RBI Date

$Risk_l^{prd}$ = 0.0061 x 32.372

= 0.1975

B. RBI Plan Date

$Risk_l^{prd}$ = 0.0953 x 32.37

= 3.085

STEP 1.3 Menghitung total risiko menggunakan persamaan (57)

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (57)

A. Risk at RBI Date

$Risk^{prd}$ = 0.1975 $m^2/year$

= 2.1255 $ft^2/year$

B. Risk at RBI Plan Date

$Risk^{prd}$ = 3.085 $m^2/year$

= 33.207 $ft^2/year$

STEP 2 Risk Matrix

Probabilty Score at RBI Date = 2E-10 + 4E-09 + 0.0061

= 6.10E-03

Probabilty Score at Plan Date = 5E-10 + 6E-08 + 0.0953

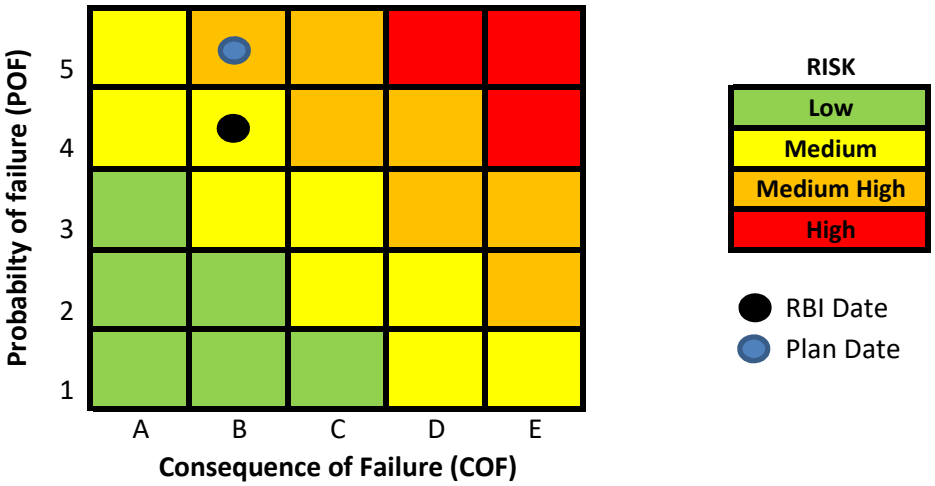
= 9.53E-02

Consequence Score = 32.37 m^2

= 348.45 ft^2

Table 4.1 Numerical Values Associated with POF and Area-Based COF Categories

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t,I_E) \leq 3.06E-05$	$D_{ftotal} \leq 1$	A	$CA \leq 100$
2	$3.06E-05 < P_f(t,I_E) \leq 3.06E-04$	$1 < D_{ftotal} \leq 10$	B	$100 < CA \leq 1.000$
3	$3.06E-04 < P_f(t,I_E) \leq 3.06E-03$	$10 < D_{ftotal} \leq 100$	C	$1.000 < CA \leq 10.000$
4	$3.06E-03 < P_f(t,I_E) \leq 3.06E-02$	$100 < D_{ftotal} \leq 1000$	D	$10.000 < CA \leq 100.000$
5	$P_f(t,I_E) > 3.06E-02$	$D_{ftotal} > 1000$	E	$CA > 100.000$



STEP 3 Inspection Date

Target date dapat dihitung dengan cara melakukan interpolasi nilai RBI Date dan PRBI Plan Date

Dalam menentukan target date, digunakan nilai risk target sebesar 40ft^2 (3.71 m^2) untuk menentukan tahun inspection date.

Data	Date	Age	Risk (m^2/yr)
RBI Date	15/03/2020	0	0.197
Risk Target	?	?	3.710
Plan Date	15/03/2024	11	3.085

$$\frac{Y - Y_1}{Y_2 - Y_1} = \frac{X - X_1}{X_2 - X_1}$$

$$Y = Y_1 + \left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)$$

$$Y = 0 + \left(\frac{3.71 - 0.197}{3.085 - 0.197}\right)(11 - 0)$$

Y = 13.380748 Year

Y = 4883.9731 Hari

= 28/07/2033

Berdasarkan standart API 510 memberikan rekomendasi interval inspeksi maksimal untuk *Pressure Reliev Device* yaitu 10 tahun dari inspeksi terakhir. Sehingga untuk jadwal inspeksi selanjutnya yaitu pada tanggal 17 juni 2026.

STEP 4 Recommendation

1 Inspection Category

Inspection Effectiveness	Description of Inspection	Date
C	Inspeksi visual telah dilakukan tanpa tes pop, di mana dokumentasi terperinci tentang kondisi internal PRD komponen dibuat.	17/06/2026
Fairly Effective	Tes trevitest atau in-situ telah dilakukan di tempat yang sebenarnya cairan proses tidak digunakan untuk memberi tekanan pada sistem.	

Berdasarkan standart API 581 Direkomendasikan menggunakan inspection effectiveness kategori C dengan mengaplikasikan Visual on-stream inspection

2 Inspection Strategy

Berdasarkan Standart API 576 berikut rekomendasi record visual inspeksi Pressure Relief Device

Unit	Location		Set Pressure	Test Interval
Make		:		
Style		:		
Body and bonnet material		:		
Nozzle and disk material		:		
Trim material		:		
Spring material		:		
Spring no		:		
Flange sizes				
	Inlet	:		
	Outlet	:		
Spring set pressure		:		
Relieving pressure		:		
normal operating temp		:		
Remark				

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 1:

DATA PRESSURE RELIEF DEVICE

PSV-1312

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

Lampiran 1 = Data Pressure Relief Device

1 GENERAL

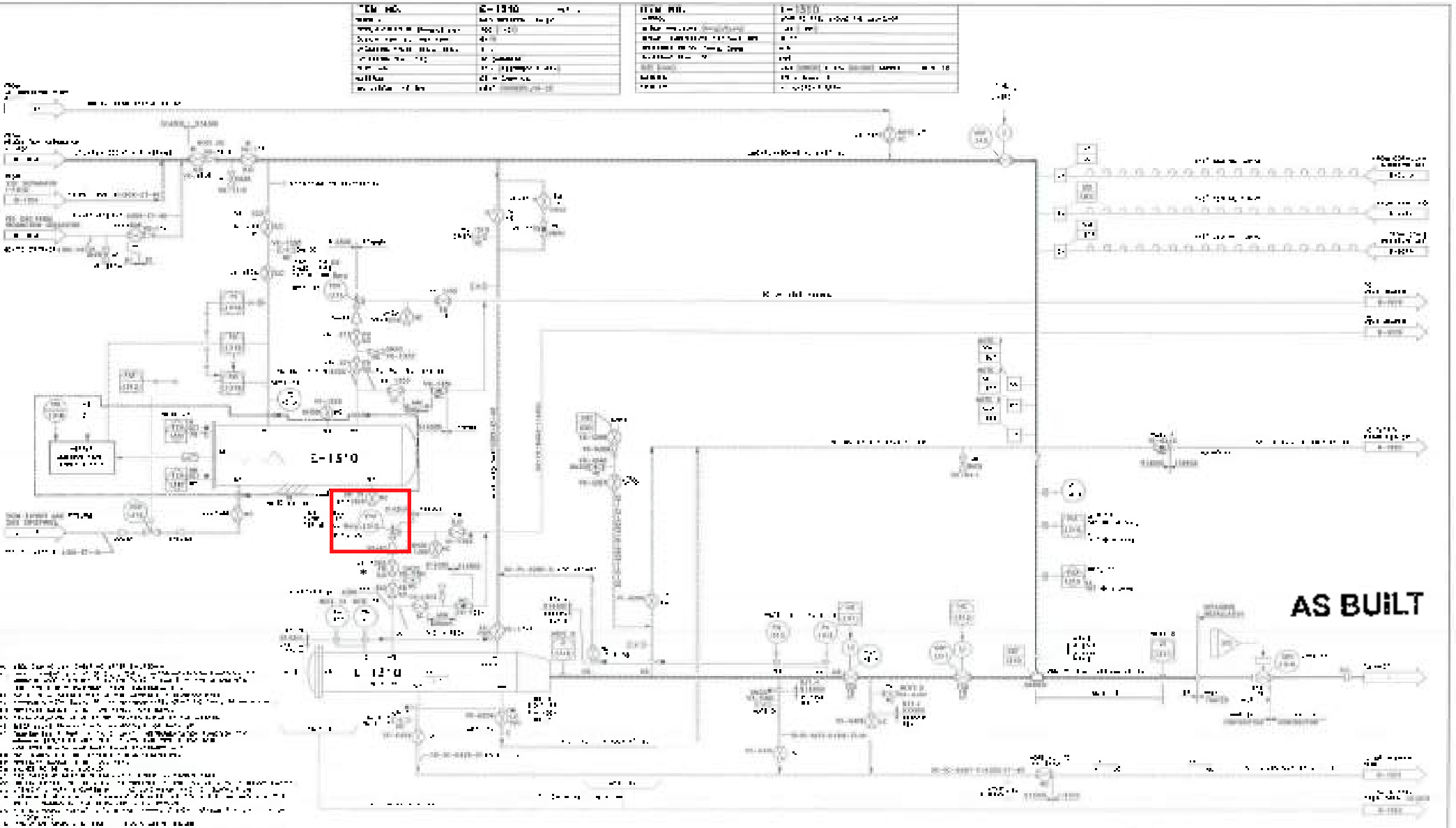
Tag Number	:	PSV-1312	
Service	:	WHP to FPSO Liquid Pig Launcher L-1	
Noozle (full/semi)	:	FULL	
PID No.	:	BTJT-A-B-1011	
Design	:	SAFETY-RELIEF	
Type	:	Conventional	
Bonnet Type	:	Closed	
Nace Requirement	:	Yes	

2 PROCESS CONDITIONS

Fluid		:	Hydrocarbon	
State		:	Gas	
Required Capacity		:	1127	lb/h
Molecular Weight		:	27.06	
Operating Pressure		:	127.6	psig
Set Pressure		:	1465	psig
Operating Temperatur		:	639	^{o}F
Reliefing Temperatur		:	639	^{o}F
Back Pressure	Constant	:	0	psig
	Variable	:	0	psi
	Total	:	110.2	psig
% Allowable Overpressure		:	21%	
Overpressure Factor		:	-	
Compressible Factor		:	0.707	
Laten Heat of Vaporation		:	-	Btu/lb
Ratio of Specific Heats (Cp/C		:	1.646	
Relief Density		:	-	Lb/ft^2
Relief Viscosity		:	-	cP
Barometric Pressure		:	14.7	psia

3 DESIGN CONDITION

Design Pressure	:	1465	psig
Design Temperatur	:	1000	^{o}F


AS BUILT

CASE 1 : MAXIMUM GAS FLOW RATE (AUGUST 2016)

Stream Name		1	1A	1B	1C	1D	1E	2	2A	2B
Description		Wellhead Flowline U/S of choke - NAG	Wellhead Flowline (BT2_A_P) U/S of choke - Long String	Wellhead Flowline (BT4_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_D_P) U/S of choke - Long String	Wellhead Flowline (BT2_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_E_P) U/S of choke - Long String	Wellhead Flowline D/S of choke - Short String (NAG)	Wellhead Flowline (BT2_A_P) D/S of choke - Long String	Wellhead Flowline (BT4_C_P1) D/S of choke - Long String
MIXTURE										
Vapour Fraction		1.0000	0.2955	0.4203	0.2920	0.3095	0.2956	1.0000	0.3159	0.4223
Temperature	C	75.0	75.0	71.0	72.0	75.0	74.0	66.4	69.2	70.2
Pressure	kPag	2959	2959	1034	1034	1034	1034	930	930	930
Pressure	bar_g	29.6	29.6	10.3	10.3	10.3	10.3	9.3	9.3	9.3
Mass Flow	kg/h	8478.39	26300.60	110228.76	22227.17	83356.85	29194.58	8478.39	26300.60	110228.76
Molar Flow	kgmole/h	449.11	841.38	3550.51	685.08	2545.47	899.18	449.11	841.38	3550.51
Molecular Weight		18.9	31.3	31.0	32.4	32.4	32.5	18.9	31.3	31.0
Heat Flow	kW	-3821	-53720	-205650	-44662	-163516	-58456	-6821	-53720	-205650
Mass Heat Capacity	kJ/kg.C	2.40	2.88	2.80	2.91	2.91	2.92	2.27	2.92	2.79
Mass Density	kg/m3	21.04	108.95	29.76	43.88	41.06	43.17	7.04	35.86	29.34
GAS PHASE										
Std Gas Flow	kNm3/h	10.05	5.56	33.39	4.48	17.62	5.95	10.05	5.95	33.54
Std Gas Flow	MMSCFD	9.00	4.98	29.91	4.01	15.79	5.33	9.00	5.33	30.05
Molar Flow	kgmole/h	449.11	248.67	1492.34	200.05	787.71	265.75	449.11	265.81	1499.40
Actual Gas Flow	ACT m3/h	403.02	217.58	3621.21	456.87	1934.34	650.66	1205.17	710.89	4009.69
Mass Flow	kg/h	8478.39	5617.70	37106.46	4989.82	19834.55	6670.73	8478.39	6309.98	37411.64
Molecular Weight		18.9	22.6	24.9	24.9	25.2	25.1	18.6	23.7	25.0
Mass Heat Capacity	kJ/kg-C	2.40	2.30	2.13	2.13	2.14	2.14	2.27	2.13	2.12
Z Factor		0.95	0.93	0.96	0.96	0.96	0.96	0.98	0.97	0.97
Thermal Conductivity	W/m-K	0.041	0.038	0.034	0.034	0.035	0.035	0.038	0.035	0.034
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mass Density	kg/m3	21.04	25.82	10.25	10.25	10.25	10.25	7.04	8.88	9.33
Cp/Cv (Gamma)		1.32	1.30	1.23	1.23	1.22	1.22	1.27	1.23	1.22
OIL PHASE										
Mass Flow	kg/h	—	11155.91	39678.59	9354.61	33942.01	12226.33	—	10545.33	39426.24
Liquid Vol Flow @Std Cond	m3/h	—	13.25	46.51	10.96	39.75	14.32	—	12.29	46.14
Liquid Vol Flow @Std Cond	barrel/day	—	2000	7021	1655	6000	2162	—	1855	6965
Actual Volume Flow	m3/h	—	13.99	48.76	11.50	41.81	15.05	—	12.85	48.32
Molecular Weight		—	174.5	196.6	197.0	198.1	197.7	—	205.6	199.4
Mass Heat Capacity	kJ/kg-C	—	2.10	2.13	2.13	2.14	2.14	—	2.11	2.12
Thermal Conductivity	W/m K	—	0.103	0.109	0.109	0.109	0.109	—	0.111	0.110
Viscosity	cP	—	1.20	1.56	1.54	1.50	1.51	—	1.76	1.62
Mass Density	kg/m3	—	787.60	813.74	813.27	811.86	812.33	—	820.69	815.97
Surface Tension	dyne/cm	—	12.91	14.73	14.88	14.57	14.61	—	15.18	14.92
AQUEOUS PHASE										
Mass Flow	kg/h	—	9526.98	33443.69	7882.74	28580.29	10297.52	—	9445.29	33390.88
Liquid Vol Flow @Std Cond	m3/h	—	9.33	32.66	7.77	28.19	10.15	—	9.31	32.90
Liquid Vol Flow @Std Cond	barrel/day	—	1417	4975	1173	4251	1532	—	1406	4967
Actual Volume Flow	m3/h	—	9.83	34.40	8.12	29.50	10.62	—	9.70	34.33
Molecular Weight		—	18.0	18.0	18.0	18.0	18.0	—	18.0	18.0
Mass Heat Capacity	kJ/kg-C	—	4.34	4.34	4.34	4.35	4.35	—	4.34	4.34
Thermal Conductivity	W/m-K	—	0.666	0.663	0.664	0.666	0.665	—	0.662	0.663
Viscosity	cP	—	0.37	0.39	0.39	0.37	0.38	—	0.41	0.40
Mass Density	kg/m3	—	969.63	972.09	971.29	968.88	969.08	—	973.51	972.66
MIXTURE COMPOSITION (Mole Fraction)										
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0055	0.0025	0.0031	0.0021	0.0022	0.0021	0.0055	0.0025	0.0031
CO2		0.0031	0.0040	0.0055	0.0038	0.0040	0.0039	0.0031	0.0040	0.0055
Methane		0.8627	0.2283	0.2801	0.2016	0.2112	0.2026	0.8627	0.2283	0.2801
Ethane		0.0453	0.0283	0.0393	0.0276	0.0290	0.0278	0.0453	0.0283	0.0393
Propane		0.0262	0.0236	0.0361	0.0260	0.0274	0.0263	0.0262	0.0236	0.0361
i-Butane		0.0072	0.0065	0.0104	0.0078	0.0082	0.0079	0.0072	0.0065	0.0104
n-Butane		0.0081	0.0084	0.0135	0.0103	0.0109	0.0105	0.0081	0.0084	0.0135
i-Pentane		0.0038	0.0040	0.0062	0.0050	0.0053	0.0051	0.0038	0.0040	0.0062
n-Pentane		0.0025	0.0034	0.0050	0.0042	0.0044	0.0043	0.0025	0.0034	0.0050
Mcyclopentan		0.0007	0.0012	0.0015	0.0014	0.0014	0.0014	0.0007	0.0012	0.0015
Benzene		0.0000	0.0003	0.0004	0.0004	0.0004	0.0004	0.0000	0.0003	0.0004
Cyclohexane		0.0004	0.0012	0.0014	0.0014	0.0014	0.0014	0.0004	0.0012	0.0014
Mcyclohexane		0.0006	0.0021	0.0023	0.0024	0.0024	0.0024	0.0000	0.0021	0.0023
Toluene		0.0000	0.0006	0.0006	0.0006	0.0006	0.0006	0.0000	0.0005	0.0006
E-Benzene		0.0000	0.0003	0.0002	0.0003	0.0003	0.0003	0.0000	0.0003	0.0002
p-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004
m-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004
o-Xylene		0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002
n-Pbenzene		0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0003
124-MBenzene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004
C6*		0.0024	0.0045	0.0058	0.0053	0.0055	0.0054	0.0024	0.0045	0.0058
C7*		0.0000	0.0035	0.0038	0.0039	0.0040	0.0040	0.0000	0.0035	0.0038
C8*		0.0000	0.0036	0.0035	0.0039	0.0039	0.0040	0.0000	0.0036	0.0035
C9*		0.0000	0.0028	0.0020	0.0031	0.0030	0.0031	0.0000	0.0028	0.0026
C10-C15*		0.0000	0.0154	0.0134	0.0164	0.0160	0.0163	0.0000	0.0154	0.0134
C16-C19*		0.0000	0.0067	0.0058	0.0071	0.0070	0.0071	0.0000	0.0067	0.0058
C20-C27*		0.0000	0.0073	0.0063	0.0078	0.0076	0.0077	0.0000	0.0073	0.0063
C28-C37*		0.0000	0.0043	0.0037	0.0045	0.0044	0.0045	0.0000	0.0043	0.0037
C38-C80*		0.0000	0.0031	0.0027	0.0033	0.0032	0.0033	0.0000	0.0031	0.0027
H2O		0.0115	0.6328	0.5354	0.6479	0.6341	0.6456	0.0115	0.6328	0.5354
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Stream Name		2C	2D	2E	3	4	4A	5	6	7	8	9	10
Description		Wellhead Flowline (BT4_D_P) D/S of choke - Long String	Wellhead Flowline (BT2_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_E_P) D/S of choke - Long String	Inlet to Production Separator	Production Separator Gas Outlet	Gas Pipeline to FPSO	Liquid Pipeline to FPSO	Export Gas from FPSO to WHP (Note 7)	Export Gas from WHP to ORF (Note 6)	Gas Lift	Gas Inlet to FPSO (Note 6)	Liquid Inlet to FPSO (Note 6)
MIXTURE													
Vapour Fraction		0.2840	0.3115	0.2976	0.4147	1.0000	1.0000	0.0002	1.0000	1.0000	1.0000	0.0841	0.0019
Temperature	C	71.4	74.3	73.4	70.3	70.5	70.2	70.5	65.8	72.9	65.8	32.1	69.7
Pressure	kPag	930	930	930	930	930	880	880	9101	7120	9101	755	522
Pressure	bar_g	9.3	9.3	9.3	9.3	9.3	8.8	8.8	91.0	71.2	91.0	7.6	5.2
Mass Flow	kg/h	22227.17	83356.85	29194.58	289534.88	92836.71	92836.71	196698.17	80517.40	72509.32	7845.62	92836.71	196698.17
Molar Flow	kgmole/h	685.08	2545.47	899.18	9400.90	3899.75	3899.75	5501.15	3833.67	3452.38	373.55	3899.75	5501.15
Molecular Weight		32.4	32.4	32.5	30.8	23.8	23.8	35.8	21.0	21.0	21.0	23.8	35.8
Heat Flow	kW	-44662	-163516	-58456	-547951	-96398	-96398	-451503	-86559	-78265	-8434	-88081	-451835
Mass Heat Capacity	kJ/kg.C	2.91	2.80	2.91	2.81	2.14	2.14	3.13	2.72	2.61	2.72	2.11	3.13
Mass Density	kg/m3	39.70	37.14	39.04	27.10	8.87	8.43	870.51	75.42	61.13	75.42	7.80	731.73
GAS PHASE													
Std Gas Flow	kNm3/h	4.51	17.74	5.99	87.21	87.24	87.24	0.01	85.76	77.23	8.36	85.80	0.23
Std Gas Flow	MMSCFD	4.64	15.89	5.36	78.12	78.15	78.15	0.02	76.83	69.19	7.49	76.91	0.21
Molar Flow	kgmole/h	201.38	792.94	267.56	3898.34	3899.75	3899.75	1.13	3833.67	3452.38	373.56	3837.74	10.47
Actual Gas Flow	ACT m3/h	540.38	2148.41	722.19	10461.79	10470.75	11011.23	3.19	1067.56	1186.11	104.02	11747.65	46.67
Mass Flow	kg/h	5048.85	20061.87	6749.04	92780.89	92836.71	92836.71	27.22	80517.40	72509.32	7845.62	91652.63	286.14
Molecular Weight		25.1	25.3	25.2	23.8	23.8	23.8	24.1	21.0	21.0	21.0	23.9	27.3
Mass Heat Capacity	kJ/kg-C	2.12	2.13	2.12	2.14	2.14	2.14	2.14	2.72	2.61	2.72	2.06	2.06
Z Factor		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.86	0.86	0.86	0.97	0.97
Thermal Conductivity	W/m-K	0.034	0.034	0.034	0.035	0.035	0.035	0.035	0.047	0.043	0.047	0.033	0.037
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Mass Density	kg/m3	9.34	9.35	9.35	8.87	8.87	8.43	8.54	75.42	61.13	75.42	7.80	6.13
Cp/Cv (Gamma)		1.22	1.22	1.22	1.23	1.23	1.23	1.23	1.46	1.44	1.46	1.24	1.20
OIL PHASE													
Mass Flow	kg/h	9304.07	33751.47	12159.37	107029.65	0.00	—	106954.00	—	—	—	80.05	106703.77
Liquid Vol Flow @Std Cond	m3/h	10.88	39.46	14.22	124.78	0.00	—	124.69	—	—	—	0.10	124.28
Liquid Vol Flow @Std Cond	barrel/day	1643	5957	2147	18838	0	—	18823	—	—	—	16	18758
Actual Volume Flow	m3/h	11.41	41.47	14.93	130.61	0.00	—	130.51	—	—	—	0.11	129.94
Molecular Weight		199.5	200.7	200.3	205.1	205.3	—	205.6	—	—	—	110.1	206.7
Mass Heat Capacity	kJ/kg-C	2.13	2.14	2.13	2.12	2.12	—	2.12	—	—	—	2.09	2.11
Thermal Conductivity	W/m K	0.110	0.110	0.110	0.111	0.111	—	0.111	—	—	—	0.107	0.112
Viscosity	cP	1.60	1.55	1.56	1.72	1.72	—	1.72	—	—	—	0.49	1.79
Mass Density	kg/m3	815.22	813.88	814.31	819.41	819.38	—	819.51	—	—	—	733.22	821.21
Surface Tension	dyne/cm	14.80	14.75	14.78	15.11	15.10	—	15.13	—	—	—	16.73	15.41
AQUEOUS PHASE													
Mass Flow	kg/h	7874.25	28543.51	10285.38	89733.93	0.00	—	89718.95	—	—	—	1104.03	89708.25
Liquid Vol Flow @Std Cond	m3/h	7.76	28.13	10.14	88.42	0.00	—	88.41	—	—	—	1.09	88.40
Liquid Vol Flow @Std Cond	barrel/day	1171	4246	1530	13348	0	—	13345	—	—	—	164	13344
Actual Volume Flow	m3/h	8.10	29.45	10.60	92.26	0.00	—	92.26	—	—	—	1.12	92.20
Molecular Weight		18.0	18.0	18.0	18.0	18.0	—	18.0	—	—	—	18.0	18.0
Mass Heat Capacity	kJ/kg-C	4.34	4.35	4.34	4.34	4.34	—	4.34	—	—	—	4.32	4.34
Thermal Conductivity	W/m-K	0.663	0.666	0.665	0.663	0.663	—	0.663	—	—	—	0.666	0.662
Viscosity	cP	0.39	0.38	0.38	0.40	0.40	—	0.40	—	—	—	0.53	0.40
Mass Density	kg/m3	971.73	969.38	970.15	972.59	972.46	—	972.44	—	—	—	968.88	972.93
MIXTURE COMPOSITION (Mole Fraction)													
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0021	0.0022	0.0021	0.0026	0.0068	0.0068	0.0000	0.0089	0.0089	0.0089	0.0068	0.0000
CO2		0.0038	0.0040	0.0039	0.0044	0.0105	0.0105	0.0001	0.0093	0.0093	0.0093	0.0105	0.0001
Methane		0.2016	0.2112	0.2026	0.3011	0.7225	0.7225	0.0023	0.8082	0.8082	0.8082	0.7225	0.0023
Ethane		0.0276	0.0290	0.0278	0.0337	0.0799	0.0799	0.0010	0.0735	0.0735	0.0735	0.0799	0.0010
Propane		0.0260	0.0274	0.0263	0.0297	0.0684	0.0684	0.0022	0.0574	0.0574	0.0574	0.0684	0.0022
i-Butane		0.0078	0.0082	0.0079	0.0087	0.0190	0.0190	0.0013	0.0151	0.0151	0.0151	0.0190	0.0013
n-Butane		0.0103	0.0109	0.0105	0.0112	0.0240	0.0240	0.0021	0.0178	0.0178	0.0178	0.0240	0.0021
i-Pentane		0.0050	0.0053	0.0051	0.0053	0.0101	0.0101	0.0019	0.0051	0.0051	0.0051	0.0101	0.0019
n-Pentane		0.0042	0.0044	0.0043	0.0043	0.0078	0.0078	0.0016	0.0032	0.0032	0.0032	0.0078	0.0016
Mcyclopentan		0.0014	0.0014	0.0014	0.0014	0.0017	0.0017	0.0011	0.0007	0.0007	0.0007	0.0017	0.0011
Benzene		0.0004	0.0004	0.0004	0.0003	0.0004	0.0004	0.0003	0.0000	0.0000	0.0000	0.0004	0.0003
Cyclohexane		0.0014	0.0014	0.0014	0.0013	0.0015	0.0015	0.0012	0.0001	0.0001	0.0001	0.0015	0.0012
Mcyclohexane		0.0024	0.0024	0.0024	0.0022	0.0017	0.0017	0.0025	0.0000	0.0000	0.0000	0.0017	0.0025
Toluene		0.0006	0.0006	0.0006	0.0006	0.0004	0.0004	0.0007	0.0000	0.0000	0.0000	0.0004	0.0007
E-Benzene		0.0003	0.0003	0.0003	0.0002	0.0001	0.0001	0.0004	0.0000	0.0000	0.0000	0.0001	0.0004
p-Xylene		0.0004	0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
m-Xylene		0.0004	0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
o-Xylene		0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0003	0.0000	0.0000	0.0000	0.0001	0.0003
n-Pbenzene		0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0005
124-MBenzene		0.0004	0.0004	0.0004	0.0004	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0006
C6*		0.0053	0.0055	0.0054	0.0051	0.0007	0.0007	0.0040	0.0008	0.0008	0.0008	0.0007	0.0040
C7*		0.0039	0.0040	0.0040	0.0035	0.0034	0.0034	0.0037	0.0002	0.0002	0.0002	0.0034	0.0037
C8*		0.0039	0.0039	0.0040	0.0034	0.0018	0.0018	0.0046	0.0000	0.0000	0.0000	0.0018	0.0046
C9*		0.0031	0.0030	0.0031	0.0027	0.0008	0.0008	0.0040	0.0000	0.0000	0.0000	0.0008	0.0040
C10-C15*		0.0164	0.0160	0.0163	0.0140	0.0001	0.0001	0.0238	0.0000	0.0000	0.0000	0.0001	0.0238
C16-C19*		0.0071	0.0070	0.0071	0.0061	0.0000	0.0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0101
C20-C27*		0.0078	0.0076	0.0077	0.0066	0.0000	0.0000	0.0113	0.0000	0.0000	0.0000	0.0000	0.0113
C28-C37*		0.0045	0.0044	0.0045	0.0030	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0064
C38-C80*		0.0033	0.0032	0.0033	0.0028	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0048
H2O		0.6470	0.6341	0.6456	0.5431	0.0318	0.0318	0.9095	0.0000	0.0000	0.0000	0.0318	0.9055
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

PSEUDO COMPONENT	LIQUID DENSITY (g/cm3)	Tc (^oC)	Pc (bara)	ACENTRIC FACTOR	NBP (^oC)	MOLECULAR WEIGHT (g/mol)	Vc (cm^3/mol)
C6*	0.66	234.2	29.7	0.3	68.7	86.2	370.0
C7*	0.74	241.4	24.5	0.4	103.1	96.0	524.1
C8*	0.77	268.2	21.7	0.4	126.8	107.0	527.9
C9*	0.78	298.1	20.0	0.4	143.6	121.0	527.8
C10-C15*	0.82	419.6	18.1	0.6	220.7	171.6	716.7
C16-C19*	0.85	539.9	14.1	0.8	304.8	242.0	1019.3
C20-C27*	0.88	658.6	12.3	0.9	376.9	318.6	1381.5
C28-C37*	0.90	831.8	10.8	1.1	452.2	441.2	1979.7
C38-C80*	0.94	1084.1	9.7	1.0	579.2	669.1	3271.8

Approved For Construction

MASTER

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.1:
PROBABILITY OF FAILURE TO OPEN CALCULATION

PSV-1312

REV.	DATE	Explanation	Done By		Approved by	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.1 = Probabilty Of Failure To Open

PART 1 : CALCULATION OF PROBABILITY OF FAILURE TO OPEN

The fundamental calculation applied to PRDs for the fail to open case is the product of an estimated overpressure demand case frequency (or demand rate), the probability of the PRD failing to open on demand, and the probability that the protected equipment at higher overpressures will lose containment.

$$P_{f,j}^{prd} = P_{fod,j} \cdot DR_j . P_{f,j}$$ equation (1)

Dimana :

$P_{f,j}^{prd}$ = POF of a PRD overpressure demand case, (failures/year)

$P_{fod,j}$ = POFOD of a PRD (failures/demand)

DR_j = demand rate (demands/year)

$P_{f,j}$ = POF (loss of containment) (failures/year)

The subscript j in the above equation indicates that the POF for the PRD,P prd f , j. needs to be calculated for each of the applicable overpressure demand cases associated with the PRD

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 tahun see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service	:	Methane
Typical Temperature	:	639 ^{o}F
Fluid Severity	:	Mild See Table 7.4
Design Type PRD	:	Conventional
Discharge Location	:	discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fc,for conventional valves discharging to closed system or to flare

F_C = 0.75 for conventional valves discharging to closed system or flare

F_C = 1.00 for all other cases

STEP 4 Determine the environment adjustment factor, Fenv using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 1.0 (see data process condition)

STEP 5 The result of the procedure outlined above will be a modified characteristic life, ηmod, as defined in equation (2)

F_C = 0.75 see step 3

F_C = 1.00 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_C x F_{env} x η_{def} equation (2)

= 0.75 x 1.00 x 37.88

= 28.41

STEP 6 Assemble the PRD's inspection history, Grade each record using the inspection effectiveness table, part 2, Annex 2.c, Table 2.C.3.1. Record the result of each inspection record; PASS/FAIL and NO LEAK/LEAK and determine the confidence factors, Cfi, as applicable, for each inspection history based on the results of the test Determine the time duration, tdur,i of each inspection cycle

STEP 6.1 Each inspection record must be graded using the PRD inspection effectifeness table, part 2, annex 2.C, table 2.C.3.1

- Inspection effectiveness : part 2, annex 2.C, Table 2.C.3.1

Tabel 2.C.3.1- Inspeksi dan pengujian keefektifan untuk PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

STEP 6.2 Record the PASS/FAIL and NO LEAK/LEAK in order to determine the confidence factors, Cfi , as applicable , for each inspection history where a test was conducted

- Inspection Record = No Leak / Leak

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i = 0.5 see table 7.8

` Determine the time duration , tdur,I ,between each inspection cycle

a. RBI Date $t_{dur,}i$ = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date $t_{dur,}i$ = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 6.4 Determine if the PRD was overhauled

- refer to section 7.7.2 and 7.7.3 ,as well as figure 7.7, for more information

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{127.63}{1464.9}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.078)}{0.90}\right)$$

= 0.1867

P_S = 127.63

P_{Set} = 1464.9

$\frac{P_s}{P_{set}}$ = 0.0871

STEP 7 Starting at the earliest inspection record, update the modifierd characteristic life ηmod ,determine in step 5 as follows

STEP 7.1 Calculate the prior POF using equation (3) . The time prior for use in equation (3) . Is the time duration of the inspection cycle , tdur,I as determine in step 6 . Note that for the first inspection record ,the modified characteristic life, ηmod, is used . sub sequent inspection record will use the update ed characteristic life ,ηupd,from step 7.5

$$P_{f,Prior}^{prd}=1-\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (3)

t = 4 see step 6

t = 8 see step 6

η_{mod} = 28.41 for the first inspection record see step 5

β = 1.80 see step 2

a. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.09714

STEP 7.2 Hitung probabilitas lulus sebelumnya menggunakan Persamaan (1.18)

$$P_{p,Prior}^{prd}= 1- P_{f,prior}^{prd}$$ equation (4)

A. RBI Date

$P_{p,Prior}^{prd}$ = 1 - 0.02892

$P_{p,Prior}^{prd}$ = 0.97108

B. RBI Plan Date

$P_{p,Prior}^{prd}$ = 1 - 0.09714

$P_{p,Prior}^{prd}$ = 0.90286

STEP 7.3 Determine the condition POF and the conditional probability of pass using Equations (5)

$$P_{f,cond}^{prd}= (1-CF_{pass}).P_{p,prior}^{prd}$$ equation (5)

CF_{pass} = 0.5 step 6.2

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (BRI Plan Date)

A. RBI Date

$P_{f,cond}^{prd}$ = 0.48554

B. RBI Plan Date

$P_{f,cond}^{prd}$ = 0.45143

step 7.4 Calculatethe weighted POF, $P_{f,wgt}^{prd}$ using the appropriate equation from table 7.9

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{f,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{f,wgt}^{prd}$ = 0.4855

B. RBI Plan Date

$P_{f,wgt}^{prd}$ = 0.4514

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (6) and the weighted POF

$$\eta_{upd} = \frac{t}{\left(-ln\left[1 - P_{f,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}}$$ equation (6)

η_{upd} = 10.62

STEP 7.6 Repeat step 7 for each of the inspection record available for the PRD until a final updated value for the characteristic life, , is determineη_{upd}

$$P_{f,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
ηupd	=	28.406	= η_{mod}	see step 5
ηupd	=	10.621		see step 7.5
β	=	1.80		see step 2

a. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.45143

STEP 8 The POFOD should be adjusted based on the overpressure scenario, The overpressure factor Fop,j, is an adjustment for overpressure scenarios higher than 1.3 times the set pressure

$F_{op,j}$ = 1.0 for $\frac{F_{op,j}}{P_{set}} < 1.3$

$F_{op,j}$ = 0.2 for $\frac{F_{op,j}}{P_{set}} > 4$

$F_{op,j}$ = $1 - \frac{1}{3.375} \cdot \left(\frac{F_{op,j}}{P_{set}} - 1.3 \right)$ for all other cases

$F_{op,j}$: overpressure likelyto accur as a result of a PRD failling to open upon demand ,associated with the J overprssure demand case,kPa(psig) = 1773 psig (see data process condition)

P_{set} : The set pressure of the PRD,kPa (psig) = 1465 psig (see data process condition)

$\frac{F_{op,j}}{P_{set}}$: $\frac{1772.5}{1464.9}$: 1.21

$F_{op,j}$: 1

$P_{fod,j} = P_{fod} \cdot F_{op,j}$

P_{fod} = 0.029 (RBI Date) see step 7.1

P_{fod} = 0.451 (RBI Plan Date) see step 7.1

$F_{op,j}$ = 1 see step 7

a. RBI Date

$P_{fod,j}$ = 0.029 x 1

= 0.02892

B. RBI Plan Date

$P_{fod,j}$ = 0.451 x 1

= 0.45143

STEP 9 Estimates for the PRD initiating event frequencies, Efj, based on the various relief overpressure demand cases that the device is providing protection Examples of the initiating event frequencies are provided in Table 7.2 Additional background on the default initiating event frequencies is provided in Table 7. 3

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	EF_j (event/year)
Fire	1 per 250 years	0.004
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 10 Determine Credit for Other Layers of Protection. The concept of a demand rate reduction factor, DRRFj , is introduced here to account for the difference in the overpressure demand case event frequency and the demand rate on the PRD. demand rate reduction factor are provide in Table 7.2

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	$DRRF_f$
Fire	1 per 250 years	0.10
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 11 for each overpressure demand case, determine the demand rate placed on the PRD,DRj.The demand rate (DR) on the PRD is calculated as the product of the initiating event frequency and the DRRFj in accordance with Equation (1.12)

$$DR_j = EF_{j.} \; . DRRF_j \qquad \text{Equation (8)}$$

EF (fire) = initiating fire frequencies = 0.004

DRRF (fire) = demand rate reduction factor = 0.10

DR (fire) = EF (fire) x DRRF (fire)

= 0.004 x 0.10

= 0.0004

EF (overfill) = initiating overfill frequencies = 0.10

DRRF (overfill) = demand rate reduction factor = 0.10

DR (overfill) = EF (overfill) . DRRF (overfill)

= 0.10 . 0.10

= 0.01

step 12 Determine the MAWP of the protected equipment

set pressure	=	1465	psig	see data
% Allowable Overpressure	=	21%		process
MAWP	=	1773	psig	

STEP 13 If an RBI Study has been completed for protected equipment, calculate its damage adjustment POF, Pf, using equation (1.1) since the DF for the protected equipment is a function of time ,the DF must be determined at the PRD inspection interval, t insp, specifide in step 1 . if a risk analysis for fix equipment has not been complated , a DF can be estimated using the values in table 7.10

Table 7. 10 – DF Classes for Protected Equipment

DF Class	DF	Description
None	1	New vessel or inspection shows little if any damage
Minimal	20	equipment has been in service for a reasonable amount of time and inspection shows evidence of minor damage . Damage mechanism have been identified and inspecton data is available.
Minor	200	One or more damage mechanisms have been identified, limited inspection data available and fairly moderate evidence of damage. Single damage mechanism identified, recent inspection indicates moderate evidence of damage.
Moderate	750	Moderate damage found during recent inspection. Low susceptible to one or more damage mechanisms, and limited inspection exists.
Severe	2000	One or more active damage mechanisms present without any recent inspection history. Limited inspection indicating high damage susceptibility

D_f = 20.0

STEP 14 Calculate the POF of the protected equipment at the elevated overpressure,Pf,j using equation (9).

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{(3.464837.\frac{Po,j}{MAWP})}$$ equation (9)

gff_{total}	=	0.0000306	see part 2 table 3.1
D_f	=	20	see step 13
F_{MS}	=	0.5	see part 2 section 3.5.4
$P_{o,j}$	=	127.63	data process condition
MAWP	=	1772.529	see step 12

$$Pf,j = (0.0312881x0.0000306x20x0.5)e^{3.464837.\frac{127.63}{1772.53}}$$

Pf,j = | 0.0000122871

STEP 15 Calculate the POF, ,using Equation (1.11)

A. RBI Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892051 x 0.0004 x 1.23E-05

= | 1.42E-10

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892051 x 0.01 x 1.23E-05

= | 3.55E-09

B. RBI Plan Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.0004 x 1.23E-05

= | 2.22E-09

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.01 x 1.23E-05

= | 5.55E-08

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.2:
PROBABILITY OF FAILURE TO LEAKAGE CALCULATION

PSV-1312

REV.	DATE	Explanation	Done By		Approved by	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

PART 2 : Calculation Procedure - POL at Specified Inspection Interval

The leakage case is different than the fail to open case since the POF is not a function of demand rate but rather is based on failure during continuous operation. The industry data associated with the probability of leakage,Pl , data is in per year units (failure/year). no multiplication by any demand rate is necessary

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 years see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service : Methane

Typical Temperature : 639 °F

Fluid Severity : Mild See Table 7.4

Design Type PRD : Conventional

Discharge Location : discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fs using section 7.3.2.g).

F_s = 1.25 for soft seated design see data material

F_s = 1.00 for all other cases

STEP 4 Determine the environmenta adjustment factor, Fenv.using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 0.6 (see data process condition)

STEP 5 calculate the modified characteristic life, ηmod, using equation (11) and the factors obtain in step 3 and 4.

F_s = 1.25 see step 3

F_{env} = 0.60 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_s . F_{env} . η_{def} equation (11)

= 1.25 x 0.60 x 37.88

= 28.41

STEP 6 Assemble the the PRDs inspection history, grade each record using the inspection effectiveness table, part 2,annex 2.C, Table 2.C.3.1. Record the result of each inspection record.; NO LEAK/LEAK and determine the confidance factors, Cfi, as applicable, for each inspection history based on the result of the test . Determine the time duration, tdur.i. of each inspection cycle.

- Inspection effectiveness : part 2,annex 2.C, Table 2.C.3.1

Table 2.C.3.1- Inspection and testing efectiveness for PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

- Inspection Record : No LEAK/ LEAK

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i : 0.5

- Determine the time duration, tdur,j. of each inspection cycle

A. RBI Date

t_{dur},i = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date

t_{dur},i = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 7 Starting at the earliest inspection record , update the modified characteristic life, ηmod, determine in step 5 as follows

STEP 7.1 Calculate the prior probability of leakage using equation (12). Note that for the first inspection record , the modified characteristic life,ηmod,is used subsequent inspection record will use the updated characteristic from STEP 7.5 below.

$$P_{l,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (12)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P^{prd}_{l,Prior}$ = 0.02892

B. RBI Plan Date

$P^{prd}_{l,Prior}$ = 0.09714

STEP 7.2 Calculate the prior probability of passing using equation (1.18)

$$P^{prd}_{p,Prior} = 1 - P^{prd}_{l,prior}$$ equation (13)

A. RBI Date

$P^{prd}_{p,Prior} = 1 - P^{prd}_{l,prior}$

$P^{prd}_{p,Prior} = 1 - 0.0289$

$P^{prd}_{p,Prior} = 0.97108$

B. RBI Plan Date

$P^{prd}_{p,Prior} = 1 - P^{prd}_{l,prior}$

$P^{prd}_{p,Prior} = 1 - 0.0971$

$P^{prd}_{p,Prior} = 0.90286$

STEP 7.3 Determine the conditional probability of leakage and conditional probability of pass using equation (14)

$$P^{prd}_{l,cond} = (1\text{-}CF_{pass}).P^{prd}_{p,prior}$$ equation (14)

CF_{pass} : 0.5 step 6

$P^{prd}_{p,Prior}$ = 0.97108 (RBI Date) step 7.2

$P^{prd}_{p,Prior}$ = 0.90286 (RBI Plan Date)

A. RBI Date

$P^{prd}_{l,cond}$ = 0.48554

B. RBI Plan Date

$P^{prd}_{l,cond}$ = 0.45143

STEP 7.4 calculate the weighted probability of leakage, $P^{prd}_{l,wgt}$, using the appropriate equation from table 7.9.

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P^{prd}_{f,wgt} = P^{prd}_{f,prior} - 0.2.P^{prd}_{f,prior}\left(\frac{t}{\eta}\right) + 0.2.P^{prd}_{f,cond}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P^{prd}_{f,wgt} = P^{prd}_{f,cond}$
Usually Effective Fail	
Fairly Effective Fail	$P^{prd}_{f,wgt} = 0.5.P^{prd}_{f,prior} + 0.5.P^{prd}_{f,cond}$

$P^{prd}_{l,wgt}$ = $P^{prd}_{f,cond}$ choose equation from table 7.9

A. RBI Date

$P_{l,wgt}^{prd}$ = 0.48554

B. RBI Plan Date

$P_{l,wgt}^{prd}$ = 0.45143

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (15) and the weighted probability of leakage, $P_{l,wgt}^{prd}$ established in step 7.4

$$\eta upd = \frac{t}{(-\ln\left[1 - P_{f,wgt}^{prd}\right])^{\frac{1}{\beta}}}$$ equation (15)

η_{upd} = 10.62

STEP 8 Calculate the probability of leakage for the specific PRD in accordance with Equation (16)

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (16)

t = 4 year see step 6

t = 8 year see step 6

β = 1.80 see step 2

η_{upd} = 28.41 = η_{mod} see step 5

η_{upd} = 10.62 see step 7.6

a. RBI Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{4}{28.41}\right)^{1.80}\right]$

P_l^{prd} = 0.02892

B. RBI Plan Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{8}{10.62}\right)^{1.80}\right]$

P_l^{prd} = 0.45143

STEP 9

The Probability of leakage needs to be adjusted based on the closedness the system is operating near the set pressure with equation (17). The set pressure factor , F_{set} , is dependent on the PRD type.

$$P_{l,j}^{prd} = P_l^{prd} . F_{set}$$ equation (1.36)

PRD Type = Conventional see data general

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{127.6}{1465}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.078)}{0.90}\right)$$

$$= 0.1867$$

$P_S =$ 127.6 see data

$P_{Set} =$ 1465 process

A. RBI Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.0289 step 8

F_{set} = 0.1867 Table 7.7

$P_{l,j}^{prd}$ = 0.0289 x 0.1867

= 0.0054

B. RBI Plan Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.45143 step 8

F_{set} = 0.1867 Table 7.7

$P_{l,j}^{prd}$ = 0.4514 x 0.1867

= 0.0843

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 3:
CONSEQUENCE OF FAILURE CALCULATION

PSV-1312

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

PART 3 CONSEQUENCE CALCULATION of FAILURE to OPEN

STEP 1 Determine the list of overpressure scenarios applicable to the piece of equipment being protected by the PRD under evaluation. Table 7.2 provides a list of overpressure demand cases specific covered.

Overpressure Demand Case for PSV-1312

1 Fire see table 7.3

2 Liquid Overfillling without administrative controls in place

step 2 For each overpressure demand case, estimate the amount of overpressure, $p_{o,j}$ likely to occur during the overpressure event if the PRD were to fail to open.

Table 7.3 - Overpressure Scenario Project

Initiating Event	Equipment Type	PRD Demand rate reduction factor	Qualifier	over pressure potential	Background and comment
1. Overpressure Scenario					
1 per 250 years	All Equipment Type	0.1 industry experience justifies this value	N/A	4.0 x MAWP (RUPTURE)	see table 7.3
2. Overpressure scenario - liquid Overfilling					
1 per 100 years (admin control)	All Equipment including process tower	1.00	downsteam of positif displacement type rotating equipment	4.0 x MAWP	see table 7.3

$P_{0,fire}$ = 4 x MAWP
= 4 x 1773
= 7092 psig

$P_{o,overfilling}$ = 4 x MAWP
= 4 x 1773
= 7092 psig

STEP 3 For instalations that have multiple PRDs, determine the total amount of installed PRD orifice area , A_{total}^{prd}, including the area of the PRD being evaluated. Calculate the overpressure adjustment factor, , in accordance with equation (1.37) F_a

$$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \qquad \text{equation (1.37)}$$

A^{prd} = is the orifice area of the PRD, mm2

A_{total}^{prd} = is the total installed orifice area of a multiple device installation,mm2

multiple PRD ? no

F_a = 1

STEP 4 Reduce the overpressures determined in step 3 by the overpressure adjustment factor accordance with equation (1.38)

$$P_{o,j} = F_a \,.\, P_{o,j} \qquad \text{equation (1.38)}$$

F_a = 1 see step 3

$P_{0,fire}$	=	7092.0		$P_{o,overfilling}$	=	7092.0	
$P_{0,fire}$	=	7092.0 x	1	$P_{o,overfilling}$	=	7092.0 x	1
	=	7092.0 psig			=	7092.0 psig	

STEP 5 for each overpressure demand case, calculate the financial consequence ,....., C_{fl}^{prd} of loss containment from protected equipment using procedures developed in part 3. use the overpressure for demand cases as determine in STEP 4 in lieu of the operating pressure, P_s

STEP 1 Determine the Representative Fluid and Associated Properties

Fluid Properties

Sifat-sifat fluida yang dibutuhkan yang diperkirakan untuk masing-masing fluida representatif disediakan dalam Tabel 4.2 API 581 Bagian 3 COF dan tergantung pada fase simpanan fluida di bawah ini:

A). Stored Liquid	
1. Normal Boiling Point	(NBP)
2. Density	(ρt)
3. Auto-iIgnition Temperature	(AIT)
B). Stored Vapor or Gas	
1. Normal Boiling Point	(NBP)
2. Morcular Weight	(MW)
3. Ideal Gas Specific Heat Capacity Ratio	(k)
4. Constant Pressure Specific Heat	(Cp)
5. Auto-iIgnition Temperature	(AIT)

STEP 1.1 Select Representative fluid group Table 4.1

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

Fluid Composition Table

Well	Composition	Symbol	Amount	Unit
	Nitrogen	N_2	0.68	% mole
	Carbon Dioxide	CO_2	1.05	% mole
	Methane	CH_4	72.25	% mole
	Ethane	C_2H_6	7.9	% mole
	Propane	C_3H_8	6.84	% mole
`	i-Butane	i-C_4H_{10}	1.9	% mole
	n-Butane	n-C_4H_{10}	2.4	% mole
	i-Pentane	i-C_5H_{12}	5.01	% mole
	n-Pentane	n-C_5H_{12}	0.47	% mole
	Hexane Plus	C_6^+	1.5	% mole
		TOTAL	100.000	% mole

Chosen Representative Fluid : C1-C2

STEP 1.2 Determine the store fluid phase, liquid or vapor, if two phase , a level 2 consequence analysis should be performed

Stored fluid phase : Gas

Step 1.3 Determine the stored fluid properties

For a stored liquid

MW – Molecular weight, kg/kg-mol (lb/lb-mol), can be estimated from Table 4.2

k – Ideal gas specific heat ratio, can be estimated using Equation (3.1) and the C P values as determined using Table 4.2

AIT – Auto-ignition temperature, K (°R), can be estimated from Table 4.2

Table 4.2 - Properties of the Representative Fluids Used in Level 1 Consequence Analysis

Fluid	MW	Liquid Density (lb/ft^3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	CP				Auto ignition Temperature (°F)
						Ideal Gas Constant A	Ideal Gas Constant B	Ideal Gas Constant C	Ideal Gas Constant D	
C1-C2	23	15.64	-193	Gas	Note 1	12.3	1.15E-01	-2.87E-03	-1.30E-09	1036
C2-C3	51	33.61	-6.3	Gas	Note 1	2.632	0.3188	-1.35E-04	1.47E-08	696
C25+	422	56.19	981	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	396

1). Molecular Weight (MW), kg/kg-mol (lb/lb-mol)

The stored vapor Molecular Weight (MW) can be estimated from Table 4.2

MW = 23.00 (kg/kg-mol)

2). Auto-Ignition Temperature, K (^oR)

The stored liquid Auto-Ignition Temperature (AIT) can be estimated from Table 4.2 of API 581 Part 3 of COF.

AIT = 1036 (^oF)

AIT = 830.927778 (K)

AIT = 446.222222 (^oR)

3). Ideal gas specific heat ratio, k

Cp_A = 12.3 J/kmol-K

Cp_B = 1.15E-01 J/kmol-K

Cp_C = -2.87E-03 J/kmol-K

Cp_D = -1.30E-09 J/kmol-K

T = 71 C

T = 159.8 F

T = 344.15 K

R = 8.314 J/kg-mol-K

$Cp = A + BT + CT^2 + DT^3$ ..... equation (19)

= 12.3 + (0.015 x 344.15) + (-0.0000287 x 344.15)^2 + (-1.3^{-9} x 344.15)^3

= 52.852822 J/kmol-K

$k = \frac{Cp}{Cp - R}$ ..... equation (20)

$= \frac{52.853}{52.853 - 8.314}$

= 1.18666861

STEP 1.4 Determine the steady state phase of the fluid after release to the atmosphere, using Table 4.3 and the phase of the fluid stored in the equipment as determine in STEP 1.2.

Table 4.3 - Level 1 Guidelines for Determining the phase of a fluid

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (After release) Condition	Determine of Final Phase for Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	model as gas usless the fluid boilling point at ambient condiitions is greater than 80 F , than model as liquid
Liquid	Liquid	Model as Liquid

The fluid is Gas in the vessel, its post release is Gas

STEP 2 Release Hole Size Selection

STEP 2.1 Based on component type and table 4.4, determine the release hole size diameters, d_n.

Table 4.4 - Release Hole Sizes and Areas Used in Level 1 and 2 Consequences Analysis

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	$d_1 = 0.25$
2	Medium	> 1/4 - 2	$d_2 = 1$
3	Large	> 2 - 6	$d_3 = 4$
4	Rupture	. 6	d_4 = min[D,16]

STEP 2.2 Determine the failure frequency, gff_n, for the nth release hole size from part 2, table 3.1, and the total generic failure frequency from this table or from equation (3.2)

$$gff_{total} = \sum_{n=1}^{4} gff_n \qquad (3.2)$$

Table 3.1 part 2, suggested component generic failure frequencies

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

Diameter = 200 mm = 7.88 inci

gff_{total} = 8.00E-06 failures/year

gff_{small} = 2.00E-05 failures/year

gff_{medium} = 2.00E-05 failures/year

gff_{large} = 6.00E-07 failures/year

$gff_{rupture}$ = 3.06E-05 failures/year

STEP 3 Release Rate Calculation

There are two regimes for flow gases through an orifice: aonic (choked) for higher internal pressure, and subssonic flow for lower pressure (nominally 15 psig (103.4 kPa) or less). The transition pressure at which the flow regime changes from sonic to subsonic is determined using below equation.

P_{atm} = 14.69 psi

k = 1.1867

$$P_{trans} = P_{atm}\left(\frac{k+1}{2}\right)^{\frac{k}{k-1}} \quad \text{..... equation (21)}$$

$$P_{trans} = 14.69\left(\frac{1.187+1}{2}\right)^{\frac{1.187}{0.187}}$$

= 18.0215241 psi

STEP 3.1 Select the appropriate release rate equation

$$W_n = \frac{Cd}{C2}\ x\ An \text{ x } Ps\sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)}\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}} \quad \text{..... equation (22)}$$

Abbreviation list :

C_d	=	Discharge coefficient, for turbulent liquid flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$			
	=	0.9			
A_n	=	Release hole sized area			
P_s	=	Storage operating pressure	=	7092	psi
P_{atm}	=	Atmosphere pressure	=	14.69	psi
k	=	Ideal gas specific heat capacity ratio	=	1.1867	
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	71	C
			=	159.8	F
			=	344.15	K

STEP 3.2 For every release hole size, calculate the release hole size area based on d_n

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

The release hole size area can be determined by formulating below equation:

$$An = \frac{\pi dn^2}{4} \quad \text{.....} \quad \text{equation (22)}$$

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

= 0.0064 m

π = 3.14

$$A1 = \frac{\pi d1^2}{4}$$

$$= \frac{3.14\ x\ (0.25)^2}{4}$$

= 0.0491 $inch^2$

= 3E-05 m^2

2). MEDIUM RELEASE HOLE SIZE AREA

d_1 = 1 inch

= 0.0254 m

π = 3.14

$$A2 = \frac{\pi d2^2}{4}$$

$$= \frac{3.14\ x\ (1)^2}{4}$$

= 0.785 $inch^2$

= 0.0005 m^2

3). LARGE RELEASE HOLE SIZE AREA

d_1 = 4 inch

= 0.1016 m

π = 3.14

$$A3 = \frac{\pi d3^2}{4}$$

= 12.56 $inch^2$

= 0.0081 m^2

4). RUPTURE RELEASE HOLE SIZE AREA

d_1 = 16 inch

= 0.4064 m

π = 3.14

$$A4 = \frac{\pi d4^2}{4}$$

$$= \frac{3.14\ x\ (16)^2}{4}$$

= 200.96 $inch^2$

= 0.1296 m^2

STEP 3.3 For liquid releases, for each release hole size, calculate the viscosity correction factor ($K_{v,n}$)

$$K_{v,n} = \left(0.9935 + \frac{2.878}{Ren^{0.5}} + \frac{342.75}{Ren^{1.5}}\right)^{-1} \quad \text{..... (equation 62)}$$

Because the store fluid phase determined in STEP 1.2 is gaseous or vapor phase, then, this step is no neeed to be considered.

STEP 3.4 For each hole size, calculate the release rate, W_n, for each release area A_n

$$W_n = \frac{Cd}{C2}\ x\ An\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Abbreviation List:

C_d = 0.9

k = 1.18666861

ρl = 250.51 kg/m^3

= 2.5051E-07 kg/mm^3

A_1 = 3.1645E-05 m^2

A_2 = 0.00050645 m^2

A_3 = 0.00810321 m^2

A_4	=	0.1296192	m^2
gc	=	1	kgm/Ns^2
	=	32.2	$lb_m ft/lb_f S^2$
Ps	=	48899.34	Kpa
P_{atm}	=	101.288	KPa
C_2	=	1	
R	=	8.314	J/(kg-mol-K)
g_c	=	9.8	m/s^2
T_s	=	344.15	K
MW	=	23.00	(kg/kg-mol)

1). SMALL RELEASE HOLE SIZE AREA

$$W_1 = \frac{Cd}{C2} x\ A1 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_1 = \frac{0.9}{C2} x\ 0.000031645 \text{ x } 48899.34 \sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 0.25248648 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$W_2 = \frac{Cd}{C2} x\ A2 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_2 = \frac{0.9}{C2} x\ 0.000506451 \text{ x } 48899.34 \sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 4.04078584 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$W_3 = \frac{Cd}{C2} x\ A3 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_3 = \frac{0.9}{C2} x\ 0.00810321 \text{ x } 48899.34 \sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 20.652507 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$W_4 = \frac{Cd}{C2} x\ A4 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_4 = \frac{0.9}{C2} x\ 0.1296192 \text{ x } 48899.34 \sqrt{\left(\frac{1.187\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 1034.18463 kg/s

STEP 4 Estimate the Fluid Inventory Available for Release

STEP 4.1 Group Component and equipment items into inventory groups (see annex 3.A)

only one component is given, and total inventory for the group

STEP 4.2 Calculate the fluid mass ,$mass_{comp}$, in the component being evaluated

ID	=	0.20	m
V_{tot}	=	3.14	m^3
	=	110.88805	ft^3
ρ_{gas}	=	8.43	kg/m^3
	=	0.5262677	lb/ft^3
L	=	100	m
$Mass_{comp}$	=	26.4702	kg

STEP 4.3 Calculate the fluid mass in each of the other components that are included in the inventory group, $mass_{comp,i}$

There are no other component, only an inventory group mass

STEP 4.4 Calculate the fluid mass in the inventory group, $mass_{inv}$, using equation (3.9)

$$mass_{inv} = \sum_{i=1}^{n} mass_{comp,i}$$

Where

$Mass_{comp}$ = is the inventory fluid mass for the component or piece of equipment being evaluated, kgs [lbs]

$Mass_{inv}$ = is the inventory group fluid mass, kgs [lbs]

= 26.4702 kg

STEP 4.5

Calculate the flow rate from a 203mm (8 inch) diameter hole, W_{max8}, using equation (3.3),(3.6)or (3.7) , as aplicable ,with A_n ,A8=32450 mm2 (50.3 inch2). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Where

C_d	=	Discharge coefficient, for turbulent gas flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$	=	0.9	
A_n	=	Release hole sized area	=	5.1031	$inch^2$
			=	129619	mm^2
			=	0.1296	m^2
P_s	=	Storage operating pressure	=	7092	psi
			=	48899	Kpa
P_{atm}	=	Atmosphere pressure	=	14.69	psi
			=	101.29	Kpa
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	71	C
			=	159.8	F
			=	344.15	K
C_2	=	SI and US customary conversion factors	=	1	
k	=	Ideal gas specific heat ratio	=	1.1867	

So,

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_{max8} = \frac{0.9}{1}\ x\ 0.1296 \text{ x } 48899 \sqrt{\left(\frac{1.1867\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.1867+1}\right)^{\frac{1.1867+1}{1.1867-1}}}$$

= 1034.18463 kg/s

STEP 4.6 For each release hole size, calculate the added fluid mass, $mass_{add,n}$, resulting from 3 (three) minutes of flow from the inventory group using equation (3.10) where Wn is the leakage rate for the release hole size being evaluated and $W_{max8,}$ is from step 4.5

$$mass_{add,n} = 180.\min\left[W_n, W_{\max 8}\right] \quad (3.10)$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[\text{W}_1 \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[0.2525, 1034.18\,]$$

$$= \quad 45.448 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add n}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 2}} = 180 \,.\, min[4.0408, 1034.18\,]$$

$$= \quad 727.34 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min\,[20.6525, 1034.18\,]$$

$$= \quad 3717.5 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[1034.18, 1034.18\,]$$

$$= \quad 186153 \text{ kgs}$$

STEP 4.7 For each release hole size, calculate the available mass for release using equation (3.11)

$$mass_{avail,n} = \min\left[\{mass_{comp} + \ mass_{add,n}\}, mass_{inv}\right]$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 1} = min\,.\,[\{26.47 + 45.45\}, 26.47\,]$$

$$= \quad 26.470 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 2} = min\,.\,[\{26.47 + 727.3\}, 26.47\,]$$

$$= \quad 26.470 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 3} = min.[\{26.47 + 3717\}, 26.47]$$

$$= 26.470 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 4} = min.[\{26.47 + 2E+05\}, 26.47]$$

$$= 26.470 \text{ kgs}$$

STEP 5 Determine the release type (continues or instantaneous)

STEP 5.1 For each release hole size, calculate the time required to release 4536kgs (10000 lbs) of fluid

$$t_n = \frac{C3}{W_n} \quad \text{.....} \quad \text{equation (24)}$$

Where

t_n = time required to release 4536 kgs (10000 lbs) of fluid

C_3 = SI and US customary conversion factors

= 4536 kgs

= 10000 lbs

W_n = Theoretical release rate associated with the nth release hole size, kg/s [lb/s]

W_1 = 0.252 kg/s

W_2 = 4.041 kg/s

W_3 = 20.653 kg/s

W_4 = 1034.185 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_1 = \frac{4536}{0.252}$$

= 17965.3182 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_2 = \frac{4536}{4.041}$$

= 1122.55392 s

3). LARGE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_3 = \frac{4536}{20.653}$$

= 219.634352 s

4). RUPTURE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_4 = \frac{4536}{1034.185}$$

= 4.38606401 s

STEP 5.2 Determine the release type for each release hole size

For each release hole size, determine the release type either instataneous or continous using this following criteria:

a. If the release hole size is 6.35 mm(0.25 inch) or less, then the release type is continous

b. If t_n<180 sec and the releaase mass is gretaer than 4536 kgs (100000 lbs), then the release is instataneous: otherwise the release is continous

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 17965 s (Continous)

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1122.6 s (Continous)

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 219.63 s (Continous)

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.3861 s (Instataneous)

STEP6 Estimate The Impact of Detection and Isolation Systems on Release Magnitude

STEP 6.1 Determine the detection and isolation systems presents in the unit

STEP 6.2 Using table 4.5, select the appropriate classification (A,B,C) for the detection system.

Table 4.5 - Detection and Isolation system rating Guide

Type of Detection System	Detection Clssification
Instrumentation designed specifically to detect material losses by changes In operating conditions (i.e., loss of pressure or flow) in the system.	A
Suitable located detectors to determine when the material is present outside the pressure-containing envelope	B
Visual detection, cameras, or detectors with marginal coverage	C
Type of Isolation Sytem	**Isolation Classification**
Isolation or shutdown system activated directly process instrumentation or detection, with no operator intervention	A
Isolation or shutdown system activated by operators in the control room or other suitable locations remote from the leak	B
isolation dependent on manually-operated valves	C

Detection Is A

STEP 6.3 Using table 4.5, select the appropriate classification (a,b,c) for the isolation system

Isolation Is A

STEP 6.4 Determine the release reduction factor factdi using Table 4.6

Table 4.6 - Adjustment to Release Based on Detection and Isolation Systems

System Classification		Release Magnitude Adjustment	duction Factor, *fac*
Detection	Isolation		
A	A	Reduce release rate or mass by 25%	0.25
A	B	Reduce release rate or mass by 20%	0.20
A or B	C	Reduce release rate or mass by 10%	0.10
B	B	Reduce release rate or mass by 15%	0.15
C	C	No adjustment to release rate or mass	0.00

Release Magnitude Adjustment	=	Reduce release rate or mass by 25%
Reduction Factor, $fact_{di}$	=	**0.25**

STEP 6.5 Determine the total leak durations for each release hole sizes using Table 4.7

Table 4.7 - Leak Durations Based on detection and Isolation Systems

Detection System Rating	Isolation System Rating	Maximum Leak Duration, ld_{max}
A	A	20 minutes for 1/4 inch leaks
		10 minutes for 1 inch leaks
		5 minutes for 4 inch leaks
A	B	30 minutes for 1/4 inch leaks
		20 minutes for 1 inch leaks
		10 minutes for 4 inch leaks
A	C	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	A or B	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	C	1 hour for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
C	A, B, or C	1 hour for 1/4 inch leaks
		40 minutes for 1 inch leaks
		20 minutes for 4 inch leaks

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 17965 s (Continous)

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1122.6 s (Continous)

$ld_{max,2}$ = 10 minutes for 1 inch leaks

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 219.63 s (Continous)

$ld_{max,3}$ = 5 minutes for 4 inch leaks

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.3861 s (Instataneous)

$ld_{max,4}$ = 5 minutes for 4 inch leaks

STEP7 Determine The Release Rate And Mass For Consequence of Failure

STEP 7.1 Calculate the adjusted release rate, raten for each release hole size

Reduction Factor, $fact_{di}$ = 0.25

W_1 = 0.252 kg/s

W_2 = 4.041 kg/s

W_3 = 20.653 kg/s

W_4 = 1034.185 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$Rate_1 = W_n\,(1 - fact_{di})$$

$$Rate_1 = 0.252\,(1 - 0.25)$$

= 0.1894 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$Rate_2 = W_n\,(1 - fact_{di})$$

$$Rate_2 = 4.041\,(1 - 0.25)$$

= 3.0306 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$Rate_3 = W_n\,(1 - fact_{di})$$

$$Rate_3 = 20.653\,(1 - 0.25)$$

= 15.489 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$Rate_4 = W_n\,(1 - fact_{di})$$

$$Rate_4 = 1043.185\,(1 - 0.25)$$

= 775.64 kg/s

STEP7.2 Calculate the leak duration, ldn, for each release hole size

$$ld_n = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\,.\,ld_{max,n}\}] \quad \text{.....} \quad \text{equation (25)}$$

$ld_{max,1}$	=	20 minutes for 1/4 inch leaks	20	$Mass_{avail,1}$	=	26.470	kgs
$ld_{max,2}$	=	10 minutes for 1 inch leaks	10	$Mass_{avail,2}$	=	26.470	kgs
$ld_{max,3}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,3}$	=	26.470	kgs
$ld_{max,4}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,4}$	=	26.470	kgs

1). SMALL RELEASE HOLE SIZE AREA

$$ld_1 = min\,.\,[\{\frac{Mass_{avail,1}}{Rate_1}\},\{60\,.\,ld_{max,1}\}]$$

$$ld_1 = min\,.\,[\{\frac{26.47}{0.189}\},\{60\,.\,20\}]$$

= 139.78 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2 = min\,.\,[\{\frac{Mass_{avail,2}}{Rate_2}\},\{60\,.\,ld_{max,2}\}]$$

$$ld_2 = min\,.\,[\{\frac{26.47}{3.031}\},\{60\,.\,10\}]$$

= 8.7343 s

3). LARGE RELEASE HOLE SIZE AREA

$$ld_3 = min\ .\ [\{\frac{Mass_{avail,3}}{Rate_3}\},\{60\ .\ ld_{max,3}\}]$$

$$ld_3 = min\ .\ [\{\frac{26.47}{15.49}\},\{60\ .\ 5\}]$$

$$= \quad 1.7089\ s$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$ld_4 = min\ .\ [\{\frac{Mass_{avail,4}}{Rate_4}\},\{60\ .\ ld_{max,4}\}]$$

$$ld_4 = min\ .\ [\{\frac{26.47}{775.6}\},\{60\ .\ 5\}]$$

$$= \quad 0.0341\ s$$

STEP 7.3 Calculate the release mass, $mass_n$, for each release hole size

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_1 = min\ .\ [\{Rate_1\ .\ ld_1\},Mass_{avail,n}]$$

$$Mass_1 = min\ .\ [\{0.189\ .\ 139.8\},26.47]$$

$$= \quad 26.4702\ kgs$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$Mass_2 = min\ .\ [\{Rate_2\ .\ ld_2\},Mass_{avail,n}]$$

$$Mass_2 = min\ .\ [\{3.031\ .\ 8.734\},26.47]$$

$$= \quad 26.4702\ kgs$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_3 = min\ .\ [\{Rate_3\ .\ ld_3\},Mass_{avail,n}]$$

$$Mass_3 = min\ .\ [\{15.49\ .1.709\},26.47]$$

$$= \quad 26.4702\ kgs$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_4 = min\ .\ [\{Rate_4\ .\ ld_4\},Mass_{avail,n}]$$

$$Mass_4 = min\ .\ [\{775.6\ .\ 0.034\},26.47]$$

$$= \quad 26.4702\ kgs$$

PART 8 : DETERMINE FLAMMABLE AND EXPLOSIVE CONSEQUENCE

8.1 CONSEQUENCE AREA EQUATIONS

1). CONTINOUS RELEASE

$CA_n^{CONT} = \alpha(rate_n)^b$ ..... equation (26)

2). INSTATANEOUS RELEASE

$CA_n^{CONT} = \alpha(mass_n)^b$ ..... equation (27)

STEP 8.1 Select the consequence area mitigation reduction factor, $fact_{mit}$, from Table 4.10

Mitigation System	Consequence Area Adjustemnet	Consequence Area Reduction Factor, factor mit
Inventory blowdown , couple with isolation system classification B or higher	Reduce consequence area by 25%	0.25
Fire water deluge system and monitors	Reduce consequence area by 20%	0.2
Fire water monitor only	Reduce consequence area by 5%	0.05
Foam spray system	Reduce consequence area by 15%	0.15

Mitigation system = Inventory blowdown , couple with isolation system classification B or higher *

Consequence Area = Reducer consequence area by 25 % *

$fact_{mit}$ = 0.25

STEP 8.2 Calculate the energy efficiency, $eneff_n$, for each hole size using equation mentioned below.

C_4 = 2205 1/kg

$eneff_n = 4.log_{10}[C_4 . mass_n] - 15$ ..... equation (28)

$Mass_1$ = 26.470 kgs

$Mass_2$ = 26.470 kgs

$Mass_3$ = 26.470 kgs

$Mass_4$ = 26.470 kgs

1. SMALL RELEASE HOLE SIZE AREA

$eneff_1 = 4 . log_{10} [C_{4A} . mass_1] - 15$

$eneff_1 = 4 . log_{10} [2205 . 26.47] - 15$

$eneff_1 = 4.064663$

2. MEDIUM RELEASE HOLE SIZE AREA

$$eneff_2 = 4 . log_{10} [C_{4A} . mass_2] - 15$$
$$eneff_2 = 4 . log_{10} [2205 . 26.47] - 15$$
$$eneff_2 = 4.064663$$

3. LARGE RELEASE HOLE SIZE AREA

$$eneff_3 = 4 . log_{10} [C_{4A} . mass_3] - 15$$
$$eneff_3 = 4 . log_{10} [2205 . 26.47] - 15$$
$$eneff_3 = 4.064663$$

4. RUPTURE RELEASE HOLE SIZE AREA

$$eneff_4 = 4 . log_{10} [C_{4A} . mass_4] - 15$$
$$eneff_4 = 4 . log_{10} [2205 . 26.47] - 15$$
$$eneff_4 = 4.06466$$

STEP 8.3 Determine the fluid type

Determine the fluid type, either TYPE 0 or TYPE 1 based on Table 4.1 of API RP 581 Part 3 of COF.

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

C_1-C_2	=	TYPE 0	AIT	=	446.222222 (^oR)
MW	=	23 (kg/kg-mol)	T	=	71 (^oC)
AIT	=	1036 (^oF)	T	=	159.8 (^oF)
AIT	=	830.927778 (K)	T	=	344.15 (K)

STEP 8.4 For each release hole size, calculate the component damage consequence areas for Auto-Ignition Not Likely, Continous Release (AINT-CONT), $CA^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

Table 4.8 - Component Damage Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	8.7	0.98			55	0.95			6.5	0.67			164	0.62		
C3-C4	10.1	1.0			64	1.0			4.7	0.7			80	0.63		

$\alpha = \alpha_{cmd,n}^{AINL-CONT} =$ 8.7 b $= b_{cmd}^{AINL-CONT} =$ 0.98

2). Calculate the consequence of area using equation below

$Rate_1$ = 0.189 kg/s

$Rate_2$ = 4.041 kg/s

$Rate_3$ = 20.653 kg/s

Rate4 = 1034.19 kg/s

$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b . (1 - fact_{mit})$ ..... equation (29)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-CONT} = \alpha(rate_1)^b . (1 - fact_{mit})$

= 1.275 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-CONT} = \alpha(rate_n)^b . (1 - fact_{mit})$

= 25.641 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-CONT} = \alpha(rate_n)^b . (1 - fact_{mit})$

= 126.84 m^2

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-CONT} = \alpha\,(rate_4)^b . (1 - fact_{mit})$

= 5873.4 m^2

STEP 8.5 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Continous Release (AIL-CONT), $CA^{AIL\text{-}CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-CONT} =$ 55.0 b $= b_{cmd}^{AIL-CONT} =$ 0.95

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$ ..... equation (30)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$

$= 8.4735\ m^2$

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$

$= 155.45\ m^2$

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$

$= 732.25\ m^2$

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-CONT} = \alpha\,(rate_4)^b.(1 - fact_{mit})$

$= 30150\ m^2$

STEP 8.6 For each release hole size, calculate the component damage consequence areas for Auto-ignition Not Likely, Instaneous Release, (AINL-INST), $CA^{AINL\text{-}INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AINL-INST} =$ 6.5 b $= b_{cmd}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \,.\left(\frac{1-fact_{mit}}{eneff_n}\right)$ ..... equation (31)

From step 7, know that :

$Mass_1$	=	26.470	kgs	$eneff_1$	=	4.065
$Mass_2$	=	26.470	kgs	$eneff_2$	=	4.065
$Mass_3$	=	26.470	kgs	$eneff_3$	=	4.065
$Mass_4$	=	26.470	kgs	$eneff_4$	=	4.065

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 6{,}469\,(26.47)^{0{,}67}.\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 10.77\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 6{,}469(26.47)^{0{,}67}.\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 10.77\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 6{,}469\,(26.47)^{0{,}67}.\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 10.77\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 6{,}469\,(26.47)^{0{,}67}.\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 10.77\ \text{m}^2$$

STEP 8.7 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Instataneous Release (AIL-INST), $CA^{AIL-INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-INST} =$ 164.0 b $= b_{cmd}^{AIL-INST} =$ 0.62

2). Calculate the consequence of area using equation below

$$CA_{cmd,n}^{AIL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{.....} \quad \text{equation (32)}$$

From step 7, know that :

$Mass_1$	=	26.470	kgs	$eneff_1$	=	4.065
$Mass_2$	=	26.470	kgs	$eneff_2$	=	4.065
$Mass_3$	=	26.470	kgs	$eneff_3$	=	4.065
$Mass_4$	=	26.470	kgs	$eneff_4$	=	4.065

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AIL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 164\,(26.47)^{0,62}.\left(\frac{1-0,25}{4.065}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 230.67\ m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AIL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 164\,(26.47)^{0,62}.\left(\frac{1-0,25}{4.065}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 230.67\ m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AIL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 164\,(26.47)^{0,62}.\left(\frac{1-0,25}{4.065}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 230.67\ m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AIL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 164\,(26.47)^{0,62}.\left(\frac{1-0,25}{4.065}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 230.67\ m^2$$

STEP 8.8 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Continous Release (AINL-CONT), $CA_{inj,n}^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

Table 4.9 - Personnel Injury Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	21.8	1.00			143	0.92			12.5	0.67			474	0.63		
C3-C4	25.6	1.0			171	1.0			9.7	0.7			270	0.63		

$\alpha = \alpha_{inj,n}^{AINL-CONT} =$ **21.8** $\quad b = b_{inj,n}^{AINL-CONT} =$ **1.00**

2). Calculate the consequence of area using equation below

$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1 - fact_{mit})$ ….. equation (33)

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-CONT} = \left[\alpha.\left(rate_1^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 3.0944 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-CONT} = \left[\alpha.\left(rate_2^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 66.161 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-CONT} = \left[\alpha.\left(rate_3^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 338.14 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-CONT} = \left[\alpha.\left(rate_4^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 16932 \text{ m}^2$$

STEP 8.9 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Continous Release (AIL-CONT), $CA_{inj,n}^{AIL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-CONT} =$ 143.2 b $= b_{inj,n}^{AIL-CONT} =$ 0.92

2). Calculate the consequence of area using equation below

$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1 - fact_{mit})$ ..... (equation)

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-CONT} = \left[\alpha.\left(rate_1^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$
$$= 23.193 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-CONT} = \left[\alpha.\left(rate_2^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$
$$= 388.13 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-CONT} = \left[\alpha.\left(rate_3^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$
$$= 1741 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-CONT} = \left[\alpha.\left(rate_4^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$
$$= 63743 \text{ m}^2$$

STEP 8.10 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Instataneous Release (AINL-INST), $CA_{inj,n}^{AINL-INST}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AINL-INST} =$ 12.5 b $= b_{inj,n}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (35)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-INST} = \left[a.\left(mass_1^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AINL-INST} = [12{,}46\ (26.47)^{0{,}67}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,1}^{AINL-INST} = 20.64\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-INST} = \left[a.\left(mass_2^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AINL-INST} = [12{,}46\ .(26.47)^{0{,}67}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,2}^{AINL-INST} = 20.64\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-INST} = \left[a.\left(mass_3^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AINL-INST} = [12{,}46\ .(26.47\ )^{0{,}67}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,3}^{AINL-INST} = 20.64\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-INST} = \left[a.\left(mass_4^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AINL-INST} = [12{,}46\ .(26.47\ )^{0{,}67}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,4}^{AINL-INST} = 20.64\ \text{m}^2$$

STEP 8.11 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Instataneous Release (AIL-INST),

$$CA_{inj,n}^{AIL-INST}$$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-INST} =$ 473.9 b $= b_{inj,n}^{AIL-INST} =$ 0.63

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \ldots\ldots\ldots \text{equation (36)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-INST} = \left[a.\left(mass_1^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AIL-INST} = [473{,}9.(26.47)^{0{,}63}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,1}^{AIL-INST} = 688.75 \quad m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-INST} = \left[a.\left(mass_2^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AIL-INST} = [473{,}9.(26.47)^{0{,}63}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,2}^{AIL-INST} = 688.75 \quad m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-INST} = \left[a.\left(mass_3^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AIL-INST} = [473{,}9.(26.47)^{0{,}63}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,3}^{AIL-INST} = 688.75 \quad m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-INST} = \left[a.\left(mass_4^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AIL-INST} = [473{,}9.(26.47)^{0{,}63}].\left(\frac{1-0{,}25}{4.065}\right)$$

$$CA_{inj,4}^{AIL-INST} = 688.75 \quad m^2$$

8.12 STEP 8.12 For each release hole size, calculate the instataneous / continous blending factor, factn^{IC}.

1). FOR CONTINOUS RELEASE

C_5 = 25.2 kg/s

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad \text{.....equation (37)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$fact_1^{IC} = \min\left[\left\{\frac{rate_1}{C_5}\right\}, 1.0\right]$$

$$= \quad 0.0075$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$fact_2^{IC} = \min\left[\left\{\frac{rate_2}{C_5}\right\}, 1.0\right]$$

$$= \quad 0.16035714$$

C). LARGE RELEASE HOLE SIZE AREA

$$fact_3^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$

$$= \quad 0.81956349$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$fact_4^{IC} = \min\left[\left\{\frac{rate_4}{C_5}\right\}, 1.0\right]$$

$$= \quad 1$$

2). FOR INSTATANEOUS RELEASE

$$fact_4^{IC} = 1$$

8.13 Calculate the AIT blending factor, $fact^{AIT}$, using these optional equation below.

$$fact^{AIT} = 0 \quad \text{for } T_S + C_6 \leq AIT \quad \text{equation (38)}$$

$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2 \,.\, C_6} \quad \text{for } T_S + C_6 > AIT > T_S - C_6$$

$$fact^{AIT} = 1 \quad \text{for } T_S - C_6 \geq AIT \quad \text{(equation 86)}$$

Ts	=	71 (^{o}C)	AIT	=	1036 (^{o}F)
Ts	=	159.8 (^{o}F)	AIT	=	830.927778 (K)
Ts	=	344.15 (K)	AIT	=	446.222222 (^{o}R)
C_6	=	55.6 (K)			

$T_s + C_6$	=	399.75 (K)
$T_s - C_6$	=	288.55 (K)
$\frac{(T_s - AIT + C_6)}{2 \,.\, C_6}$	=	-3.8775 (K)

$fact^{AIT}$ = 0

STEP 8.14 Calculate the continuous/instantaneous blended consequence area for the component using equation (3.53) through (3.56) based on the consequence areas calculated in previous steps $fact_n^{IC}$

A. Componen demage for auto-ignition Likely, Continous - Instataneous release

$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} . fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} . (1 - fact_n^{IC})$ equation (40)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-INST}$	=	10.77	m^2
$fact_1^{IC}$	=	0.0075	
$CA_{cmd,1}^{AIL-CONT}$	=	1.2750085	m^2
$CA_{cmd,1}^{AIL}$	=	1.3462175	m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-INST}$	=	10.77	m^2
$fact_2^{IC}$	=	0.160357	
$CA_{cmd,2}^{AIL-CONT}$	=	25.641273	m^2
$CA_{cmd,2}^{AIL}$	=	23.256486	m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-INST}$	=	10.77	m^2
$fact_3^{IC}$	=	0.819563	
$CA_{cmd,3}^{AIL-CONT}$	=	126.84227	m^2
$CA_{cmd,3}^{AIL}$	=	31.713302	m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-INST}$ = 10.77 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AIL-CONT}$ = 5873.36 m^2

$CA_{cmd,4}^{AIL}$ = 10.769546 m^2

B. Personal Injury for auto-ignition Likely, Continous - Instataneous release

$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} . fact_n^{IC} + CA_{inj,n}^{AIL-CONT} . (1 - fact_n^{IC})$ .....equation (41)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AIL-INST}$ = 688.75 m^2

$fact_{n1}^{IC}$ = 0.0075

$CA_{inj,1}^{AIL-CONT}$ = 23.192584 m^2

$CA_{inj,1}^{AIL}$ = 28.184251 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AIL-INST}$ = 688.75 m^2

$fact_{n2}^{IC}$ = 0.1603571

$CA_{inj,2}^{AIL-CONT}$ = 388.12715 m^2

$CA_{inj,2}^{AIL}$ = 436.33388 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AIL-INST}$ = 688.75 m^2

$fact_{n3}^{IC}$ = 0.8195635

$CA_{inj,3}^{AIL-CONT}$ = 1740.9599 m^2

$CA_{inj,3}^{AIL}$ = 878.60557 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AIL-INST}$ = 688.75 m^2

$fact_{n4}^{IC}$ = 1

$CA_{inj,4}^{AIL-CONT}$ = 63743.317 m^2

$CA_{inj,4}^{AIL}$ = 688.74816 m^2

C. Componen demage for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST} . fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (42)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-INST}$ = 10.77 m^2

$fact_1^{IC}$ = 0.0075

$CA_{cmd,1}^{AINL-CONT}$ = 1.2750085 m^2

$CA_{cmd,1}^{AINL}$ = 1.3462175 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-INST}$ = 10.77 m^2

$fact_2^{IC}$ = 0.160357

$CA_{cmd,2}^{AINL-CONT}$ = 25.641273 m^2

$CA_{cmd,2}^{AINL}$ = 23.256486 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-INST}$ = 10.77 m^2

$fact_3^{IC}$ = 0.8196

$CA_{cmd,3}^{AINL-CONT}$ = 126.84227 m^2

$CA_{cmd,3}^{AINL}$ = 31.713302 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-INST}$ = 10.77 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AINL-CONT}$ = 5873.36 m^2

$CA_{cmd,4}^{AINL}$ = 10.769546 m^2

D. Personal Injury for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} . fact_n^{IC} + CA_{inj,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (43)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AINL-INST}$ = 20.64 m^2

$fact_1^{IC}$ = 0.0075

$CA_{inj,1}^{AINL-CONT}$ = 3.0944025 m^2

$CA_{inj,1}^{AINL}$ = 3.2260274 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AINL-INST}$ = 20.64 m^2

$fact_2^{IC}$ = 0.160357

$CA_{inj,2}^{AINL-CONT}$ = 66.161273 m^2

$CA_{inj,2}^{AINL}$ = 58.862315 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AINL-INST}$ = 20.64 m^2

$fact_3^{IC}$ = 0.8196

$CA_{inj,3}^{AINL-CONT}$ = 338.14124 m^2

$CA_{inj,3}^{AINL}$ = 77.932414 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AINL-INST}$ = 20.64 m^2

$fact_4^{IC}$ = 1

$CA_{inj,4}^{AINL-CONT}$ = 16932.194 m^2

$CA_{inj,4}^{AINL}$ = 20.644391 m^2

STEP 8.15 Calculate the AIT blended consequence areas for the component using equations (3.57) and (3.58) based on the consequence areas determined in step 8.14 and the AIT blending factors, , calculate in step 8.13. the resulting consequence areas are the component damage and personnel injury flammable consequence areas, and for each release hole size selected in step 2.2 $CA_{cmd,n}^{flam}$ $CA_{inj,n}^{flam}$

A. Componen Demage

$CA_{cmd,n}^{flam} = CA_{smd,n}^{AIL} . fact^{AIT} + CA_{cmd,n}^{AINL} . (1 - fact^{AIT})$ .....equation (44)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL}$ = 1.3462175 m^2

$fact^{AIT}$ = 0

$CA_{cmd,1}^{AINL}$ = 1.3462175 m^2

$CA_{cmd,1}^{flam}$ = 1.3462175 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL}$ = 23.256486 m^2

$fact^{AIT}$ = 0

$CA_{cmd,2}^{AINL}$ = 23.256486 m^2

$CA_{cmd,2}^{flam}$ = 23.256486 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL}$ = 31.713302 m^2

$fact^{AIT}$ = 0

$CA_{cmd,3}^{AINL}$ = 31.713302 m^2

$CA_{cmd,3}^{flam}$ = 31.713302 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL}$ = 10.769546 m^2

$fact^{AIT}$ = 0

$CA_{cmd,4}^{AINL}$ = 10.769546 m^2

$CA_{cmd,4}^{flam}$ = 10.769546 m^2

B. Personal Injury

$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} . fact^{AIT} + CA_{inj,n}^{AINL} . (1 - fact^{AIT})$ …….. equation (45)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{flam-AIL}$ = 28.184251 m^2

$fact^{AIT}$ = 0

$CA_{inj,1}^{AINL}$ = 3.2260274 m^2

$CA_{inj,1}^{flam}$ = 3.2260274 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{flam-AIL}$ = 436.33388 m^2

$fact^{AIT}$ = 0

$CA_{inj,2}^{AINL}$ = 58.862315 m^2

$CA_{inj,2}^{flam}$ = 58.862315 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{flam-AIL} = 878.60557 \ m^2$

$fact^{AIT} = 0$

$CA_{inj,3}^{AINL} = 77.932414 \ m^2$

$CA_{inj3}^{flam} = 77.932414 \ m^2$

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{flam-AIL} = 688.74816 \ m^2$

$fact^{AIT} = 0$

$CA_{inj,4}^{AINL} = 20.644391 \ m^2$

$CA_{inj4}^{flam} = 20.644391 \ m^2$

STEP 8.16 Determine the consequence areas (probability weighted on release hole size) for component damage and personnel injury using equations (3.59) and (3.60) based on the consequence area from step 8.15

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

CONSEQUENCE AREA FOR COMPONENT DAMAGE

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad \text{.....(equation)}$$

$$CA_{cmd}^{flam} = \left(\frac{(gff_{1.}\, CA_{cmd,1}^{flam}) + (gff_{2.}\, CA_{cmd,2}^{flam}) + (gff_{3.}\, CA_{cmd,3}^{flam}) + (gff_{4.}\, CA_{cmd,4}^{flam})}{gff_{total}} \right)$$

$$= 36.49 \ m^2$$

CONSEQUENCE AREA FOR PERSONNEL INJURY

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad \text{(equation 94)}$$

$$CA_{inj}^{flam} = \left(\frac{\left(gff_1 \cdot CA_{inj,1}^{flam}\right) + \left(gff_2 \cdot CA_{inj,2}^{flam}\right) + \left(gff_3 \cdot CA_{inj,3}^{flam}\right) + \left(gff_4 \cdot CA_{inj,4}^{flam}\right)}{gff_{total}} \right.$$

$$= \left. 90.657\ m^2 \right.$$

PART 9 : CALCULATE THE TOXIC CONSEQUENCES AREA

Table 4.113 Continuous Gas and Liquid Release Toxic Consequence Equation Constantsfor Miscellaneous Chemicals

Chemical	Release Duration (minutes)	Gas Release Constants		Liquid Release Constants	
		e	f	e	f
Aluminum Chloride (Alcl3)	ALL	17.663	0.9411	N/A	N/A
Carbon Monoxide (CO)	3	41.412	1.15	N/A	N/A
	5	279.79	1.06	N/A	N/A
	10	834.48	1.13	N/A	N/A
	20	2915.9	1.11	N/A	N/A
	40	5346.8	1.17	N/A	N/A
	60	6293.7	1.21	N/A	N/A
Hydrogen Chloride (HCL)	3	215.48	1.09	N/A	N/A
	5	536.28	1.15	N/A	N/A
	10	2397.5	1.1	N/A	N/A
	20	4027	1.18	N/A	N/A
	40	7534.5	1.2	N/A	N/A
	60	8625.1	1.23	N/A	N/A
Nitric Acid	3	53.013	1.25	5110	1.08
	5	68.7	1.25	9640.8	1.02
	10	96.325	1.24	12.453	1.06
	20	126.942	1.23	19.149	1.06
	40	146.941	1.22	31.145	1.06
	60	156.345	1.22	41.999	1.12
Nitrogen Dioxide (NO2)	3	6633.1	0.7	2132.9	0.98
	5	9221.4	0.68	2887	1.04
	10	11.965	0.68	6194.4	1.07
	20	14.248	0.72	13.843	1.08
	40	22.411	0.7	27.134	1.12
	60	24.994	0.71	41.657	1.13

Phosgene	3	12.902	1.2	3414.8	1.06
	5	22.976	1.29	6857.1	1.1
	10	48.985	1.24	21.215	1.12
	20	108.298	1.27	63.361	1.16
	40	244.67	1.3	178.841	1.2
	60	367.877	1.31	314.608	1.23
Toluene Diisocyanate (TDI)	3	N/A	N/A	3692.5	1.06
	5	N/A	N/A	3849.2	1.09
	10	N/A	N/A	4564.9	1.1
	20	N/A	N/A	4777.5	1.06
	40	N/A	N/A	4953.2	1.06
	60	N/A	N/A	5972.1	1.03
Ethylene Glycol Monoethyl Ether (EE)	1.5	3.819	1.171	N/A	N/A
	3	7.438	1.181	N/A	N/A
	5	17.735	1.122	N/A	N/A
	10	33.721	1.111	3.081	1.105
	20	122.68	0.971	16.877	1.065
	40	153.03	0.995	43.292	1.132
	60	315.57	0.899	105.74	1.104

Because of no chemical toxic in this equipment, so this step not calculate.

PART 10 : CALCULATE THE NON-FLAMMABLE, NON-TOXIC CA

Step 10.1 For each release hole size, calculate the non-flammable , non-toxic

For steam-calculate $CA_{inj,N}^{CONT}$ using equation (43) and $CA_{inj,N}^{INST}$

1). FOR STEAM

Steam represents a hazard to personnel who are exposed to it at high temperatures. In general, steam is at 100oC (212oF) immediately after exiting a hole in an equipment item. Within a few feet, the steam will begin to mix with air cool, and condensed. The approach used here is that injury occurs above 60oC (140oF). In this case of Production Separator, the temperatur inside the presssure vessel is maximally working at 100oC (212oF). So, steam leaks is potentially occur at this situation.

$Mass_1$ = 26.4702 kgs
$Mass_2$ = 26.4702 kgs
$Mass_3$ = 26.4702 kgs
$Mass_4$ = 26.4702 kgs
$Rate_1$ = 0.1890 kg/s
$Rate_2$ = 4.0410 kg/s
$Rate_3$ = 20.6530 kg/s
$Rate_4$ = 1034.1850 kg/s
C_9 = 0.123 m^2.sec/kg
C_{10} = 9.744 $m^2/kg^{0.06384}$
$fact_1^{IC}$ = 0.0075
$fact_2^{IC}$ = 0.1603571
$fact_3^{IC}$ = 0.8195635
$fact_4^{IC}$ = 1

$CA_{inj,n}^{CONT} = C_9 . Rate_n$) ..... equation (48)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{CONT} = C_9 . Rate_1$)
= 0.02325 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{CONT} = C_9 . Rate_2$)
= 0.49704 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{CONT} = C_9 . Rate_3$)
= 2.54032 m^2

$CA_{inj,n}^{INST} = C_{10} . Mass_n)^{0.6384}$ ..... equation (49)

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{INST} = C_{10} . Mass_4)^{0.6384}$
= 34.633636 m^2

2). FOR ACIDS AND CAUSTIC

For Acids or caustics- compute, $CA_{inj,n}^{CONT}$ using equation (3.72), (3.73), (3.74). Note that the data is not provided for an instantaneous release ; therefore,

No acid or caustic, thus value are 0.

Step 10.2 For each release hole size, calculate the instantaneous/continuous blending factor, $fact_n^{IC}$. For steam, use equation (3.71).

for acids or caustics, $fact_n^{IC}$ =0.0

Step 10.3 For each release hole size , compute the blended non-flammable , non-toxic personnel injury consequence area for steam or acid leaks, $CA_{inj,n}^{leak}$, using equation (3.76) based on the consequence are from step 10.1 and the blending factor , $fact_n^{IC}$, from step 10.2 note that there is no need to calculate component damage area for the level 1 non-flammable release (steam or acid/caustic) :

$CA_{cmd,n}^{leak}$ = 0 m^2

$CA_{inj,n}^{leak} = CA_{inj,n}^{INST}.\ fact_n^{IC} + CA_{inj,n}^{CONT}.(1 - fact_n^{IC})$ ..... equation (50)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{leak} = CA_{inj,1}^{INST}.\ fact_1^{IC} + CA_{inj,1}^{CONT}.(1 - fact_1^{IC})$

= 0.0230726 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{leak} = CA_{inj,2}^{INST}.\ fact_2^{IC} + CA_{inj,2}^{CONT}.(1 - fact_2^{IC})$

= 0.4173386 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{leak} = CA_{inj,3}^{INST}.\ fact_3^{IC} + CA_{inj,3}^{CONT}.(1 - fact_3^{IC})$

= 0.45836629 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{leak} = CA_{inj,4}^{INST}.\ fact_4^{IC} + CA_{inj,4}^{CONT}.(1 - fact_4^{IC})$

= 34.633636 m^2

Step 10.4 Determine the final non-flammable, non toxic consequence areas for personnil injury, CA_{icmd}^{nfnt} using equation (3.80) based on consequence areas calculated for each release hole size in step 10.3 . Note that there is no need to calculate a final-flammable, non-toxic consequence area for component damage area for the level 1 non-flammable release (steam or acid/caustic, or :

$CA_{cmd,n}^{lnfnt} = 0 \ m^2$

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}} \right) \quad \text{..... (equation)}$$

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

$$CA_{inj}^{nfnt} = \left(\frac{(gff_1 \cdot CA_{inj,1}^{leak}) + (gff_2 \cdot CA_{inj,2}^{leak}) + (gff_3 \cdot CA_{inj,3}^{leak}) + (gff_4 \cdot CA_{inj,4}^{leak})}{gff_{total}} \right)$$

$= 1.25748 \ m^2$

PART 11 : CALCULATION OF FINAL CONSEQUENCE AREA

Step 11.1 Calculate the final component damage consequence area, Cacmd

Note that since the component damage consequence areas for toxic releases, CAcmd^{tox}, and non-flammable, non-toxic releases, CAcmd^{nfnt}, are both equal to zero. Then, the final component damage consequence area is equal to the consequence area calculated for flammable releases, CAcmd^{flam}.

CA_{cmd}= CA_{cmd}^{flam} ..... equation (52)

= 36.49 m^2

Step 11.2 Calculate the final personnel injury consequence area, CA_{inj}

CA_{inj} = max $\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$ ..... equation (53)

CA_{inj}^{flam} = 90.657 m^2

CA_{inj}^{tox} = 0.00 m^2

CA_{inj}^{nfnt} = 1.25748 m^2

CA_{inj} = max $\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$

= 90.6565177 m^2

Step 11.3 Calculate the final consequence area, CA, using equation below:

CA=max$\left[CA_{cmd}, CA_{inj}\right]$

= 90.66 m^2

= 975.818635 ft^2

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 4 :

INSPECTION PLANNING AND RECOMMENDATION

PSV-1312

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 4 = Inspection Planning and Recommendation

STEP 1 CALCULATION OF RISK ANALYSIS

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (54)

dimana :

$Risk^{prd}$ = total risiko PRD

$Risk_f^{prd}$ = risiko PRD gagal membuka

$Risk_l^{prd}$ = risiko PRD bocor

STEP 1 Menghitung resiko dari peluang kegagalan PRD untuk gagal membuka $Risk_{f.j}^{prd}$

A. RBI Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 1.42E-10

$C_{f,j}^{prd}$ = 90.66 m^2

$Risk_{f.j}^{prd}$ = 1E-10 x 90.657 = 1.29E-08

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 3.55E-09

$C_{f,j}^{prd}$ = 90.66 m^2

$Risk_{f.j}^{prd}$ = 4E-09 x 90.657 = 3.22E-07

B. RBI Plan Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 2.22E-09

$C_{f,j}^{prd}$ = 90.66 m^2

$Risk_{f.j}^{prd}$ = 2E-09 x 90.657 = 2.01E-07

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 5.55E-08

$C_{f,j}^{prd}$ = 90.66 m^2

$Risk_{f.j}^{prd}$ = 6E-08 x 90.657 = 5.03E-06

$$Risk_f^{prd} = \sum_{j=1}^{ndc} P_{f,j}^{prd} . C_{f,j}^{prd}$$

A. RBI Date

$Risk_f^{prd}$ = 1E-08 + 3E-07

= 3.347E-07

B. RBI Plan Date

$Risk_f^{prd}$ = 2E-07 + 5E-06

= 5.2327E-06

STEP 3 Hitung risiko untuk kasus kebocoran PRD, $Risk_l^{prd}$

$Risk_l^{prd} = P_l^{prd} . C_l^{prd}$ equation (56)

Dimana :

P_l^{prd} = 0.0054 (RBI Date)

P_l^{prd} = 0.0843 (RBI Plan Date)

C_l^{prd} = 90.66 m^2

A. RBI Date

$Risk_l^{prd}$ = 0.0054 x 90.657

= 4.90E-01

B. RBI Plan Date

$Risk_l^{prd}$ = 0.0843 x 90.66

= 7.64E+00

STEP 4 Menghitung total risiko menggunakan persamaan (57)

$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$ equation (57)

A. Risk at RBI Date

$Risk^{prd}$ = 0.4895 m^2/year

= 5.2694 ft^2/year

B. Risk at RBI Plan Date

$Risk^{prd}$ = 7.6423 m^2/year

= 82.262 ft^2/year

STEP 2 Risk Matrix

Probabilty Score at RBI Date = 1E-10 + 4E-09 + 0.0054

= 5.40E-03

Probabilty Score at Plan Date = 2E-09 + 6E-08 + 0.0843

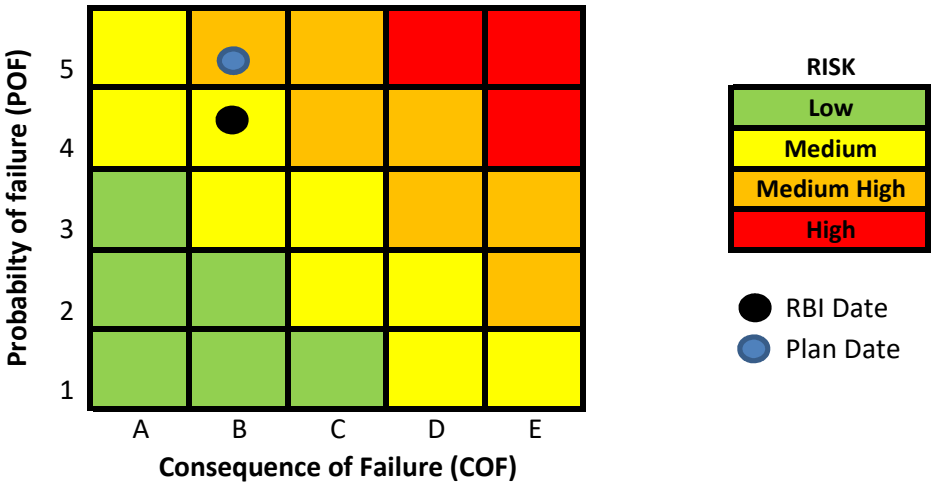
= 8.43E-02

Consequence Score = 90.66 m^2

= 975.82 ft^2

Table 4.1 Numerical Values Associated with POF and Area-Based COF Categories

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t,I_E) \leq 3.06E-05$	$D_{ftotal} \leq 1$	A	$CA \leq 100$
2	$3.06E-05 < P_f(t,I_E) \leq 3.06E-04$	$1 < D_{ftotal} \leq 10$	B	$100 < CA \leq 1.000$
3	$3.06E-04 < P_f(t,I_E) \leq 3.06E-03$	$10 < D_{ftotal} \leq 100$	C	$1.000 < CA \leq 10.000$
4	$3.06E-03 < P_f(t,I_E) \leq 3.06E-02$	$100 < D_{ftotal} \leq 1000$	D	$10.000 < CA \leq 100.000$
5	$P_f(t,I_E) > 3.06E-02$	$D_{ftotal} > 1000$	E	$CA > 100.000$



STEP 3 Inspection Date

Target date dapat dihitung dengan cara melakukan interpolasi nilai RBI Date dan PRBI Plan Date

Dalam menentukan target date, digunakan nilai risk target sebesar 40ft^2 (3.71 m^2) untuk menentukan tahun inspection date.

Data	Date	Age	Risk (m^2/yr)
RBI Date	15/03/2020	0	0.490
Risk Target	?	?	3.710
Plan Date	15/03/2024	11	7.642

$$\frac{Y - Y_1}{Y_2 - Y_1} = \frac{X - X_1}{X_2 - X_1}$$

$$Y = Y_1 + \left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)$$

$$Y = 0 + \left(\frac{3.71 - 0.49}{7.642 - 0.49}\right)(11 - 0)$$

Y = 4.952603 Year

Y = 1807.7001 Hari

= 24/02/2025

Interval inspeksi equipment berikutnya berdasarkan hasil inspeksi berbasis risiko yaitu pada tanggal 24 Febuari 2025

STEP 4 Recommendation

1 Inspection Category

Inspection Effectiveness	Description of Inspection	Date
C	Inspeksi visual telah dilakukan tanpa tes pop, di mana dokumentasi terperinci tentang kondisi internal PRD komponen dibuat.	24/02/2025
Fairly Effective	Tes trevitest atau in-situ telah dilakukan di tempat yang sebenarnya cairan proses tidak digunakan untuk memberi tekanan pada sistem.	

Berdasarkan standart API 581 Direkomendasikan menggunakan inspection effectiveness kategori C dengan mengaplikasikan Visual on-stream inspection

2 Inspection Strategy

Berdasarkan Standart API 576 berikut rekomendasi record visual inspeksi Pressure Relief Device

Unit	Location		Set Pressure	Test Interval
Make		:		
Style		:		
Body and bonnet material		:		
Nozzle and disk material		:		
Trim material		:		
Spring material		:		
Spring no		:		
Flange sizes				
	Inlet	:		
	Outlet	:		
Spring set pressure		:		
Relieving pressure		:		
normal operating temp		:		
Remark				

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 1:

DATA PRESSURE RELIEF DEVICE

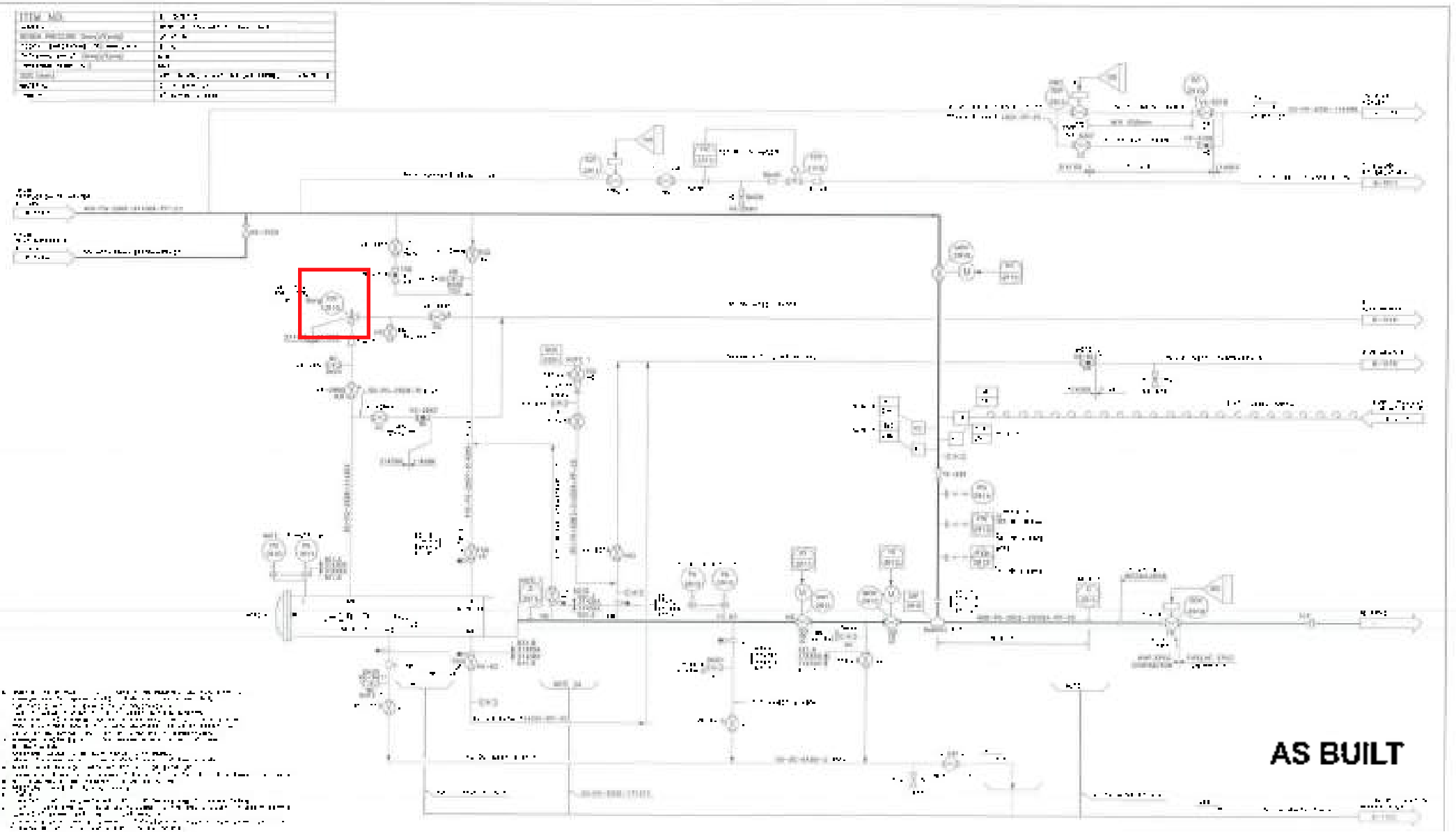
PSV-2910

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

Lampiran 1 = Data Pressure Relief Device

1	GENERAL			
	Tag Number	:	PSV-2910	
	Service	:	WHP to FPSO Gas Pig Launcher	
	Noozle (full/semi)	:	FULL	
	PID No.	:	BTJT-A-B-1012	
	Design	:	SAFETY-RELIEF	
	Type	:	Conventional	
	Bonnet Type	:	Closed	
	Nace Requirement	:	Yes	
2	PROCESS CONDITIONS			
	Fluid	:	Hydrocarbon	
	State	:	Gas	
	Required Capacity	:	149	lb/h
	Molecular Weight	:	23.81	
	Operating Pressure	:	127.6	psig
	Set Pressure	:	512.7	psig
	Operating Temperatur	:	990	^{o}F
	Reliefing Temperatur	:	990	^{o}F
	Back Pressure Constant	:	0	psig
	Back Pressure Variable	:	0	psi
	Back Pressure Total	:	18.42	psig
	% Allowable Overpressure	:	21%	
	Overpressure Factor	:	-	
	Compressible Factor	:	1.006	
	Laten Heat of Vaporation	:	-	Btu/lb
	Ratio of Specific Heats (Cp/C	:	1.112	
	Relief Density	:	-	Lb/ft^2
	Relief Viscosity	:	-	cP
	Barometric Pressure	:	14.7	psia
3	DESIGN CONDITION			
	Design Pressure	:	512.7	psig
	Design Temperatur	:	1000	^{o}F


AS BUILT

CASE 1 : MAXIMUM GAS FLOW RATE (AUGUST 2016)

Stream Name		1	1A	1B	1C	1D	1E	2	2A	2B	2C	2D	2E
Description		Wellhead Flowline U/S of choke - NAG	Wellhead Flowline (BT2_A_P) U/S of choke - Long String	Wellhead Flowline (BT4_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_D_P) U/S of choke - Long String	Wellhead Flowline (BT2_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_E_P) U/S of choke - Long String	Wellhead Flowline D/S of choke - Short String (NAG)	Wellhead Flowline (BT2_A_P) D/S of choke - Long String	Wellhead Flowline (BT4_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_D_P) D/S of choke - Long String	Wellhead Flowline (BT2_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_E_P) D/S of choke - Long String
MIXTURE													
Vapour Fraction		1.0000	0.2955	0.4203	0.2920	0.3055	0.2956	1.0000	0.3159	0.4223	0.2840	0.3115	0.2976
Temperature	C	75.0	75.0	71.0	72.0	75.0	74.0	66.4	69.2	70.2	71.4	74.3	73.4
Pressure	kPag	2959	2959	1034	1034	1034	1034	930	930	930	930	930	930
Pressure	bar g	29.6	29.6	10.3	10.3	10.3	10.3	9.3	9.3	9.3	9.3	9.3	9.3
Mass Flow	kg/h	8478.39	26300.60	110228.76	22227.17	82356.85	29194.58	8478.39	26300.60	110228.76	22227.17	82356.85	29194.58
Molar Flow	kgmole/h	449.11	841.38	3550.51	685.08	2545.47	899.18	449.11	841.38	3550.51	685.08	2545.47	899.18
Molecular Weight		18.9	31.3	31.0	32.4	32.4	32.5	18.9	31.3	31.0	32.4	32.4	32.5
Heat Flow	kW	-9821	-53720	-205650	-44662	-163516	-58456	-9821	-53720	-205650	-44662	-163516	-58456
Mass Heat Capacity	kJ/kg C	2.40	2.98	2.80	2.91	2.91	2.92	2.27	2.92	2.78	2.91	2.90	2.91
Mass Density	kg/m3	21.04	108.95	29.76	43.88	41.06	43.17	7.04	35.86	29.94	38.70	37.14	39.04
GAS PHASE													
Std Gas Flow	kNm3/h	10.05	5.56	33.39	4.46	17.62	5.95	10.05	5.95	33.54	4.51	17.74	5.99
Std Gas Flow	MMSCFD	9.00	4.98	29.91	4.01	15.79	5.33	9.00	5.33	30.05	4.04	15.89	5.36
Molar Flow	kgmole/h	449.11	248.67	1492.34	200.05	787.71	265.75	449.11	265.81	1499.40	201.38	792.94	267.56
Actual Gas Flow	ACT m3/h	403.02	217.58	3621.21	456.87	1934.34	650.66	1205.17	710.89	4009.69	540.36	2148.41	722.19
Mass Flow	kg/h	8478.39	5617.70	37106.46	4989.82	19834.55	6670.73	8478.39	6309.08	37411.64	5048.85	20061.87	6749.84
Molecular Weight		18.9	22.6	24.9	24.9	25.2	25.1	18.9	23.7	25.0	25.1	25.3	25.2
Mass Heat Capacity	kJ/kg-C	2.40	2.30	2.13	2.13	2.14	2.14	2.27	2.13	2.12	2.12	2.13	2.12
Z Factor		0.95	0.93	0.96	0.96	0.96	0.96	0.98	0.97	0.97	0.97	0.97	0.97
Thermal Conductivity	W/m-K	0.041	0.038	0.034	0.034	0.035	0.035	0.038	0.035	0.034	0.034	0.034	0.034
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mass Density	kg/m3	21.04	25.82	10.25	10.25	10.25	10.25	7.04	8.86	9.33	9.34	9.35	9.35
Cp/Cv (Gamma)		1.32	1.30	1.23	1.23	1.22	1.22	1.27	1.23	1.22	1.22	1.22	1.22
OIL PHASE													
Mass Flow	kg/h	—	11155.91	39678.59	9354.61	33942.01	12226.33	—	10545.33	39426.24	9304.07	33751.47	12159.37
Liquid Vol Flow @Std Cond	m3/h	—	13.25	46.51	10.96	39.75	14.32	—	12.29	46.14	10.89	39.46	14.22
Liquid Vol Flow @Std Cond	barrel/day	—	2000	7021	1655	6000	2162	—	1855	6965	1643	5957	2147
Actual Volume Flow	m3/h	—	13.99	48.76	11.50	41.81	15.05	—	12.85	48.32	11.41	41.47	14.93
Molecular Weight		—	174.5	196.6	197.0	198.1	197.7	—	205.6	198.4	199.5	200.7	200.3
Mass Heat Capacity	kJ/kg-C	—	2.16	2.13	2.13	2.14	2.14	—	2.11	2.12	2.13	2.14	2.13
Thermal Conductivity	W/m K	—	0.103	0.109	0.109	0.109	0.109	—	0.111	0.110	0.110	0.110	0.110
Viscosity	cP	—	1.20	1.56	1.54	1.50	1.51	—	1.76	1.62	1.60	1.55	1.56
Mass Density	kg/m3	—	797.60	813.74	813.27	811.86	812.33	—	820.69	815.97	815.22	813.88	814.31
Surface Tension	dyne/cm	—	12.91	14.73	14.89	14.57	14.61	—	15.18	14.92	14.80	14.75	14.78
AQUEOUS PHASE													
Mass Flow	kg/h	—	9526.98	33443.69	7882.74	28580.29	10297.52	—	9445.29	33390.88	7874.25	28543.51	10285.38
Liquid Vol Flow @Std Cond	m3/h	—	9.33	32.56	7.77	28.16	10.15	—	9.31	32.90	7.76	28.13	10.14
Liquid Vol Flow @Std Cond	barrel/day	—	1417	4975	1173	4251	1532	—	1406	4967	1171	4246	1530
Actual Volume Flow	m3/h	—	9.83	34.40	8.12	29.50	10.62	—	9.70	34.33	8.10	29.45	10.60
Molecular Weight		—	18.0	18.0	18.0	18.0	18.0	—	18.0	18.0	18.0	18.0	18.0
Mass Heat Capacity	kJ/kg-C	—	4.34	4.34	4.34	4.35	4.35	—	4.34	4.34	4.34	4.35	4.34
Thermal Conductivity	W/m-K	—	0.666	0.663	0.664	0.666	0.665	—	0.662	0.663	0.663	0.666	0.665
Viscosity	cP	—	0.37	0.39	0.39	0.37	0.38	—	0.41	0.40	0.39	0.38	0.38
Mass Density	kg/m3	—	969.63	972.09	971.29	968.88	969.68	—	973.51	972.66	971.73	969.38	970.15
MIXTURE COMPOSITION (Mole Fraction)													
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0055	0.0025	0.0031	0.0021	0.0022	0.0021	0.0055	0.0025	0.0031	0.0021	0.0022	0.0021
CO2		0.0031	0.0040	0.0055	0.0038	0.0040	0.0039	0.0031	0.0040	0.0055	0.0038	0.0040	0.0039
Methane		0.8827	0.2283	0.2001	0.2016	0.2112	0.2026	0.8827	0.2283	0.2001	0.2016	0.2112	0.2026
Ethane		0.0453	0.0283	0.0393	0.0276	0.0290	0.0278	0.0453	0.0283	0.0393	0.0276	0.0290	0.0278
Propane		0.0262	0.0236	0.0361	0.0260	0.0274	0.0263	0.0262	0.0236	0.0361	0.0260	0.0274	0.0263
i-Butane		0.0072	0.0065	0.0104	0.0078	0.0082	0.0078	0.0072	0.0065	0.0104	0.0078	0.0082	0.0079
n-Butane		0.0081	0.0084	0.0135	0.0103	0.0109	0.0105	0.0081	0.0084	0.0135	0.0103	0.0109	0.0105
i-Pentane		0.0038	0.0040	0.0062	0.0050	0.0053	0.0051	0.0038	0.0040	0.0062	0.0050	0.0053	0.0051
n-Pentane		0.0025	0.0034	0.0050	0.0042	0.0044	0.0043	0.0025	0.0034	0.0050	0.0042	0.0044	0.0043
Mcyclopentan		0.0007	0.0012	0.0015	0.0014	0.0014	0.0014	0.0007	0.0012	0.0015	0.0014	0.0014	0.0014
Benzene		0.0000	0.0003	0.0004	0.0004	0.0004	0.0004	0.0000	0.0003	0.0004	0.0004	0.0004	0.0004
Cyclohexane		0.0004	0.0012	0.0014	0.0014	0.0014	0.0014	0.0004	0.0012	0.0014	0.0014	0.0014	0.0014
Mcyclohexane		0.0006	0.0021	0.0023	0.0024	0.0024	0.0024	0.0000	0.0021	0.0023	0.0024	0.0024	0.0024
Toluene		0.0000	0.0006	0.0006	0.0006	0.0006	0.0006	0.0000	0.0006	0.0006	0.0006	0.0006	0.0006
E-Benzene		0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0002	0.0003	0.0003	0.0003
p-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0004	0.0004
m-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0004	0.0004
o-Xylene		0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002	0.0002	0.0002	0.0002
n-Pbenzene		0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0003	0.0003	0.0003	0.0003
124-Mbenzene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004	0.0004	0.0004
C6*		0.0024	0.0045	0.0056	0.0053	0.0055	0.0054	0.0024	0.0045	0.0058	0.0053	0.0056	0.0054
C7*		0.0000	0.0035	0.0036	0.0039	0.0040	0.0040	0.0000	0.0035	0.0036	0.0039	0.0040	0.0040
C8*		0.0000	0.0036	0.0035	0.0039	0.0039	0.0040	0.0000	0.0036	0.0035	0.0039	0.0039	0.0040
C9*		0.0000	0.0028	0.0020	0.0031	0.0030	0.0031	0.0000	0.0028	0.0026	0.0031	0.0030	0.0031
C10-C15*		0.0000	0.0154	0.0134	0.0164	0.0160	0.0163	0.0000	0.0154	0.0134	0.0164	0.0160	0.0163
C16-C19*		0.0000	0.0057	0.0056	0.0071	0.0070	0.0071	0.0000	0.0057	0.0056	0.0071	0.0070	0.0071
C20-C27*		0.0000	0.0073	0.0063	0.0078	0.0076	0.0077	0.0000	0.0073	0.0063	0.0078	0.0076	0.0077
C28-C37*		0.0000	0.0043	0.0037	0.0045	0.0044	0.0045	0.0000	0.0043	0.0037	0.0045	0.0044	0.0045
C38-C80*		0.0000	0.0031	0.0027	0.0033	0.0032	0.0033	0.0000	0.0031	0.0027	0.0033	0.0032	0.0033
H2O		0.0115	0.6328	0.5354	0.6479	0.6343	0.6456	0.0115	0.6328	0.5354	0.6479	0.6341	0.6456
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Stream Name		3	4	4A	5	6	7	8	9	10
Description		Inlet to Production Separator	Production Separator Gas Outlet	Gas Pipeline to FPSO	Liquid Pipeline to FPSO	Export Gas from FPSO to WHP (Note 7)	Export Gas from WHP to ORF (Note 6)	Gas Lift	Gas Inlet to FPSO (Note 6)	Liquid Inlet to FPSO (Note 6)
MIXTURE										
Vapour Fraction		0.4147	1.0000	1.0000	0.0002	1.0000	1.0000	1.0000	0.0841	0.0019
Temperature	C	70.3	70.5	70.2	70.5	65.8	72.9	65.8	32.1	69.7
Pressure	kPag	930	930	880	880	9101	7120	9101	755	522
Pressure	bar g	9.3	9.3	8.8	8.8	91.0	71.2	91.0	7.6	5.2
Mass Flow	kg/h	289534.88	92836.71	92836.71	196698.17	80517.40	72509.32	7845.62	92836.71	196698.17
Molar Flow	kgmole/h	9400.90	3899.75	3899.75	5501.15	3833.67	3452.38	373.55	3899.75	5501.15
Molecular Weight		30.8	23.8	23.8	35.8	21.0	21.0	21.0	23.8	35.8
Heat Flow	kW	-547951	-96398	-96398	-451503	-86559	-78265	-8434	-96081	-451835
Mass Heat Capacity	kJ/kg C	2.81	2.14	2.14	3.13	2.72	2.61	2.72	2.11	3.13
Mass Density	kg/m3	27.10	8.87	8.43	870.51	75.42	61.13	75.42	7.80	731.73
GAS PHASE										
Std Gas Flow	kNm3/h	87.21	87.24	87.24	0.01	85.76	77.23	8.36	85.80	0.23
Std Gas Flow	MMSCFD	78.12	78.15	78.15	0.02	76.83	69.19	7.49	76.91	0.21
Molar Flow	kgmole/h	3898.34	3899.75	3899.75	1.13	3833.67	3452.38	373.55	3837.74	10.47
Actual Gas Flow	ACT m3/h	10461.79	10470.75	11011.23	3.19	1067.56	1186.11	104.02	11747.85	46.67
Mass Flow	kg/h	92780.89	92836.71	92836.71	27.22	80517.40	72509.32	7845.62	91652.63	286.14
Molecular Weight		23.8	23.8	23.8	24.1	21.0	21.0	21.0	23.9	27.3
Mass Heat Capacity	kJ/kg-C	2.14	2.14	2.14	2.14	2.72	2.61	2.72	2.06	2.06
Z Factor		0.97	0.97	0.97	0.97	0.86	0.86	0.86	0.97	0.97
Thermal Conductivity	W/m-K	0.035	0.035	0.035	0.035	0.047	0.043	0.047	0.033	0.037
Viscosity	cP	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Mass Density	kg/m3	8.87	8.87	8.43	8.54	75.42	61.13	75.42	7.80	6.13
Cp/Cv (Gamma)		1.23	1.23	1.23	1.23	1.46	1.44	1.46	1.24	1.20
OIL PHASE										
Mass Flow	kg/h	107020.05	0.00	—	106954.00	—	—	—	80.05	106703.77
Liquid Vol Flow @Std Cond	m3/h	124.78	0.00	—	124.69	—	—	—	0.10	124.26
Liquid Vol Flow @Std Cond	barrel/day	18834	0	—	18823	—	—	—	16	18758
Actual Volume Flow	m3/h	130.61	0.00	—	130.51	—	—	—	0.11	129.94
Molecular Weight		205.1	205.3	—	205.6	—	—	—	110.1	206.7
Mass Heat Capacity	kJ/kg-C	2.12	2.12	—	2.12	—	—	—	2.02	2.11
Thermal Conductivity	W/m K	0.111	0.111	—	0.111	—	—	—	0.107	0.112
Viscosity	cP	1.72	1.72	—	1.72	—	—	—	0.49	1.79
Mass Density	kg/m3	819.41	819.38	—	819.51	—	—	—	733.22	821.21
Surface Tension	dyne/cm	15.11	15.10	—	15.13	—	—	—	16.73	15.41
AQUEOUS PHASE										
Mass Flow	kg/h	89733.93	0.00	—	89716.95	—	—	—	1104.03	89708.25
Liquid Vol Flow @Std Cond	m3/h	88.42	0.00	—	88.41	—	—	—	1.09	88.40
Liquid Vol Flow @Std Cond	barrel/day	13348	0	—	13345	—	—	—	164	13344
Actual Volume Flow	m3/h	92.26	0.00	—	92.26	—	—	—	1.12	92.20
Molecular Weight		18.0	18.0	—	18.0	—	—	—	18.0	18.0
Mass Heat Capacity	kJ/kg-C	4.34	4.34	—	4.34	—	—	—	4.32	4.34
Thermal Conductivity	W/m-K	0.663	0.663	—	0.663	—	—	—	0.646	0.662
Viscosity	cP	0.40	0.40	—	0.43	—	—	—	0.53	0.40
Mass Density	kg/m3	972.59	972.40	—	972.44	—	—	—	966.88	972.93
MIXTURE COMPOSITION (Mole Fraction)										
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0026	0.0068	0.0068	0.0000	0.0089	0.0089	0.0089	0.0068	0.0000
CO2		0.0044	0.0105	0.0105	0.0001	0.0093	0.0093	0.0093	0.0105	0.0001
Methane		0.3011	0.7225	0.7225	0.0023	0.8082	0.8082	0.8082	0.7225	0.0023
Ethane		0.0317	0.0790	0.0799	0.0010	0.0735	0.0735	0.0735	0.0799	0.0010
Propane		0.0297	0.0684	0.0684	0.0022	0.0574	0.0574	0.0574	0.0684	0.0022
i-Butane		0.0087	0.0190	0.0190	0.0013	0.0151	0.0151	0.0151	0.0190	0.0013
n-Butane		0.0112	0.0240	0.0240	0.0021	0.0178	0.0178	0.0178	0.0240	0.0021
i-Pentane		0.0053	0.0101	0.0101	0.0019	0.0051	0.0051	0.0051	0.0101	0.0019
n-Pentane		0.0043	0.0078	0.0078	0.0016	0.0032	0.0032	0.0032	0.0078	0.0016
Mcyclopentan		0.0014	0.0017	0.0017	0.0011	0.0002	0.0002	0.0002	0.0017	0.0011
Benzene		0.0003	0.0004	0.0004	0.0003	0.0000	0.0000	0.0000	0.0004	0.0003
Cyclohexane		0.0013	0.0015	0.0015	0.0012	0.0001	0.0001	0.0001	0.0015	0.0012
Mcyclohexane		0.0022	0.0017	0.0017	0.0025	0.0000	0.0000	0.0000	0.0017	0.0025
Toluene		0.0000	0.0004	0.0004	0.0007	0.0000	0.0000	0.0000	0.0004	0.0007
E-Benzene		0.0002	0.0001	0.0001	0.0004	0.0000	0.0000	0.0000	0.0001	0.0004
p-Xylene		0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
m-Xylene		0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
o-Xylene		0.0002	0.0001	0.0001	0.0003	0.0000	0.0000	0.0000	0.0001	0.0003
n-Pbenzene		0.0003	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0005
124-Mbenzene		0.0004	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0006
C6*		0.0051	0.0007	0.0007	0.0060	0.0008	0.0008	0.0008	0.0007	0.0060
C7*		0.0035	0.0034	0.0034	0.0037	0.0002	0.0002	0.0002	0.0034	0.0037
C8*		0.0034	0.0018	0.0018	0.0046	0.0000	0.0000	0.0000	0.0018	0.0046
C9*		0.0027	0.0008	0.0008	0.0040	0.0000	0.0000	0.0000	0.0008	0.0040
C10-C15*		0.0140	0.0001	0.0001	0.0238	0.0000	0.0000	0.0000	0.0001	0.0238
C16-C19*		0.0061	0.0000	0.0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0104
C20-C27*		0.0066	0.0000	0.0000	0.0113	0.0000	0.0000	0.0000	0.0000	0.0113
C28-C37*		0.0038	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0066
C38-C80*		0.0028	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0048
H2O		0.5431	0.0318	0.0318	0.9055	0.0000	0.0000	0.0000	0.0318	0.9055
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

PSEUDO COMPONENT	LIQUID DENSITY (g/cm3)	Tc (°C)	Pc (bara)	ACENTRIC FACTOR	NBP (°C)	MOLECULAR WEIGHT (g/mol)	Vc (cm³/mol)
C6*	0.66	234.2	29.7	0.3	68.7	86.2	370.0
C7*	0.74	241.4	24.5	0.4	103.1	96.0	524.1
C8*	0.77	268.2	21.7	0.4	126.8	107.0	527.9
C9*	0.78	298.1	20.0	0.4	143.6	121.0	527.8
C10-C15*	0.82	419.6	18.1	0.6	220.7	171.6	716.7
C16-C19*	0.85	539.9	14.1	0.8	304.8	242.0	1019.3
C20-C27*	0.88	658.6	12.3	0.9	376.9	318.6	1381.5
C28-C37*	0.90	831.8	10.8	1.1	462.2	441.2	1979.7
C38-C80*	0.94	1084.1	0.7	1.0	579.2	669.1	3271.8

Approved For Construction

MASTER

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.1:
PROBABILITY OF FAILURE TO OPEN CALCULATION

PSV-2910

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.1 = Probabilty Of Failure To Open

PART 1 : CALCULATION OF PROBABILITY OF FAILURE TO OPEN

The fundamental calculation applied to PRDs for the fail to open case is the product of an estimated overpressure demand case frequency (or demand rate), the probability of the PRD failing to open on demand, and the probability that the protected equipment at higher overpressures will lose containment.

$$P_{f,j}^{prd} = P_{fod,j} \cdot DR_j \cdot P_{f,j}$$ equation (1)

Dimana :

$P_{f,j}^{prd}$ = POF of a PRD overpressure demand case, (failures/year)

$P_{fod,j}$ = POFOD of a PRD (failures/demand)

DR_j = demand rate (demands/year)

$P_{f,j}$ = POF (loss of containment) (failures/year)

The subscript j in the above equation indicates that the POF for the PRD,P prd f , j. needs to be calculated for each of the applicable overpressure demand cases associated with the PRD

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 tahun see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service	:	Methane
Typical Temperature	:	990 ^{o}F
Fluid Severity	:	Mild See Table 7.4
Design Type PRD	:	Conventional
Discharge Location	:	discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fc,for conventional valves discharging to closed system or to flare

F_C = 0.75 for conventional valves discharging to closed system or flare

F_C = 1.00 for all other cases

STEP 4 Determine the environment adjustment factor, Fenv using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 1.0 (see data process condition)

STEP 5 The result of the procedure outlined above will be a modified characteristic life, ηmod, as defined in equation (2)

F_C = 0.75 see step 3

F_C = 1.00 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_C x F_{env} x η_{def} equation (2)

= 0.75 x 1.00 x 37.88

= 28.41

STEP 6 Assemble the PRD's inspection history, Grade each record using the inspection effectiveness table, part 2, Annex 2.c, Table 2.C.3.1. Record the result of each inspection record; PASS/FAIL and NO LEAK/LEAK and determine the confidence factors, Cfi, as applicable, for each inspection history based on the results of the test Determine the time duration, tdur,i of each inspection cycle

STEP 6.1 Each inspection record must be graded using the PRD inspection effectifeness table, part 2, annex 2.C, table 2.C.3.1

- Inspection effectiveness : part 2, annex 2.C, Table 2.C.3.1

Tabel 2.C.3.1- Inspeksi dan pengujian keefektifan untuk PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

STEP 6.2 Record the PASS/FAIL and NO LEAK/LEAK in order to determine the confidence factors, Cfi , as applicable , for each inspection history where a test was conducted

- Inspection Record = No Leak / Leak

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak,CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i = 0.5 see table 7.8

STEP 6.3 Determine the time duration , tdur,I ,between each inspection cycle

a. RBI Date $t_{dur,}i$ = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date $t_{dur,}i$ = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 6.4 Determine if the PRD was overhauled

- refer to section 7.7.2 and 7.7.3 ,as well as figure 7.7, for more information

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{127.63}{512.7}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.224)}{0.90}\right)$$

= 0.2766

P_S = 127.63

P_{Set} = 512.7

$\frac{P_s}{P_{set}}$ = 0.2489

STEP 7 Starting at the earliest inspection record, update the modifierd characteristic life ηmod ,determine in step 5 as follows

STEP 7.1 Calculate the prior POF using equation (3) . The time prior for use in equation (3) . Is the time duration of the inspection cycle , tdur,I as determine in step 6 . Note that for the first inspection record ,the modified characteristic life, ηmod, is used . sub sequent inspection record will use the update ed characteristic life ,ηupd,from step 7.5

$$P_{f,Prior}^{prd}=1-\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.09714

STEP 7.2 Hitung probabilitas lulus sebelumnya menggunakan Persamaan (1.18)

$$P_{p,Prior}^{prd}= 1- P_{f,prior}^{prd}$$ equation (4)

A. RBI Date

$P_{p,Prior}^{prd}$ = 1 - 0.0289

$P_{p,Prior}^{prd}$ = 0.97108

B. RBI Plan Date

$P_{p,Prior}^{prd}$ = 1 - 0.0971

$P_{p,Prior}^{prd}$ = 0.90286

STEP 7.3 Determine the condition POF and the conditional probability of pass using Equations (5)

$$P_{f,cond}^{prd}= (1-CF_{pass}).P_{p,prior}^{prd}$$ equation (5)

CF_{pass} = 0.5 step 6.2

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (BRI Plan Date) step 7.2

A. RBI Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48554

B. RBI Plan Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45143

step 7.4 Calculatethe weighted POF, $P_{f,wgt}^{prd}$ using the appropriate equation from table 7.9

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{f,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{f,wgt}^{prd}$ = 0.4855

B. RBI Plan Date

$P_{f,wgt}^{prd}$ = 0.4514

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (6) and the weighted POF

$$\eta_{upd} = \frac{t}{\left(-ln\left[1 - P_{f,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}}$$ equation (6)

η_{upd} = 10.62

STEP 7.6 Repeat step 7 for each of the inspection record available for the PRD until a final updated value for the characteristic life, η_{upd}, is determin

$$P_{f,Prior}^{prd} = 1 - \exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
ηupd	=	28.406	= η_{mod}	see step 5
ηupd	=	10.621		see step 7.5
β	=	1.80		see step 2

A. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.45143

STEP 8 The POFOD should be adjusted based on the overpressure scenario, The overpressure factor Fop,j, is an adjustment for overpressure scenarios higher than 1.3 times the set pressure

$F_{op,j}$ = 1.0 for $\frac{F_{op,j}}{P_{set}} < 1.3$

$F_{op,j}$ = 0.2 for $\frac{F_{op,j}}{P_{set}} > 4$

$F_{op,j}$ = $1 - \frac{1}{3.375} \cdot \left(\frac{F_{op,j}}{P_{set}} - 1.3\right)$ for all other cases

$F_{op,j}$: overpressure likelyto accur as a result of a PRD failling to open upon demand ,associated with the J overprssure demand case,kPa(psig) = 620.4 psig (see data process condition)

P_{set} : The set pressure of the PRD,kPa (psig) = 512.7 psig (see data process condition)

$\frac{F_{op,j}}{P_{set}}$: $\frac{620.37}{512.7}$: 1.21

$F_{op,j}$: 1

$P_{fod,j} = P_{fod} \cdot F_{op,j}$ equation (7)

P_{fod} = 0.029 (RBI Date) see step 7.1

P_{fod} = 0.451 (RBI Plan Date) see step 7.1

$F_{op,j}$ = 1 see step 7

A. RBI Date

$P_{fod,j}$ = 0.029 x 1

= 0.02892

B. RBI Plan Date

$P_{fod,j}$ = 0.451 x 1

= 0.45143

STEP 9 Estimates for the PRD initiating event frequencies, Efj, based on the various relief overpressure demand cases that the device is providing protection Examples of the initiating event frequencies are provided in Table 7.2 Additional background on the default initiating event frequencies is provided in Table 7. 3

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	EF_j (event/year)
Fire	1 per 250 years	0.004
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 10 Determine Credit for Other Layers of Protection. The concept of a demand rate reduction factor, DRRFj , is introduced here to account for the difference in the overpressure demand case event frequency and the demand rate on the PRD. demand rate reduction factor are provide in Table 7.2

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	$DRRF_f$
Fire	1 per 250 years	0.10
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 11 for each overpressure demand case, determine the demand rate placed on the PRD,DRj.The demand rate (DR) on the PRD is calculated as the product of the initiating event frequency and the DRRFj in accordance with Equation (1.12)

$$DR_j = EF_{j.} \; . DRRF_j$$ Equation (8)

EF (fire) = initiating fire frequencies = 0.004

DRRF (fire) = demand rate reduction factor = 0.10

DR (fire) = EF (fire) x DRRF (fire)

= 0.004 x 0.10

= 0.0004

EF (overfill) = initiating overfill frequencies = 0.10

DRRF (overfill) = demand rate reduction factor = 0.10

DR (overfill) = EF (overfill) x DRRF (overfill)

= 0.10 x 0.10

= 0.01

step 12 Determine the MAWP of the protected equipment

set pressure	=	512.7 psig	see data
% Allowable Overpressure	=	21%	process
MAWP	=	620.4 psig	

STEP 13 If an RBI Study has been completed for protected equipment, calculate its damage adjustment POF, Pf, using equation (1.1) since the DF for the protected equipment is a function of time ,the DF must be determined at the PRD inspection interval, t insp, specifide in step 1 . if a risk analysis for fix equipment has not been complated , a DF can be estimated using the values in table 7.10

Table 7. 10 – DF Classes for Protected Equipment

DF Class	DF	Description
None	1	New vessel or inspection shows little if any damage
Minimal	20	equipment has been in service for a reasonable amount of time and inspection shows evidence of minor damage . Damage mechanism have been identified and inspecton data is available.
Minor	200	One or more damage mechanisms have been identified, limited inspection data available and fairly moderate evidence of damage. Single damage mechanism identified, recent inspection indicates moderate evidence of damage.
Moderate	750	Moderate damage found during recent inspection. Low susceptible to one or more damage mechanisms, and limited inspection exists.
Severe	2000	One or more active damage mechanisms present without any recent inspection history. Limited inspection indicating high damage susceptibility

D_f = 20.0

STEP 14 Calculate the POF of the protected equipment at the elevated overpressure,Pf,j using equation (9).

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{(3.464837..\frac{Po,j}{MAWP})}$$ equation (9)

gff_{total}	=	0.0000306	see part 2 table 3.1
D_f	=	20.0	see step 13
F_{MS}	=	0.5	see part 2 section 3.5.4
$P_{o,j}$	=	127.63	data process condition
MAWP	=	620.367	see step 12

$$Pf,j = (0.0312881x0.0000306x20x0.5)e^{3.464837..\frac{127.63}{620.367}}$$

Pf,j = | 0.0000195290

STEP 15 Calculate the POF, ,using Equation (1.11)

A. RBI Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892 x 0.0004 x 1.9529E-05

= | 2.26E-10

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892 x 0.01 x 1.95E-05

= | 5.65E-09

B. RBI Plan Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.0004 x 1.95E-05

= | 3.53E-09

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.01 x 1.95E-05

= | 8.82E-08

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.2:
PROBABILITY OF FAILURE TO LEAKAGE CALCULATION

PSV-2910

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

PART 2 : Calculation Procedure - POL at Specified Inspection Interval

The leakage case is different than the fail to open case since the POF is not a function of demand rate but rather is based on failure during continuous operation. The industry data associated with the probability of leakage,Pl , data is in per year units (failure/year). no multiplication by any demand rate is necessary

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 years see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service : Methane
Typical Temperature : 990 °F
Fluid Severity : Mild See Table 7.4
Design Type PRD : Conventional
Discharge Location : discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80
η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5
: 37.875

STEP 3 Determine the adjustment factor, Fs using section 7.3.2.g).

F_s = 1.25 for soft seated design see data material
F_s = 1.00 for all other cases

STEP 4 Determine the environmenta adjustment factor, Fenv.using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 0.6 (see data process condition)

STEP 5 calculate the modified characteristic life, ηmod, using equation (11) and the factors obtain in step 3 and 4.

F_s = 1.25 see step 3

F_{env} = 0.60 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_s . F_{env} . η_{def} equation (11)

= 1.25 x 0.60 x 37.88

= 28.41

STEP 6 Assemble the the PRDs inspection history, grade each record using the inspection effectiveness table, part 2,annex 2.C, Table 2.C.3.1. Record the result of each inspection record.; NO LEAK/LEAK and determine the confidance factors, Cfi, as applicable, for each inspection history based on the result of the test . Determine the time duration, tdur.i. of each inspection cycle.

- Inspection effectiveness : part 2,annex 2.C, Table 2.C.3.1

Table 2.C.3.1- Inspection and testing efectiveness for PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

- Inspection Record : No LEAK / LEAK

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak,CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i : 0.5

- Determine the time duration, tdur,j. of each inspection cycle

A. RBI Date

$t_{dur,}i$ = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date

$t_{dur,}i$ = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 7 Starting at the earliest inspection record , update the modified characteristic life, ηmod, determine in step 5 as follows

STEP 7.1 Calculate the prior probability of leakage using equation (12). Note that for the first inspection record , the modified characteristic life,ηmod,is used subsequent inspection record will use the updated characteristic from STEP 7.5 below.

$$P_{l,Prior}^{prd}=1-\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right] \quad \text{equation (12)}$$

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{l,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{l,Prior}^{prd}$ = 0.09714

STEP 7.2 Calculate the prior probability of passing using equation (1.18)

$$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$$ equation (13)

A. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0289

= 0.97108

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0971

= 0.90286

STEP 7.3 Determine the conditional probability of leakage and conditional probability of pass using equation (14)

$$P_{l,cond}^{prd} = (1 - CF_{pass}).P_{p,prior}^{prd}$$ equation (14)

CF_{pass} : 0.5 step 6

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (RBI Plan Date) step 7.2

A. RBI Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48554

B. RBI Plan Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45143

STEP 7.4 calculate the weighted probability of leakage, $P_{l,wgt}^{prd}$, using the appropriate equation from table 7.9.

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{l,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{l,wgt}^{prd}$ = 0.48554

B. RBI Plan Date

$P_{l,wgt}^{prd}$ = 0.45143

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (15) and the weighted probability of leakage, $P_{l,wgt}^{prd}$ established in step 7.4

$$\eta upd = \frac{t}{(-\ln\left[1 - P_{f,wgt}^{prd}\right])^{\frac{1}{\beta}}}$$

η_{upd} = 10.62

STEP 8 Calculate the probability of leakage for the specific PRD in accordance with Equation (16)

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (16)

t	=	4	year	see step 6
t	=	8	year	see step 6
β	=	1.80		see step 2
η_{upd}	=	28.41	= η_{mod}	see step 5
η_{upd}	=	10.62		see step 7.5

a. RBI Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{4}{28.41}\right)^{1.80}\right]$

P_l^{prd} = 0.02892

B. RBI Plan Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{8}{10.62}\right)^{1.80}\right]$

P_l^{prd} = 0.45143

STEP 9

The Probability of leakage needs to be adjusted based on the closedness the system is operating near the set pressure with equation (17). The set pressure factor , F_{set} , is dependent on the PRD type.

$$P_{l,j}^{prd} = P_l^{prd} . F_{set}$$ equation (17)

PRD Type = Conventional see data general

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{127.6}{512.7}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.224)}{0.90}\right)$$

$$= 0.2766$$

$P_S =$ 127.63 see data

$P_{Set} =$ 512.7 process

A. RBI Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.0289 step 8

F_{set} = 0.2766 Table 7.7

$P_{l,j}^{prd}$ = 0.0289 x 0.2766

= 0.008

B. RBI Plan Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.45143 step 8

F_{set} = 0.2766 Table 7.7

$P_{l,j}^{prd}$ = 0.4514 x 0.2766

= 0.1249

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 3 :
CONSEQUENCE OF FAILURE CALCULATION

PSV-2910

REV.	DATE	Explanation	Done By		Approved by	
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PART 3 CONSEQUENCE CALCULATION of FAILURE to OPEN

STEP 1 Determine the list of overpressure scenarios applicable to the piece of equipment being protected by the PRD under evaluation. Table 7.2 provides a list of overpressure demand cases specific covered.

Overpressure Demand Case for PSV-2910

1 Fire see table 7.3

2 Liquid Overfillling without administrative controls in place

step 2 For each overpressure demand case, estimate the amount of overpressure, $p_{o,j}$ likely to occur during the overpressure event if the PRD were to fail to open.

Table 7.3 - Overpressure Scenario Project

Initiating Event	Equipment Type	PRD Demand rate reduction factor	Qualifier	over pressure potential	Background and comment
1. Overpressure Scenario					
1 per 250 years	All Equipment Type	0.1 industry experience justifies this value	N/A	4.0 x MAWP (RUPTURE)	see table 7.3
2. Overpressure scenario - liquid Overfilling					
1 per 100 years (admin control)	All Equipment including process tower	1.00	downsteam of positif displacement type rotating equipment	4.0 x MAWP	see table 7.3

$P_{0,fire}$ = 4 x MAWP
= 4 x 620.4
= 2481.6 psig

$P_{o,overfilling}$ = 4 x MAWP
= 4 x 620.4
= 2481.6 psig

STEP 3 For instalations that have multiple PRDs, determine the total amount of installed PRD orifice area , A_{total}^{prd}, including the area of the PRD being evaluated. Calculate the overpressure adjustment factor, , in accordance with equation (1.37) F_a

$$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \qquad \text{equation (1.37)}$$

A^{prd} = is the orifice area of the PRD, mm2

A_{total}^{prd} = is the total installed orifice area of a multiple device installation,mm2

multiple PRD ? no

F_a = 1

STEP 4 Reduce the overpressures determined in step 3 by the overpressure adjustment factor accordance with equation (1.38)

$$P_{o,j} = F_a \,.\, P_{o,j} \qquad \text{equation (1.38)}$$

F_a = 1 see step 3

$P_{0,fire}$	=	2481.6		$P_{o,overfilling}$	=	2481.6	
$P_{0,fire}$	=	2481.6 x	1	$P_{o,overfilling}$	=	2481.6 x	1
	=	2481.6 psig			=	2481.6 psig	

STEP 5 for each overpressure demand case, calculate the financial consequence ,....., C_{rla}^{prd} of loss containment from protected equipment using procedures developed in part 3. use the overpressure for demand cases as determine in STEP 4 in lieu of the operating pressure, P_s

STEP 1 Determine the Representative Fluid and Associated Properties

Fluid Properties

Sifat-sifat fluida yang dibutuhkan yang diperkirakan untuk masing-masing fluida representatif disediakan dalam Tabel 4.2 API 581 Bagian 3 COF dan tergantung pada fase simpanan fluida di bawah ini:

A). Stored Liquid	
1. Normal Boiling Point	(NBP)
2. Density	(ρt)
3. Auto-iIgnition Temperature	(AIT)
B). Stored Vapor or Gas	
1. Normal Boiling Point	(NBP)
2. Morcular Weight	(MW)
3. Ideal Gas Specific Heat Capacity Ratio	(k)
4. Constant Pressure Specific Heat	(Cp)
5. Auto-iIgnition Temperature	(AIT)

STEP 1.1 Select Representative fluid group Table 4.1

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

Fluid Composition Table

Well	Composition	Symbol	Amount	Unit
	Nitrogen	N_2	0.68	% mole
	Carbon Dioxide	CO_2	1.05	% mole
	Methane	CH_4	72.25	% mole
	Ethane	C_2H_6	7.9	% mole
	Propane	C_3H_8	6.84	% mole
`	i-Butane	i-C_4H_{10}	1.9	% mole
	n-Butane	n-C_4H_{10}	2.4	% mole
	i-Pentane	i-C_5H_{12}	5.01	% mole
	n-Pentane	n-C_5H_{12}	0.47	% mole
	Hexane Plus	C_6^+	1.5	% mole
		TOTAL	100.000	% mole

Chosen Representative Fluid : C1-C2

STEP 1.2 Determine the store fluid phase, liquid or vapor, if two phase , a level 2 consequence analysis should be performed

Stored fluid phase : Gas

Step 1.3 Determine the stored fluid properties

For a stored liquid

MW – Molecular weight, kg/kg-mol (lb/lb-mol), can be estimated from Table 4.2

k – Ideal gas specific heat ratio, can be estimated using Equation (3.1) and the C P values as determined using Table 4.2

AIT – Auto-ignition temperature, K (°R), can be estimated from Table 4.2

Table 4.2 - Properties of the Representative Fluids Used in Level 1 Consequence Analysis

Fluid	MW	Liquid Density (lb/ft^3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	CP				Auto ignition Temperature (°F)
						Ideal Gas Constant A	Ideal Gas Constant B	Ideal Gas Constant C	Ideal Gas Constant D	
C1-C2	23	15.64	-193	Gas	Note 1	12.3	1.15E-01	-2.87E-03	-1.30E-09	1036
C2-C3	51	33.61	-6.3	Gas	Note 1	2.632	0.3188	-1.35E-04	1.47E-08	696
C25+	422	56.19	981	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	396

1). Molecular Weight (MW), kg/kg-mol (lb/lb-mol)

The stored vapor Molecular Weight (MW) can be estimated from Table 4.2

MW = 23.00 (kg/kg-mol)

2). Auto-Ignition Temperature, K (^oR)

The stored liquid Auto-Ignition Temperature (AIT) can be estimated from Table 4.2 of API 581 Part 3 of COF.

AIT = 1036 (^oF)

AIT = 830.927778 (K)

AIT = 446.222222 (^oR)

3). Ideal gas specific heat ratio, k

Cp_A = 12.3 J/kmol-K

Cp_B = 1.15E-01 J/kmol-K

Cp_C = -2.87E-03 J/kmol-K

Cp_D = -1.30E-09 J/kmol-K

T = 71 C

T = 159.8 F

T = 344.15 K

R = 8.314 J/kg-mol-K

$Cp = A + BT + CT^2 + DT^3$ ..... equation (19)

= $12.3 + (0.015 \times 344.15) + (-0.0000287 \times 344.15)^2 + (-1.3^{-9} \times 344.15)^3$

= 52.852822 J/kmol-K

$k = \frac{Cp}{Cp - R}$ ..... equation (20)

= $\frac{52.853}{52.853 - 8.314}$

= 1.18666861

STEP 1.4 Determine the steady state phase of the fluid after release to the atmosphere, using Table 4.3 and the phase of the fluid stored in the equipment as determine in STEP 1.2.

Table 4.3 - Level 1 Guidelines for Determining the phase of a fluid

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (After release) Condition	Determine of Final Phase for Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	model as gas usless the fluid boilling point at ambient condiitions is greater than 80 F , than model as liquid
Liquid	Liquid	Model as Liquid

The fluid is Gas in the vessel, its post release is Gas

STEP 2 Release Hole Size Selection

STEP 2.1 Based on component type and table 4.4, determine the release hole size diameters, d_n.

Table 4.4 - Release Hole Sizes and Areas Used in Level 1 and 2 Consequences Analysis

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

STEP 2.2 Determine the failure frequency, gff_n, for the nth release hole size from part 2, table 3.1, and the total generic failure frequency from this table or from equation (3.2)

$$gff_{total} = \sum_{n=1}^{4} gff_n \qquad (3.2)$$

Table 3.1 part 2, suggested component generic failure frequencies

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

Diameter = 400 mm = 15.76 inci

gff_{total} = 8.00E-06 failures/year

gff_{small} = 2.00E-05 failures/year

gff_{medium} = 2.00E-05 failures/year

gff_{large} = 6.00E-07 failures/year

$gff_{rupture}$ = 3.06E-05 failures/year

STEP 3 Release Rate Calculation

There are two regimes for flow gases through an orifice: aonic (choked) for higher internal pressure, and subssonic flow for lower pressure (nominally 15 psig (103.4 kPa) or less). The transition pressure at which the flow regime changes from sonic to subsonic is determined using below equation.

P_{atm} = 14.69 psi

k = 1.1867

$$P_{trans} = P_{atm}\left(\frac{k+1}{2}\right)^{\frac{k}{k-1}} \quad \text{..... equation (21)}$$

$$P_{trans} = 14.69\left(\frac{1.187+1}{2}\right)^{\frac{1.187}{0.187}}$$

= 18.0215241 psi

STEP 3.1 Select the appropriate release rate equation

$$W_n = \frac{Cd}{C2}\, x\, An \text{ x } Ps \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad \text{..... equation 22)}$$

Abbreviation list :

C_d = Discharge coefficient, for turbulent liquid flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$

= 0.9

A_n = Release hole sized area

P_s = Storage operating pressure = 2481.6 psi

P_{atm} = Atmosphere pressure = 14.69 psi

k = Ideal gas specific heat capacity ratio = 1.1867

MW = Molecular weight = 23.00 (kg/kg-mol)

g_c = Gravitational constant = 9.8 m/s^2

R = Universal gas constant = 8.314 J/(kg-mol-K)

T_s = Storage or normal operating temperatur = 71 C

= 159.8 F

= 344.15 K

STEP 3.2 For every release hole size, calculate the release hole size area based on d_n

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

The release hole size area can be determined by formulating below equation:

$$An = \frac{\pi dn^2}{4} \quad \text{.....} \quad \text{equation (22)}$$

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch
= 0.0064 m
π = 3.14

$$A1 = \frac{\pi d1^2}{4}$$

$$= \frac{3.14\ x\ (0.25)^2}{4}$$

= 0.0491 inch^2
= 3E-05 m^2

2). MEDIUM RELEASE HOLE SIZE AREA

d_1 = 1 inch
= 0.0254 m
π = 3.14

$$A2 = \frac{\pi d2^2}{4}$$

$$= \frac{3.14\ x\ (1)^2}{4}$$

= 0.785 inch^2
= 0.0005 m^2

3). LARGE RELEASE HOLE SIZE AREA

d_1 = 4 inch

= 0.1016 m

π = 3.14

$$A3 = \frac{\pi d3^2}{4}$$

= 12.56 $inch^2$

= 0.0081 m^2

4). RUPTURE RELEASE HOLE SIZE AREA

d_1 = 16 inch

= 0.4064 m

π = 3.14

$$A4 = \frac{\pi d4^2}{4}$$

$$= \frac{3.14\ x\ (16)^2}{4}$$

= 200.96 $inch^2$

= 0.1296 m^2

STEP 3.3 For liquid releases, for each release hole size, calculate the viscosity correction factor ($K_{v,n}$)

$$K_{v,n} = \left(0.9935 + \frac{2.878}{Ren^{0.5}} + \frac{342.75}{Ren^{1.5}}\right)^{-1} \quad \text{.....} \quad \text{equation (23)}$$

Because the store fluid phase determined in STEP 1.2 is gaseous or vapor phase, then, this step is no neeed to be considered.

STEP 3.4 For each hole size, calculate the release rate, W_n, for each release area A_n

$$W_n = \frac{Cd}{C2}\ x\ An\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Abbreviation List:

C_d = 0.9

k = 1.18666861

ρl = 250.51 kg/m^3

= 2.5051E-07 kg/mm^3

A_1 = 3.1645E-05 m^2

A_2 = 0.00050645 m^2

A_3 = 0.00810321 m^2

A_4	=	0.1296192	m^2
gc	=	1	kgm/Ns^2
	=	32.2	$lb_m ft/lb_f S^2$
Ps	=	17110.63	Kpa
P_{atm}	=	101.288	KPa
C_2	=	1	
R	=	8.314	J/(kg-mol-K)
g_c	=	9.8	m/s^2
T_s	=	344.15	K
MW	=	23.00	(kg/kg-mol)

1). SMALL RELEASE HOLE SIZE AREA

$$W_1 = \frac{Cd}{C2} \; x \; A1 \text{ x Ps} \sqrt{\left(\frac{k \; x \; MW \; x \; gc}{R \; x \; Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_1 = \frac{0.9}{C2} \; x \; 0.000031645 \text{ x } 17110.6 \sqrt{\left(\frac{1.187 \; x \; 23 \; x \; 9.8}{8.314 \; x \; 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 0.08834891 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$W_2 = \frac{Cd}{C2} \; x \; A2 \text{ x Ps} \sqrt{\left(\frac{k \; x \; MW \; x \; gc}{R \; x \; Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_2 = \frac{0.9}{C2} \; x \; 0.000506451 \text{ x } 17110.6 \sqrt{\left(\frac{1.187 \; x \; 23 \; x \; 9.8}{8.314 \; x \; 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 1.41393318 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$W_3 = \frac{Cd}{C2} \; x \; A3 \text{ x Ps} \sqrt{\left(\frac{k \; x \; MW \; x \; gc}{R \; x \; Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_3 = \frac{0.9}{C2} \; x \; 0.00810321 \text{ x } 17110.6 \sqrt{\left(\frac{1.187 \; x \; 23 \; x \; 9.8}{8.314 \; x \; 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 7.22663021 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$W_4 = \frac{Cd}{C2} \; x \; A4 \text{ x Ps} \sqrt{\left(\frac{k \; x \; MW \; x \; gc}{R \; x \; Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_4 = \frac{0.9}{C2} \; x \; 0.1296192 \text{ x } 17110.6 \sqrt{\left(\frac{1.187 \; x \; 23 \; x \; 9.8}{8.314 \; x \; 344.15}\right)\left(\frac{2}{1.187+1}\right)^{\frac{1.187+1}{1.187-1}}}$$

= 361.877127 kg/s

STEP 4 Estimate the Fluid Inventory Available for Release

STEP 4.1 Group Component and equipment items into inventory groups (see annex 3.A)

only one component is given, and total inventory for the group

STEP 4.2 Calculate the fluid mass ,$mass_{comp}$, in the component being evaluated

ID	=	0.40	m
V_{tot}	=	12.56	m^3
	=	443.55221	ft^3
ρ_{gas}	=	8.43	kg/m^3
	=	0.5262677	lb/ft^3
L	=	100	m
$Mass_{comp}$	=	105.8808	kg

STEP 4.3 Calculate the fluid mass in each of the other components that are included in the inventory group, $mass_{comp,i}$

There are no other component, only an inventory group mass

STEP 4.4 Calculate the fluid mass in the inventory group, $mass_{inv}$, using equation (3.9)

$$mass_{inv} = \sum_{i=1}^{n} mass_{comp,i}$$

Where

$Mass_{comp}$ = is the inventory fluid mass for the component or piece of equipment being evaluated, kgs [lbs]

$Mass_{inv}$ = is the inventory group fluid mass, kgs [lbs]

= 105.8808 kg

STEP 4.5

Calculate the flow rate from a 203mm (8 inch) diameter hole, W_{max8}, using equation (3.3),(3.6)or (3.7) , as aplicable ,with A_n ,A8=32450 mm2 (50.3 inch2). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Where

C_d	=	Discharge coefficient, for turbulent gas flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$	=	0.9	
A_n	=	Release hole sized area	=	5.1031	$inch^2$
			=	129619	mm^2
			=	0.1296	m^2
P_s	=	Storage operating pressure	=	2481.6	psi
			=	17111	Kpa
P_{atm}	=	Atmosphere pressure	=	14.69	psi
			=	101.29	Kpa
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	71	C
			=	159.8	F
			=	344.15	K
C_2	=	SI and US customary conversion factors	=	1	
k	=	Ideal gas specific heat ratio	=	1.1867	

So,

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_{max8} = \frac{0.9}{1}\ x\ 0.1296 \text{ x } 17111\sqrt{\left(\frac{1.1867\ x\ 23\ x\ 9.8}{8.314\ x\ 344.15}\right)\left(\frac{2}{1.1867+1}\right)^{\frac{1.1867+1}{1.1867-1}}}$$

$$= 361.877127 \text{ kg/s}$$

STEP 4.6 For each release hole size, calculate the added fluid mass, $mass_{add,n}$, resulting from 3 (three) minutes of flow from the inventory group using equation (3.10) where Wn is the leakage rate for the release hole size being evaluated and $W_{max8,}$ is from step 4.5

$$mass_{add,n} = 180.\min\left[W_n, W_{\max 8}\right] \qquad (3.10)$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[\text{W}_1 \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[0.088, 361.88\,]$$

$$= \quad 15.903 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add n}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 2}} = 180 \,.\, min[1.4139, 361.88\,]$$

$$= \quad 254.51 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min\,[7.2266, 361.88\,]$$

$$= \quad 1300.8 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[361.88, 361.88\,]$$

$$= \quad 65138 \text{ kgs}$$

STEP 4.7 For each release hole size, calculate the available mass for release using equation (3.11)

$$mass_{avail,n} = \min\left[\{mass_{comp} + \ mass_{add,n}\}, mass_{inv}\right]$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 1} = min\,.\,[\{105.88 + 15.9\}, 105.88\,]$$

$$= \quad 105.881 \quad \text{kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 2} = min\,.\,[\{105.88 + 254.5\}, 105.88\,]$$

$$= \quad 105.881 \quad \text{kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 3} = min.[\{105.88 + 1301\}, 105.88]$$

$$= 105.881 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 4} = min.[\{105.88 + 65138\}, 105.88]$$

$$= 105.881 \text{ kgs}$$

STEP 5 Determine the release type (continues or instantaneous)

STEP 5.1 For each release hole size, calculate the time required to release 4536kgs (10000 lbs) of fluid

$$t_n = \frac{C3}{W_n} \quad \text{.....} \quad \text{equation (24)}$$

Where

t_n = time required to release 4536 kgs (10000 lbs) of fluid

C_3 = SI and US customary conversion factors

= 4536 kgs

= 10000 lbs

W_n = Theoretical release rate associated with the nth release hole size, kg/s [lb/s]

W_1 = 0.088 kg/s

W_2 = 1.414 kg/s

W_3 = 7.227 kg/s

W_4 = 361.877 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_1 = \frac{4536}{0.088}$$

= 51341.8909 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_2 = \frac{4536}{1.414}$$

= 3208.07238 s

3). LARGE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_3 = \frac{4536}{7.227}$$

= 627.678443 s

4). RUPTURE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_4 = \frac{4536}{361.877}$$

= 12.5346413 s

STEP 5.2 Determine the release type for each release hole size

For each release hole size, determine the release type either instataneous or continous using this following criteria:

a. If the release hole size is 6.35 mm(0.25 inch) or less, then the release type is continous

b. If t_n<180 sec and the releaase mass is gretaer than 4536 kgs (100000 lbs), then the release is instataneous: otherwise the release is continous

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 51342 s (Continous)

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 3208.1 s (Continous)

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 627.68 s (Continous)

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 12.535 s (Instataneous)

STEP6 Estimate The Impact of Detection and Isolation Systems on Release Magnitude

STEP 6.1 Determine the detection and isolation systems presents in the unit

STEP 6.2 Using table 4.5, select the appropriate classification (A,B,C) for the detection system.

Table 4.5 - Detection and Isolation system rating Guide

Type of Detection System	Detection Clssification
Instrumentation designed specifically to detect material losses by changes In operating conditions (i.e., loss of pressure or flow) in the system.	A
Suitable located detectors to determine when the material is present outside the pressure-containing envelope	B
Visual detection, cameras, or detectors with marginal coverage	C
Type of Isolation Sytem	**Isolation Classification**
Isolation or shutdown system activated directly process instrumentation or detection, with no operator intervention	A
Isolation or shutdown system activated by operators in the control room or other suitable locations remote from the leak	B
isolation dependent on manually-operated valves	C

Detection Is A

STEP 6.3 Using table 4.5, select the appropriate classification (a,b,c) for the isolation system

Isolation Is A

STEP 6.4 Determine the release reduction factor factdi using Table 4.6

Table 4.6 - Adjustment to Release Based on Detection and Isolation Systems

System Classification		Release Magnitude Adjustment	duction Factor, *fac*
Detection	Isolation		
A	A	Reduce release rate or mass by 25%	0.25
A	B	Reduce release rate or mass by 20%	0.20
A or B	C	Reduce release rate or mass by 10%	0.10
B	B	Reduce release rate or mass by 15%	0.15
C	C	No adjustment to release rate or mass	0.00

Release Magnitude Adjustment	=	Reduce release rate or mass by 25%
Reduction Factor, $fact_{di}$	=	**0.25**

STEP 6.5 Determine the total leak durations for each release hole sizes using Table 4.7

Table 4.7 - Leak Durations Based on detection and Isolation Systems

Detection System Rating	Isolation System Rating	Maximum Leak Duration, ld_{max}
A	A	20 minutes for 1/4 inch leaks
		10 minutes for 1 inch leaks
		5 minutes for 4 inch leaks
A	B	30 minutes for 1/4 inch leaks
		20 minutes for 1 inch leaks
		10 minutes for 4 inch leaks
A	C	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	A or B	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	C	1 hour for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
C	A, B, or C	1 hour for 1/4 inch leaks
		40 minutes for 1 inch leaks
		20 minutes for 4 inch leaks

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 51342 s (Continous)

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 3208.1 s (Continous)

$ld_{max,2}$ = 10 minutes for 1 inch leaks

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 627.68 s (Continous)

$ld_{max,3}$ = 5 minutes for 4 inch leaks

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 12.535 s (Instataneous)

$ld_{max,4}$ = 5 minutes for 4 inch leaks

STEP7 Determine The Release Rate And Mass For Consequence of Failure

STEP 7.1 Calculate the adjusted release rate, raten for each release hole size

Reduction Factor, $fact_{di}$ = 0.25

W_1 = 0.088 kg/s

W_2 = 1.414 kg/s

W_3 = 7.227 kg/s

W_4 = 361.877 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$Rate_1 = W_n (1 - fact_{di})$$

$$Rate_1 = 0.088 (1 - 0.25)$$

= 0.0663 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$Rate_2 = W_n (1 - fact_{di})$$

$$Rate_2 = 1.414 (1 - 0.25)$$

= 1.0604 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$Rate_3 = W_n\,(1 - fact_{di})$$

$$Rate_3 = 7.227\,(1 - 0.25)$$

= 5.42 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$Rate_4 = W_n\,(1 - fact_{di})$$

$$Rate_4 = 361.877\,(1 - 0.25)$$

= 271.41 kg/s

STEP7.2 Calculate the leak duration, ldn, for each release hole size

$$ld_n = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\,.\,ld_{max,n}\}] \quad \text{.....} \quad \text{equation (25)}$$

$ld_{max,1}$	=	20 minutes for 1/4 inch leaks	20	$Mass_{avail,1}$	=	105.88	kgs
$ld_{max,2}$	=	10 minutes for 1 inch leaks	10	$Mass_{avail,2}$	=	105.88	kgs
$ld_{max,3}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,3}$	=	105.88	kgs
$ld_{max,4}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,4}$	=	105.88	kgs

1). SMALL RELEASE HOLE SIZE AREA

$$ld_1 = min\,.\,[\{\frac{Mass_{avail,1}}{Rate_1}\},\{60\,.\,ld_{max,1}\}]$$

$$ld_1 = min\,.\,[\{\frac{105.88}{0.066}\},\{60\,.\,20\}]$$

= 1200 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2 = min\,.\,[\{\frac{Mass_{avail,2}}{Rate_2}\},\{60\,.\,ld_{max,2}\}]$$

$$ld_2 = min\,.\,[\{\frac{105.88}{1.06}\},\{60\,.\,10\}]$$

= 99.845 s

3). LARGE RELEASE HOLE SIZE AREA

$$ld_3 = min\ .\ [\{\frac{Mass_{avail,3}}{Rate_3}\},\{60\ .\ ld_{max,3}\}]$$

$$ld_3 = min\ .\ [\{\frac{105.88}{5.42}\},\{60\ .\ 5\}]$$

$$= 19.535\ s$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$ld_4 = min\ .\ [\{\frac{Mass_{avail,4}}{Rate_4}\},\{60\ .\ ld_{max,4}\}]$$

$$ld_4 = min\ .\ [\{\frac{105.88}{271.4}\},\{60\ .\ 5\}]$$

$$= 0.3901\ s$$

STEP 7.3 Calculate the release mass, $mass_n$, for each release hole size

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_1 = min\ .\ [\{Rate_1\ .\ ld_1\},Mass_{avail,n}]$$

$$Mass_1 = min\ .\ [\{0.066\ .\ 1200\},105.88]$$

$$= 79.5140172\ kgs$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$Mass_2 = min\ .\ [\{Rate_2\ .\ ld_2\},Mass_{avail,n}]$$

$$Mass_2 = min\ .\ [\{1.06\ .\ 99.85\},105.88]$$

$$= 105.8808\ kgs$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_3 = min\ .\ [\{Rate_3\ .\ ld_3\},Mass_{avail,n}]$$

$$Mass_3 = min\ .\ [\{5.42\ .\ 19.54\},105.88]$$

$$= 105.8808\ kgs$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_4 = min\ .\ [\{Rate_4\ .\ ld_4\},Mass_{avail,n}]$$

$$Mass_4 = min\ .\ [\{271.4\ .\ 0.39\},105.88]$$

$$= 105.8808\ kgs$$

PART 8 : DETERMINE FLAMMABLE AND EXPLOSIVE CONSEQUENCE

8.1 CONSEQUENCE AREA EQUATIONS

1). CONTINOUS RELEASE

$CA_n^{CONT} = \alpha(rate_n)^b$ ..... equation (26)

2). INSTATANEOUS RELEASE

$CA_n^{CONT} = \alpha(mass_n)^b$ ..... equation (27)

STEP 8.1 Select the consequence area mitigation reduction factor, $fact_{mit}$, from Table 4.10

Mitigation System	Consequence Area Adjustemnet	Consequence Area Reduction Factor, factor mit
Inventory blowdown , couple with isolation system classification B or higher	Reduce consequence area by 25%	0.25
Fire water deluge system and monitors	Reduce consequence area by 20%	0.2
Fire water monitor only	Reduce consequence area by 5%	0.05
Foam spray system	Reduce consequence area by 15%	0.15

Mitigation system = Inventory blowdown , couple with isolation system classification B or higher *

Consequence Area = Reducer consequence area by 25 % *

$fact_{mit}$ = 0.25

STEP 8.2 Calculate the energy efficiency, $eneff_n$, for each hole size using equation mentioned below.

C_4 = 2205 1/kg

$eneff_n = 4.log_{10}[C_4 . mass_n] - 15$ ..... equation (28)

$Mass_1$ = 79.514 kgs

$Mass_2$ = 105.881 kgs

$Mass_3$ = 105.881 kgs

$Mass_4$ = 105.881 kgs

1. SMALL RELEASE HOLE SIZE AREA

$eneff_1 = 4 . log_{10} [C_{4A} . mass_1] - 15$

$eneff_1 = 4 . log_{10} [2205 . 79.514] - 15$

$eneff_1 = 5.975409$

2. MEDIUM RELEASE HOLE SIZE AREA

$$eneff_2 = 4 . log_{10} [C_{4A} . mass_2] - 15$$
$$eneff_2 = 4 . log_{10} [2205 . 105.881] - 15$$
$$eneff_2 = 6.472903$$

3. LARGE RELEASE HOLE SIZE AREA

$$eneff_3 = 4 . log_{10} [C_{4A} . mass_3] - 15$$
$$eneff_3 = 4 . log_{10} [2205 . 105.881] - 15$$
$$eneff_3 = 6.472903$$

4. RUPTURE RELEASE HOLE SIZE AREA

$$eneff_4 = 4 . log_{10} [C_{4A} . mass_4] - 15$$
$$eneff_4 = 4 . log_{10} [2205 . 105.881] - 15$$
$$eneff_4 = 6.47290$$

STEP 8.3 Determine the fluid type

Determine the fluid type, either TYPE 0 or TYPE 1 based on Table 4.1 of API RP 581 Part 3 of COF.

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

C_1-C_2	=	TYPE 0	AIT	=	446.222222 (^oR)
MW	=	23 (kg/kg-mol)	T	=	71 (^oC)
AIT	=	1036 (^oF)	T	=	159.8 (^oF)
AIT	=	830.927778 (K)	T	=	344.15 (K)

STEP 8.4 For each release hole size, calculate the component damage consequence areas for Auto-Ignition Not Likely, Continous Release (AINT-CONT), $CA^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

Table 4.8 - Component Damage Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	8.7	0.98			55	0.95			6.5	0.67			164	0.62		
C3-C4	10.1	1.0			64	1.0			4.7	0.7			80	0.63		

$\alpha = \alpha_{cmd,n}^{AINL-CONT} =$ 8.7 b $= b_{cmd}^{AINL-CONT} =$ 0.98

2). Calculate the consequence of area using equation below

$Rate_1$ = 0.066 kg/s

$Rate_2$ = 1.06 kg/s

$Rate_3$ = 5.42 kg/s

Rate4 = 271.4 kg/s

$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$ ..... equation (29)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-CONT} = \alpha(rate_1)^b \cdot (1 - fact_{mit})$

= 0.4547 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

= 6.9084 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

= 34.19 m^2

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$

= 1583.1 m^2

STEP 8.5 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Continous Release (AIL-CONT), $CA^{AIL\text{-}CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-CONT} =$ 55.0 b $= b_{cmd}^{AIL-CONT} =$ 0.95

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$ ..... equation (30)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 3.1188\ m^2$

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 43.598\ m^2$

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 205.46\ m^2$

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$

$= 8459.7\ m^2$

STEP 8.6 For each release hole size, calculate the component damage consequence areas for Auto-ignition Not Likely, Instaneous Release, (AINL-INST), $CA^{AINL\text{-}INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AINL-INST} =$ 6.5 b $= b_{cmd}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right)$ ..... equation (31)

From step 7, know that :

$Mass_1$	=	79.514	kgs	$eneff_1$	=	5.975
$Mass_2$	=	105.881	kgs	$eneff_2$	=	6.473
$Mass_3$	=	105.881	kgs	$eneff_3$	=	6.473
$Mass_4$	=	105.881	kgs	$eneff_4$	=	6.473

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 6{,}469\,(79.514)^{0{,}67}.\left(\frac{1-0{,}25}{5.975}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 15.31\ m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 6{,}469(105.881)^{0{,}67}.\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 17.12\ m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 6{,}469\,(105.881)^{0{,}67}.\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 17.12\ m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 6{,}469\,(105.881)^{0{,}67}.\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 17.12\ m^2$$

STEP 8.7 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Instataneous Release (AIL-INST), $CA^{AIL-INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-INST} =$ 164.0 b = $b_{cmd}^{AIL-INST} =$ 0.62

2). Calculate the consequence of area using equation below

$$CA_{cmd,n}^{AIL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{.....} \quad \text{equation (32)}$$

From step 7, know that :

$Mass_1$	=	79.514	kgs	$eneff_1$	=	5.975
$Mass_2$	=	105.881	kgs	$eneff_2$	=	6.473
$Mass_3$	=	105.881	kgs	$eneff_3$	=	6.473
$Mass_4$	=	105.881	kgs	$eneff_4$	=	6.473

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AIL-INST} = \alpha\,(mass_1)^b \cdot \left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 164\,(79.514)^{0,62} \cdot \left(\frac{1-0,25}{5.975}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 310.32\ m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AIL-INST} = \alpha\,(mass_2)^b \cdot \left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 164\,(105.881)^{0,62} \cdot \left(\frac{1-0,25}{6.473}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 342.13\ m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AIL-INST} = \alpha\,(mass_3)^b \cdot \left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 164\,(105.881)^{0,62} \cdot \left(\frac{1-0,25}{6.473}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 342.13\ m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AIL-INST} = \alpha\,(mass_4)^b \cdot \left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 164\,(105.881)^{0,62} \cdot \left(\frac{1-0,25}{6.473}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 342.13\ m^2$$

STEP 8.8 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Continous Release (AINL-CONT), $CA_{inj,n}^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

Table 4.9 - Personnel Injury Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	21.8	1.00			143	0.92			12.5	0.67			474	0.63		
C3-C4	25.6	1.0			171	1.0			9.7	0.7			270	0.63		

$\alpha = \alpha_{inj,n}^{AINL-CONT} =$ **21.8** $\quad b = b_{inj,n}^{AINL-CONT} =$ **1.00**

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1 - fact_{mit}) \quad \text{..... equation (33)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-CONT} = \left[\alpha.\left(rate_1^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 1.0806 \ \text{m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-CONT} = \left[\alpha.\left(rate_2^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 17.355 \ \text{m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-CONT} = \left[\alpha.\left(rate_3^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 88.739 \ \text{m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-CONT} = \left[\alpha.\left(rate_4^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 4443.5 \ \text{m}^2$$

STEP 8.9 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Continous Release (AIL-CONT), $CA_{inj,n}^{AIL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-CONT} =$ 143.2 b $= b_{inj,n}^{AIL-CONT} =$ 0.92

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1 - fact_{mit}) \quad \text{..... equation (34)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-CONT} = \left[\alpha.\left(rate_1^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 8.8102 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-CONT} = \left[\alpha.\left(rate_2^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 113.31 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-CONT} = \left[\alpha.\left(rate_3^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 508.49 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-CONT} = \left[\alpha.\left(rate_4^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 18618 \text{ m}^2$$

STEP 8.10 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Instataneous Release (AINL-INST), $CA_{inj,n}^{AINL-INST}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AINL-INST} =$ 12.5 b $= b_{inj,n}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (35)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-INST} = \left[a.\left(mass_1^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AINL-INST} = [12{,}46\ (79.514)^{0{,}67}].\left(\frac{1-0{,}25}{5.975}\right)$$

$$CA_{inj,1}^{AINL-INST} = 29.34\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-INST} = \left[a.\left(mass_2^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AINL-INST} = [12{,}46\ .(105.881\ )^{0{,}67}].\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{inj,2}^{AINL-INST} = 32.82\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-INST} = \left[a.\left(mass_3^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AINL-INST} = [12{,}46\ .(105.881)^{0{,}67}].\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{inj,3}^{AINL-INST} = 32.82\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-INST} = \left[a.\left(mass_4^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AINL-INST} = [12{,}46\ .(105.881\ )^{0{,}67}].\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{inj,4}^{AINL-INST} = 32.82\ \text{m}^2$$

STEP 8.11 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Instataneous Release (AIL-INST),

$$CA_{inj,n}^{AIL-INST}$$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-INST} =$ 473.9 b $= b_{inj,n}^{AIL-INST} =$ 0.63

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \ldots\ldots\ldots \text{equation (36)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-INST} = \left[a.\left(mass_1^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AIL-INST} = [473{,}9.(79.514)^{0{,}63}].\left(\frac{1-0{,}25}{5.975}\right)$$

$$CA_{inj,1}^{AIL-INST} = 936.83 \quad m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-INST} = \left[a.\left(mass_2^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AIL-INST} = [473{,}9.(105.881)^{0{,}63}].\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{inj,2}^{AIL-INST} = 1035.82 \quad m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-INST} = \left[a.\left(mass_3^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AIL-INST} = [473{,}9.(105.881)^{0{,}63}].\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{inj,3}^{AIL-INST} = 1035.82 \quad m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-INST} = \left[a.\left(mass_4^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AIL-INST} = [473{,}9.(105.881)^{0{,}63}].\left(\frac{1-0{,}25}{6.473}\right)$$

$$CA_{inj,4}^{AIL-INST} = 1035.82 \quad m^2$$

8.12 STEP 8.12 For each release hole size, calculate the instataneous / continous blending factor, $fact_n^{IC}$.

1). FOR CONTINOUS RELEASE

$C_5 = 25.2$ kg/s

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad \text{.....equation (37)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$fact_1^{IC} = \min\left[\left\{\frac{rate_1}{C_5}\right\}, 1.0\right]$$

$$= 0.00261905$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$fact_2^{IC} = \min\left[\left\{\frac{rate_2}{C_5}\right\}, 1.0\right]$$

$$= 0.04206349$$

C). LARGE RELEASE HOLE SIZE AREA

$$fact_3^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$

$$= 0.21507937$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$fact_4^{IC} = \min\left[\left\{\frac{rate_4}{C_5}\right\}, 1.0\right]$$

$$= 1$$

2). FOR INSTATANEOUS RELEASE

$$fact_4^{IC} = 1$$

8.13 Calculate the AIT blending factor, $fact^{AIT}$, using these optional equation below.

$$fact^{AIT} = 0 \quad \text{for } T_S + C_6 \leq AIT \quad \text{equation (38)}$$

$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2 \,.\, C_6} \quad \text{for } T_S + C_6 > AIT > T_S - C_6$$

$$fact^{AIT} = 1 \quad \text{for } T_S - C_6 \geq AIT \quad \text{equation (39)}$$

Ts	=	71 (^{o}C)	AIT	=	1036 (^{o}F)
Ts	=	159.8 (^{o}F)	AIT	=	830.927778 (K)
Ts	=	344.15 (K)	AIT	=	446.222222 (^{o}R)
C_6	=	55.6 (K)			

$T_s + C_6$	=	399.75 (K)
$T_s - C_6$	=	288.55 (K)
$\frac{(T_s - AIT + C_6)}{2 \,.\, C_6}$	=	-3.8775 (K)

$fact^{AIT}$ = 0

STEP 8.14 Calculate the continuous/instantaneous blended consequence area for the component using equation (3.53) through (3.56) based on the consequence areas calculated in previous steps $fact_n^{IC}$

A. Componen demage for auto-ignition Likely, Continous - Instataneous release

$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} . fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} . (1 - fact_n^{IC})$ equation (40)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-INST}$	=	15.31	m^2
$fact_1^{IC}$	=	0.0026	
$CA_{cmd,1}^{AIL-CONT}$	=	0.454709	m^2
$CA_{cmd,1}^{AIL}$	=	0.4936092	m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-INST}$	=	17.12	m^2
$fact_2^{IC}$	=	0.042063	
$CA_{cmd,2}^{AIL-CONT}$	=	6.9084444	m^2
$CA_{cmd,2}^{AIL}$	=	7.3379769	m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-INST}$	=	17.12	m^2
$fact_3^{IC}$	=	0.215079	
$CA_{cmd,3}^{AIL-CONT}$	=	34.190056	m^2
$CA_{cmd,3}^{AIL}$	=	30.518633	m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-INST}$ = 17.12 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AIL-CONT}$ = 1583.14 m^2

$CA_{cmd,4}^{AIL}$ = 17.119972 m^2

B. Personal Injury for auto-ignition Likely, Continous - Instataneous release

$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} . fact_n^{IC} + CA_{inj,n}^{AIL-CONT} . (1 - fact_n^{IC})$.....equation (41)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AIL-INST}$ = 936.83 m^2

$fact_{n1}^{IC}$ = 0.0026

$CA_{inj,1}^{AIL-CONT}$ = 8.8101784 m^2

$CA_{inj,1}^{AIL}$ = 11.240701 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AIL-INST}$ = 1035.82 m^2

$fact_{n2}^{IC}$ = 0.0420635

$CA_{inj,2}^{AIL-CONT}$ = 113.31455 m^2

$CA_{inj,2}^{AIL}$ = 152.11829 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AIL-INST}$ = 1035.82 m^2

$fact_{n3}^{IC}$ = 0.2150794

$CA_{inj,3}^{AIL-CONT}$ = 508.49141 m^2

$CA_{inj,3}^{AIL}$ = 621.90861 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AIL-INST}$ = 1035.82 m^2

$fact_{n4}^{IC}$ = 1

$CA_{inj,4}^{AIL-CONT}$ = 18617.67 m^2

$CA_{inj,4}^{AIL}$ = 1035.8186 m^2

C. Componen demage for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST} . fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (42)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-INST}$ = 15.31 m^2

$fact_1^{IC}$ = 0.0026

$CA_{cmd,1}^{AINL-CONT}$ = 0.454709 m^2

$CA_{cmd,1}^{AINL}$ = 0.4936092 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-INST}$ = 17.12 m^2

$fact_2^{IC}$ = 0.042063

$CA_{cmd,2}^{AINL-CONT}$ = 6.9084444 m^2

$CA_{cmd,2}^{AINL}$ = 7.3379769 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-INST}$ = 17.12 m^2

$fact_3^{IC}$ = 0.2151

$CA_{cmd,3}^{AINL-CONT}$ = 34.190056 m^2

$CA_{cmd,3}^{AINL}$ = 30.518633 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-INST}$ = 17.12 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AINL-CONT}$ = 1583.14 m^2

$CA_{cmd,4}^{AINL}$ = 17.119972 m^2

D. Personal Injury for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} . fact_n^{IC} + CA_{inj,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (43)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AINL-INST}$ = 29.34 m^2

$fact_1^{IC}$ = 0.0026

$CA_{inj,1}^{AINL-CONT}$ = 1.080585 m^2

$CA_{inj,1}^{AINL}$ = 1.1546064 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AINL-INST}$ = 32.82 m^2

$fact_2^{IC}$ = 0.042063

$CA_{inj,2}^{AINL-CONT}$ = 17.35485 m^2

$CA_{inj,2}^{AINL}$ = 18.00527 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AINL-INST}$ = 32.82 m^2

$fact_3^{IC}$ = 0.2151

$CA_{inj,3}^{AINL-CONT}$ = 88.73895 m^2

$CA_{inj,3}^{AINL}$ = 76.711436 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AINL-INST}$ = 32.82 m^2

$fact_4^{IC}$ = 1

$CA_{inj,4}^{AINL-CONT}$ = 4443.4965 m^2

$CA_{inj,4}^{AINL}$ = 32.817669 m^2

STEP 8.15 Calculate the AIT blended consequence areas for the component using equations (3.57) and (3.58) based on the consequence areas determined in step 8.14 and the AIT blending factors, , calculate in step 8.13. the resulting consequence areas are the component damage and personnel injury flammable consequence areas, and for each release hole size selected in step 2.2

$CA_{cmd,n}^{flam}$ $CA_{inj,n}^{flam}$

A. Componen Demage

$CA_{cmd,n}^{flam} = CA_{smd,n}^{AIL} . fact^{AIT} + CA_{cmd,n}^{AINL} . (1 - fact^{AIT})$ .....equation (44)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL}$ = 0.4936092 m^2

$fact^{AIT}$ = 0

$CA_{cmd,1}^{AINL}$ = 0.4936092 m^2

$CA_{cmd,1}^{flam}$ = 0.4936092 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL}$ = 7.3379769 m^2

$fact^{AIT}$ = 0

$CA_{cmd,2}^{AINL}$ = 7.3379769 m^2

$CA_{cmd,2}^{flam}$ = 7.3379769 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL}$ = 30.518633 m^2

$fact^{AIT}$ = 0

$CA_{cmd,3}^{AINL}$ = 30.518633 m^2

$CA_{cmd,3}^{flam}$ = 30.518633 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL}$ = 17.119972 m^2

$fact^{AIT}$ = 0

$CA_{cmd,4}^{AINL}$ = 17.119972 m^2

$CA_{cmd,4}^{flam}$ = 17.119972 m^2

B. Personal Injury

$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} . fact^{AIT} + CA_{inj,n}^{AINL} . (1 - fact^{AIT})$ …….. equation (45)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{flam-AIL}$ = 11.240701 m^2

$fact^{AIT}$ = 0

$CA_{inj,1}^{AINL}$ = 1.1546064 m^2

$CA_{inj,1}^{flam}$ = 1.1546064 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{flam-AIL}$ = 152.11829 m^2

$fact^{AIT}$ = 0

$CA_{inj,2}^{AINL}$ = 18.00527 m^2

$CA_{inj,2}^{flam}$ = 18.00527 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{flam-AIL}$ = 621.90861 m^2

$fact^{AIT}$ = 0

$CA_{inj,3}^{AINL}$ = 76.711436 m^2

CA_{inj3}^{flam} = 76.711436 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{flam-AIL}$ = 1035.8186 m^2

$fact^{AIT}$ = 0

$CA_{inj,4}^{AINL}$ = 32.817669 m^2

CA_{inj4}^{flam} = 32.817669 m^2

STEP 8.16 Determine the consequence areas (probability weighted on release hole size) for component damage and personnel injury using equations (3.59) and (3.60) based on the consequence area from step 8.15

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

CONSEQUENCE AREA FOR COMPONENT DAMAGE

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad \text{.....(equation)}$$

$$CA_{cmd}^{flam} = \left(\frac{(gff_{1.}\, CA_{cmd,1}^{flam}) + (gff_{2.}\, CA_{cmd,2}^{flam}) + (gff_{3.}\, CA_{cmd,3}^{flam}) + (gff_{4.}\, CA_{cmd,4}^{flam})}{gff_{total}} \right)$$

$$= 25.21\ m^2$$

CONSEQUENCE AREA FOR PERSONNEL INJURY

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad \text{(equation 94)}$$

$$CA_{inj}^{flam} = \left(\frac{\left(gff_1 \cdot CA_{inj,1}^{flam}\right) + \left(gff_2 \cdot CA_{inj,2}^{flam}\right) + \left(gff_3 \cdot CA_{inj,3}^{flam}\right) + \left(gff_4 \cdot CA_{inj,4}^{flam}\right)}{gff_{total}} \right.$$

$$= \left. 62.852\ m^2 \right.$$

PART 9 : CALCULATE THE TOXIC CONSEQUENCES AREA

Table 4.113 Continuous Gas and Liquid Release Toxic Consequence Equation Constantsfor Miscellaneous Chemicals

Chemical	Release Duration (minutes)	Gas Release Constants		Liquid Release Constants	
		e	f	e	f
Aluminum Chloride (Alcl3)	ALL	17.663	0.9411	N/A	N/A
Carbon Monoxide (CO)	3	41.412	1.15	N/A	N/A
	5	279.79	1.06	N/A	N/A
	10	834.48	1.13	N/A	N/A
	20	2915.9	1.11	N/A	N/A
	40	5346.8	1.17	N/A	N/A
	60	6293.7	1.21	N/A	N/A
Hydrogen Chloride (HCL)	3	215.48	1.09	N/A	N/A
	5	536.28	1.15	N/A	N/A
	10	2397.5	1.1	N/A	N/A
	20	4027	1.18	N/A	N/A
	40	7534.5	1.2	N/A	N/A
	60	8625.1	1.23	N/A	N/A
Nitric Acid	3	53.013	1.25	5110	1.08
	5	68.7	1.25	9640.8	1.02
	10	96.325	1.24	12.453	1.06
	20	126.942	1.23	19.149	1.06
	40	146.941	1.22	31.145	1.06
	60	156.345	1.22	41.999	1.12
Nitrogen Dioxide (NO2)	3	6633.1	0.7	2132.9	0.98
	5	9221.4	0.68	2887	1.04
	10	11.965	0.68	6194.4	1.07
	20	14.248	0.72	13.843	1.08
	40	22.411	0.7	27.134	1.12
	60	24.994	0.71	41.657	1.13

Phosgene	3	12.902	1.2	3414.8	1.06
	5	22.976	1.29	6857.1	1.1
	10	48.985	1.24	21.215	1.12
	20	108.298	1.27	63.361	1.16
	40	244.67	1.3	178.841	1.2
	60	367.877	1.31	314.608	1.23
Toluene Diisocyanate (TDI)	3	N/A	N/A	3692.5	1.06
	5	N/A	N/A	3849.2	1.09
	10	N/A	N/A	4564.9	1.1
	20	N/A	N/A	4777.5	1.06
	40	N/A	N/A	4953.2	1.06
	60	N/A	N/A	5972.1	1.03
Ethylene Glycol Monoethyl Ether (EE)	1.5	3.819	1.171	N/A	N/A
	3	7.438	1.181	N/A	N/A
	5	17.735	1.122	N/A	N/A
	10	33.721	1.111	3.081	1.105
	20	122.68	0.971	16.877	1.065
	40	153.03	0.995	43.292	1.132
	60	315.57	0.899	105.74	1.104

Because of no chemical toxic in this equipment, so this step not calculate.

PART 10 : CALCULATE THE NON-FLAMMABLE, NON-TOXIC CA

Step 10.1 For each release hole size, calculate the non-flammable , non-toxic For steam-calculate $CA_{inj,N}^{CONT}$ using equation (43) and $CA_{inj,N}^{INST}$

1). FOR STEAM

Steam represents a hazard to personnel who are exposed to it at high temperatures. In general, steam is at 100oC (212oF) immediately after exiting a hole in an equipment item. Within a few feet, the steam will begin to mix with air cool, and condensed. The approach used here is that injury occurs above 60oC (140oF). In this case of Production Separator, the temperatur inside the presssure vessel is maximally working at 100oC (212oF). So, steam leaks is potentially occur at this situation.

$Mass_1$ = 79.5140 kgs
$Mass_2$ = 105.8808 kgs
$Mass_3$ = 105.8808 kgs
$Mass_4$ = 105.8808 kgs
$Rate_1$ = 0.0660 kg/s
$Rate_2$ = 1.0600 kg/s
$Rate_3$ = 5.4200 kg/s
$Rate_4$ = 271.4000 kg/s
C_9 = 0.123 m^2.sec/kg
C_{10} = 9.744 $m^2/kg^{0.06384}$
$fact_1^{IC}$ = 0.0026
$fact_2^{IC}$ = 0.0420635
$fact_3^{IC}$ = 0.2150794
$fact_4^{IC}$ = 1

$CA_{inj,n}^{CONT} = C_9 . Rate_n)$ ..... equation (48)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{CONT} = C_9 . Rate_1)$
= 0.00812 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{CONT} = C_9 . Rate_2)$
= 0.13038 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{CONT} = C_9 . Rate_3)$
= 0.66666 m^2

$CA_{inj,n}^{INST} = C_{10} . Mass_n)^{0.6384}$ ..... equation (49)

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{INST} = C_{10} . Mass_4)^{0.6384}$
= 83.917625 m^2

2). FOR ACIDS AND CAUSTIC

For Acids or caustics- compute, $CA_{inj,n}^{CONT}$ using equation (3.72), (3.73), (3.74). Note that the data is not provided for an instantaneous release ; therefore,

No acid or caustic, thus value are 0.

Step 10.2 For each release hole size, calculate the instantaneous/continuous blending factor, $fact_n^{IC}$. For steam, use equation (3.71).

for acids or caustics, $fact_n^{IC}$ =0.0

Step 10.3 For each release hole size , compute the blended non-flammable , non-toxic personnel injury consequence area for steam or acid leaks, $CA_{cmd,n}^{leak}$, using equation (3.76) based on the consequence are from step 10.1 and the blending factor , $fact_n^{IC}$, from step 10.2 note that there is no need to calculate component damage area for the level 1 non-flammable release (steam or acid/caustic) :

$CA_{cmd,n}^{leak}$ = 0 m^2

$CA_{inj,n}^{leak} = CA_{inj,n}^{INST}.\ fact_n^{IC} + CA_{inj,n}^{CONT}.(1 - fact_n^{IC})$ ..... equation (50)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{leak} = CA_{inj,1}^{INST}.\ fact_1^{IC} + CA_{inj,1}^{CONT}.(1 - fact_1^{IC})$

= 0.0080967 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{leak} = CA_{inj,2}^{INST}.\ fact_2^{IC} + CA_{inj,2}^{CONT}.(1 - fact_2^{IC})$

= 0.1248958 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{leak} = CA_{inj,3}^{INST}.\ fact_3^{IC} + CA_{inj,3}^{CONT}.(1 - fact_3^{IC})$

= 0.52327519 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{leak} = CA_{inj,4}^{INST}.\ fact_4^{IC} + CA_{inj,4}^{CONT}.(1 - fact_4^{IC})$

= 83.917625 m^2

Step 10.4 Determine the final non-flammable, non toxic consequence areas for personnil injury, CA_{icmd}^{nfnt} using equation (3.80) based on consequence areas calculated for each release hole size in step 10.3 . Note that there is no need to calculate a final-flammable, non-toxic consequence area for component damage area for the level 1 non-flammable release (steam or acid/caustic, or :

$CA_{cmd,n}^{lnfnt} = 0 \ m^2$

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}} \right) \quad \text{..... (equation)}$$

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

$$CA_{inj}^{nfnt} = \left(\frac{(gff_1 \cdot CA_{inj,1}^{leak}) + (gff_2 \cdot CA_{inj,2}^{leak}) + (gff_3 \cdot CA_{inj,3}^{leak}) + (gff_4 \cdot CA_{inj,4}^{leak})}{gff_{total}} \right)$$

$= 2.07120 \ m^2$

PART 11 : CALCULATION OF FINAL CONSEQUENCE AREA

Step 11.1 Calculate the final component damage consequence area, Cacmd

Note that since the component damage consequence areas for toxic releases, CAcmd^{tox}, and non-flammable, non-toxic releases, CAcmd^{nfnt}, are both equal to zero. Then, the final component damage consequence area is equal to the consequence area calculated for flammable releases, CAcmd^{flam}.

CA_{cmd}= CA_{cmd}^{flam} ..... equation (52)

= 25.21 m^2

Step 11.2 Calculate the final personnel injury consequence area, CA_{inj}

CA_{inj} = max $\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$ ..... equation (53)

CA_{inj}^{flam} = 62.852 m^2

CA_{inj}^{tox} = 0.00 m^2

CA_{inj}^{nfnt} = 2.07120 m^2

CA_{inj} = max $\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$

= 62.8516857 m^2

Step 11.3 Calculate the final consequence area, CA, using equation below:

CA=max$\left[CA_{cmd}, CA_{inj}\right]$

= 62.85 m^2

= 676.529914 ft^2

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 4 :

INSPECTION PLANNING AND RECOMMENDATION

PSV-2910

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 4 = Inspection Planning and Recommendation

STEP 1 CALCULATION OF RISK ANALYSIS

$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$ equation (54)

dimana :

$Risk^{prd}$ = total risiko PRD

$Risk_f^{prd}$ = risiko PRD gagal membuka

$Risk_l^{prd}$ = risiko PRD bocor

STEP 1 Menghitung resiko dari peluang kegagalan PRD untuk gagal membuka

$Risk_{f.j}^{prd}$

A. RBI Date

FIRE CASE

$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 2.26E-10 $Risk_{f.j}^{prd}$ = 2E-10 x 62.852

$C_{f,j}^{prd}$ = 62.85 m^2 = 1.4204E-08

OVERFILLING CASE

$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 3.53E-09 $Risk_{f.j}^{prd}$ = 4E-09 x 62.852

$C_{f,j}^{prd}$ = 62.85 m^2 = 2.2187E-07

B. RBI Plan Date

FIRE CASE

$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 3.53E-09 $Risk_{f.j}^{prd}$ = 4E-09 x 62.852

$C_{f,j}^{prd}$ = 62.85 m^2 = 2.2187E-07

OVERFILLING CASE

$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 8.82E-08 $Risk_{f.j}^{prd}$ = 9E-08 x 62.852

$C_{f,j}^{prd}$ = 62.85 m^2 = 5.5435E-06

$$Risk_f^{prd} = \sum_{j=1}^{ndc} P_{f,j}^{prd} . C_{f,j}^{prd}$$

A. RBI Date

$Risk_f^{prd}$ = 1E-08 + 2E-07

= 2.3607E-07

B. RBI Plan Date

$Risk_f^{prd}$ = 2E-07 + 6E-06

= 5.7654E-06

STEP 1.2 Hitung risiko untuk kasus kebocoran PRD, $Risk_l^{prd}$

$$Risk_l^{prd} = P_l^{prd} . C_l^{prd}$$ equation (56)

Dimana :

P_l^{prd} = 0.0080 (RBI Date)

P_l^{prd} = 0.1249 (RBI Plan Date)

C_l^{prd} = 62.85 m^2

A. RBI Date

$Risk_l^{prd}$ = 0.0080 x 62.852

= 0.50281

B. RBI Plan Date

$Risk_l^{prd}$ = 0.1249 x 62.85

= 7.85018

STEP 1.3 Menghitung total risiko menggunakan persamaan (57)

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (57)

A. Risk at RBI Date

$Risk^{prd}$ = 0.5028 m^2/year

= 5.4122 ft^2/year

B. Risk at RBI Plan Date

$Risk^{prd}$ = 7.8502 m^2/year

= 84.499 ft^2/year

STEP 2 Risk Matrix

Probabilty Score at RBI Date = 2E-10 + 4E-09 + 0.0080

= 8.00E-03

Probabilty Score at Plan Date = 4E-09 + 9E-08 + 0.1249

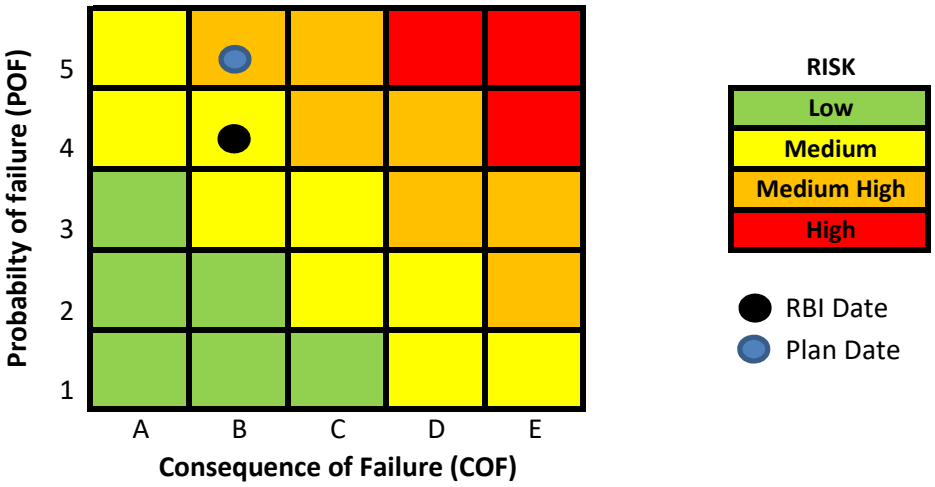
= 1.25E-01

Consequence Score = 62.85 m^2

= 676.53 ft^2

Table 4.1 Numerical Values Associated with POF and Area-Based COF Categories

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t,I_E) \leq 3.06E-05$	$D_{ftotal} \leq 1$	A	$CA \leq 100$
2	$3.06E-05 < P_f(t,I_E) \leq 3.06E-04$	$1 < D_{ftotal} \leq 10$	B	$100 < CA \leq 1.000$
3	$3.06E-04 < P_f(t,I_E) \leq 3.06E-03$	$10 < D_{ftotal} \leq 100$	C	$1.000 < CA \leq 10.000$
4	$3.06E-03 < P_f(t,I_E) \leq 3.06E-02$	$100 < D_{ftotal} \leq 1000$	D	$10.000 < CA \leq 100.000$
5	$P_f(t,I_E) > 3.06E-02$	$D_{ftotal} > 1000$	E	$CA > 100.000$



STEP 3 Inspection Date

Target date dapat dihitung dengan cara melakukan interpolasi nilai RBI Date dan PRBI Plan Date

Dalam menentukan target date, digunakan nilai risk target sebesar 40ft^2 (3.71 m^2) untuk menentukan tahun inspection date.

Data	Date	Age	Risk (m^2/yr)
RBI Date	15/03/2020	0	0.503
Risk Target	?	?	3.710
Plan Date	15/3/2024	11	7.850

$$\frac{Y - Y_1}{Y_2 - Y_1} = \frac{X - X_1}{X_2 - X_1}$$

$$Y = Y_1 + \left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)$$

$$Y = 0 + \left(\frac{3.71 - 0.503}{7.85 - 0.503}\right)(11 - 0)$$

Y = 4.8015903 Year

Y = 1752.5805 Hari

= 31/12/2024

Interval inspeksi equipment berikutnya berdasarkan hasil inspeksi berbasis risiko yaitu pada tanggal 31 Desember 2024

STEP 4 Recommendation

1 Inspection Category

Inspection Effectiveness	Description of Inspection	Date
C	Inspeksi visual telah dilakukan tanpa tes pop, di mana dokumentasi terperinci tentang kondisi internal PRD komponen dibuat.	31/12/2024
Fairly Effective	Tes trevitest atau in-situ telah dilakukan di tempat yang sebenarnya cairan proses tidak digunakan untuk memberi tekanan pada sistem.	

Berdasarkan standart API 581 Direkomendasikan menggunakan inspection effectiveness kategori C dengan mengaplikasikan Visual on-stream inspection

2 Inspection Strategy

Berdasarkan Standart API 576 berikut rekomendasi record visual inspeksi Pressure Relief Device

Unit	Location		Set Pressure	Test Interval
Make		:		
Style		:		
Body and bonnet material		:		
Nozzle and disk material		:		
Trim material		:		
Spring material		:		
Spring no		:		
Flange sizes				
	Inlet	:		
	Outlet	:		
Spring set pressure		:		
Relieving pressure		:		
normal operating temp		:		
Remark				

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 1:

DATA PRESSURE RELIEF DEVICE

PSV-2921

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

Lampiran 1 = Data Pressure Relief Device

1 GENERAL

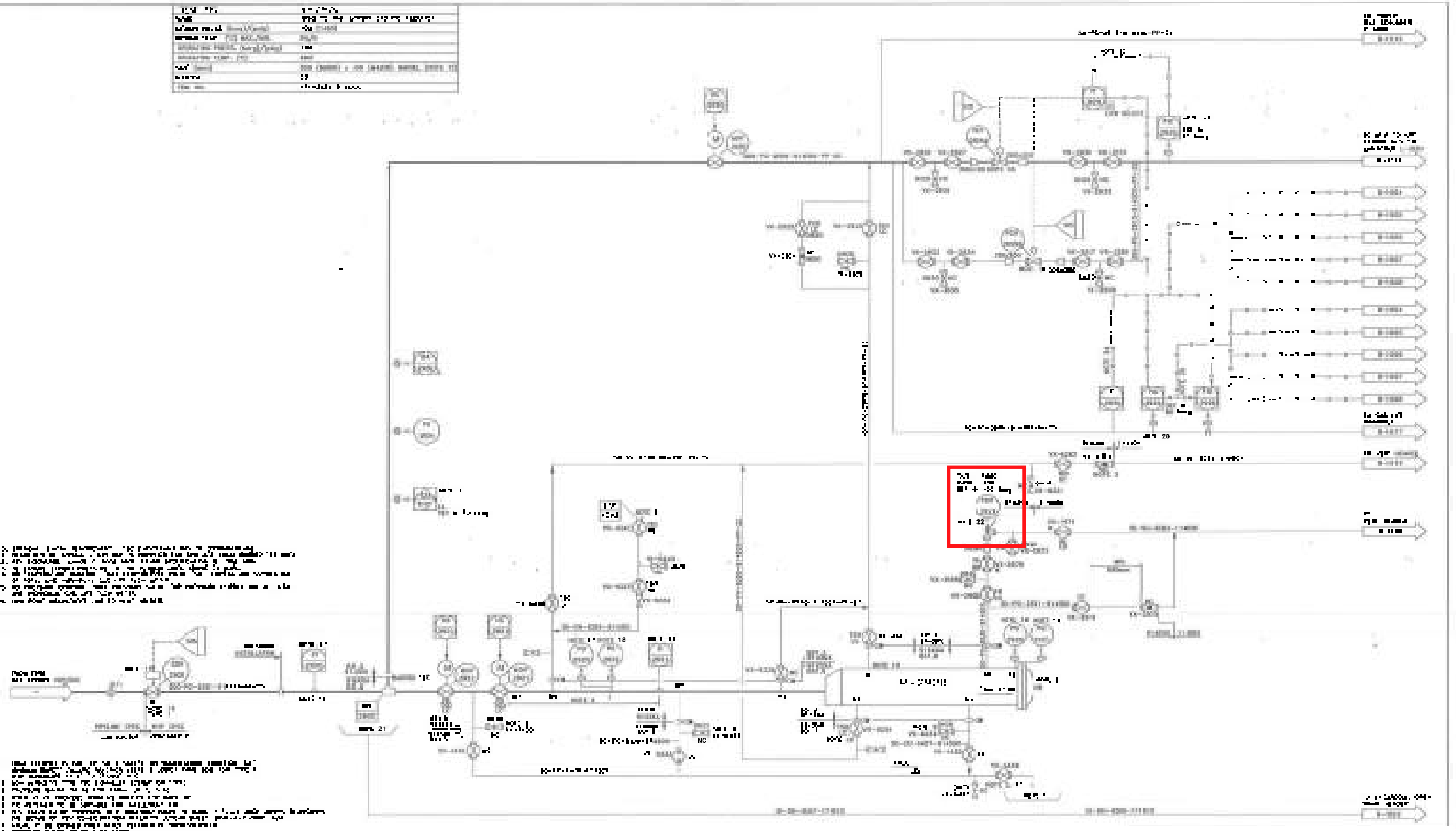
Tag Number	:	PSV-2921	
Service	:	FPSO to WHP Export Gas Pig Launcher	
Noozle (full/semi)	:	FULL	
PID No.	:	BTJT-A-B-1015	
Design	:	SAFETY-RELIEF	
Type	:	Conventional	
Bonnet Type	:	Closed	
Nace Requirement	:	Yes	

2 PROCESS CONDITIONS

Fluid		:	Hydrocarbon	
State		:	Gas	
Required Capacity		:	2323	lb/h
Molecular Weight		:	21	
Operating Pressure		:	14.69	psig
Set Pressure		:	1465	psig
Operating Temperatur		:	397	^{o}F
Reliefing Temperatur		:	397	^{o}F
Back Pressure	Constant	:	0	psig
	Variable	:	0	psi
	Total	:	81.94	psig
% Allowable Overpressure		:	21%	
Overpressure Factor		:	-	
Compressible Factor		:	0.961	
Laten Heat of Vaporation		:	-	Btu/lb
Ratio of Specific Heats (Cp/C		:	1.276	
Relief Density		:	-	Lb/ft^2
Relief Viscosity		:	-	cP
Barometric Pressure		:	14.7	psia

3 DESIGN CONDITION

Design Pressure	:	1465	psig
Design Temperatur	:	500	^{o}F



CASE 1 : MAXIMUM GAS FLOW RATE (AUGUST 2016)

Stream Name		1	1A	1B	1C	1D	1E	2	2A	2B	2C
Description		Wellhead Flowline U/S of choke - NAG	Wellhead Flowline (BT2_A_P) U/S of choke - Long String	Wellhead Flowline (BT4_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_D_P) U/S of choke - Long String	Wellhead Flowline (BT2_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_E_P) U/S of choke - Long String	Wellhead Flowline D/S of choke - Short String (NAG)	Wellhead Flowline (BT2_A_P) D/S of choke - Long String	Wellhead Flowline (BT4_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_D_P) D/S of choke - Long String
MIXTURE											
Vapour Fraction		1.0000	0.2955	0.4203	0.2920	0.3095	0.2956	1.0000	0.3159	0.4223	0.2940
Temperature	C	75.0	75.0	71.0	72.0	75.0	74.0	66.4	69.2	70.2	71.4
Pressure	kPag	2959	2959	1034	1034	1034	1034	930	930	930	930
Pressure	bar_g	29.6	29.6	10.3	10.3	10.3	10.3	9.3	9.2	9.2	9.3
Mass Flow	kg/h	8478.39	26300.60	110228.76	22227.17	83356.85	29194.58	8478.39	26300.60	110228.76	22227.17
Molar Flow	kgmole/h	449.11	841.38	3550.51	685.06	2545.47	899.18	449.11	841.38	3550.51	685.06
Molecular Weight		18.9	31.3	31.0	32.4	32.4	32.5	18.9	31.3	31.0	32.4
Heat Flow	kW	-3821	-53720	-205650	-44662	-163516	-58456	-3821	-53720	-205650	-44662
Mass Heat Capacity	kJ/kg C	2.40	2.88	2.80	2.91	2.91	2.92	2.27	2.92	2.78	2.91
Mass Density	kg/m3	21.04	108.95	29.76	43.88	41.06	43.17	7.04	35.86	29.94	39.70
GAS PHASE											
Std Gas Flow	kNm3/h	10.05	5.56	33.39	4.46	17.62	5.95	10.05	5.95	33.54	4.51
Std Gas Flow	MMSCFD	9.00	4.98	29.91	4.01	15.79	5.33	9.00	5.33	30.05	4.04
Molar Flow	kgmole/h	449.11	248.67	1492.34	200.05	787.71	265.75	449.11	265.81	1499.40	201.38
Actual Gas Flow	ACT m3/h	403.02	217.58	3621.21	488.87	1934.34	650.60	1205.17	710.89	4009.69	540.38
Mass Flow	kg/h	8478.39	5617.70	37106.46	4989.82	19834.53	6670.73	8478.39	6309.08	37411.64	5048.85
Molecular Weight		18.9	22.6	24.9	24.9	25.2	25.1	18.9	23.7	25.0	25.1
Mass Heat Capacity	kJ/kg-C	2.40	2.30	2.13	2.13	2.14	2.14	2.27	2.13	2.12	2.12
Z Factor		0.95	0.93	0.96	0.96	0.96	0.96	0.98	0.97	0.97	0.97
Thermal Conductivity	W/m-K	0.041	0.038	0.034	0.034	0.035	0.035	0.038	0.035	0.034	0.034
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mass Density	kg/m3	21.04	25.82	10.25	10.25	10.25	10.25	7.04	8.88	9.33	9.34
Cp/Cv (Gamma)		1.32	1.30	1.23	1.23	1.22	1.22	1.27	1.23	1.22	1.22
OIL PHASE											
Mass Flow	kg/h	—	11155.91	39678.59	9354.61	33942.01	12226.33	—	10545.33	39426.24	9304.07
Liquid Vol Flow @Std Cond	m3/h	—	13.25	46.51	10.96	39.75	14.37	—	12.29	46.14	10.88
Liquid Vol Flow @Std Cond	barrel/day	—	2000	7021	1655	6000	2162	—	1855	6965	1643
Actual Volume Flow	m3/h	—	13.99	48.76	11.50	41.81	15.05	—	12.85	48.32	11.41
Molecular Weight		—	174.5	196.6	197.0	198.1	197.7	—	205.6	198.4	199.5
Mass Heat Capacity	kJ/kg-C	—	2.16	2.13	2.13	2.14	2.14	—	2.11	2.12	2.13
Thermal Conductivity	W/m K	—	0.103	0.109	0.109	0.109	0.109	—	0.111	0.110	0.110
Viscosity	cP	—	1.20	1.56	1.54	1.50	1.51	—	1.76	1.62	1.60
Mass Density	kg/m3	—	797.60	813.74	813.27	811.86	812.33	—	820.69	815.97	815.22
Surface Tension	dyne/cm	—	12.91	14.73	14.88	14.57	14.61	—	15.18	14.92	14.80
AQUEOUS PHASE											
Mass Flow	kg/h	—	9526.58	33443.69	7882.74	28580.29	10297.52	—	9445.29	33390.88	7874.25
Liquid Vol Flow @Std Cond	m3/h	—	9.33	32.86	7.73	28.16	10.15	—	9.31	32.80	7.76
Liquid Vol Flow @Std Cond	barrel/day	—	1417	4975	1173	4251	1532	—	1406	4967	1171
Actual Volume Flow	m3/h	—	9.83	34.40	8.12	29.50	10.62	—	9.70	34.33	8.10
Molecular Weight		—	18.0	18.0	18.0	18.0	18.0	—	18.0	18.0	18.0
Mass Heat Capacity	kJ/kg-C	—	4.34	4.34	4.34	4.35	4.35	—	4.34	4.34	4.34
Thermal Conductivity	W/m-K	—	0.666	0.663	0.664	0.666	0.665	—	0.662	0.663	0.663
Viscosity	cP	—	0.37	0.39	0.39	0.37	0.38	—	0.41	0.40	0.39
Mass Density	kg/m3	—	969.63	972.09	971.29	968.88	969.68	—	973.51	972.66	971.73
MIXTURE COMPOSITION (Mole Fraction)											
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0055	0.0025	0.0031	0.0021	0.0022	0.0021	0.0055	0.0025	0.0031	0.0021
CO2		0.0031	0.0040	0.0055	0.0038	0.0040	0.0039	0.0031	0.0040	0.0055	0.0038
Methane		0.6627	0.2283	0.2001	0.2016	0.2112	0.2026	0.6627	0.2283	0.2001	0.2016
Ethane		0.0453	0.0283	0.0393	0.0276	0.0290	0.0278	0.0453	0.0283	0.0393	0.0276
Propane		0.0262	0.0236	0.0361	0.0260	0.0274	0.0263	0.0262	0.0236	0.0361	0.0260
i-Butane		0.0072	0.0065	0.0104	0.0078	0.0082	0.0078	0.0072	0.0065	0.0104	0.0078
n-Butane		0.0081	0.0084	0.0135	0.0103	0.0109	0.0105	0.0081	0.0084	0.0135	0.0103
i-Pentane		0.0038	0.0040	0.0062	0.0050	0.0053	0.0051	0.0038	0.0040	0.0062	0.0050
n-Pentane		0.0025	0.0034	0.0050	0.0042	0.0044	0.0043	0.0025	0.0034	0.0050	0.0042
Mcyclopentan		0.0007	0.0012	0.0015	0.0014	0.0014	0.0014	0.0007	0.0012	0.0015	0.0014
Benzene		0.0000	0.0003	0.0004	0.0004	0.0004	0.0004	0.0000	0.0003	0.0004	0.0004
Cyclohexane		0.0001	0.0012	0.0014	0.0014	0.0014	0.0014	0.0001	0.0012	0.0014	0.0014
Mcyclohexane		0.0006	0.0021	0.0023	0.0024	0.0024	0.0024	0.0006	0.0021	0.0023	0.0024
Toluene		0.0000	0.0006	0.0006	0.0006	0.0006	0.0006	0.0000	0.0006	0.0006	0.0006
E-Benzene		0.0000	0.0003	0.0002	0.0003	0.0003	0.0003	0.0000	0.0003	0.0002	0.0003
p-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
m-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
o-Xylene		0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002	0.0002
n-Pbenzene		0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0003	0.0003
124-MBenzene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
C6*		0.0024	0.0045	0.0056	0.0053	0.0055	0.0054	0.0024	0.0045	0.0056	0.0053
C7*		0.0000	0.0035	0.0038	0.0039	0.0040	0.0040	0.0000	0.0035	0.0038	0.0039
C8*		0.0000	0.0036	0.0035	0.0039	0.0039	0.0040	0.0000	0.0036	0.0035	0.0039
C9*		0.0000	0.0026	0.0026	0.0031	0.0030	0.0031	0.0000	0.0026	0.0026	0.0031
C10-C15*		0.0000	0.0154	0.0134	0.0164	0.0160	0.0163	0.0000	0.0154	0.0134	0.0164
C16-C19*		0.0000	0.0057	0.0056	0.0071	0.0070	0.0071	0.0000	0.0057	0.0056	0.0071
C20-C27*		0.0000	0.0073	0.0063	0.0078	0.0076	0.0077	0.0000	0.0073	0.0063	0.0078
C28-C37*		0.0000	0.0043	0.0037	0.0045	0.0044	0.0045	0.0000	0.0043	0.0037	0.0045
C38-C80*		0.0000	0.0031	0.0027	0.0033	0.0032	0.0033	0.0000	0.0031	0.0027	0.0033
H2O		0.0115	0.6328	0.5354	0.6479	0.6343	0.6456	0.0115	0.6328	0.5354	0.6479
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Stream Name		2D	2E	3	4	4A	5	6	7	8	9	10
Description		Wellhead Flowline (BT2_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_E_P) D/S of choke - Long String	Inlet to Production Separator	Production Separator Gas Outlet	Gas Pipeline to FPSO	Liquid Pipeline to FPSO	Export Gas from FPSO to WHP (Note 7)	Export Gas from WHP to ORF (Note 6)	Gas Lift	Gas Inlet to FPSO (Note 6)	Liquid Inlet to FPSO (Note 6)
MIXTURE												
Vapour Fraction		0.3115	0.2978	0.4147	1.0000	1.0000	0.0002	1.0000	1.0000	1.0000	0.0841	0.0019
Temperature	C	74.3	73.4	70.3	70.5	70.2	70.5	65.8	72.9	65.8	32.1	69.7
Pressure	kPag	930	930	930	930	880	880	9101	7120	9101	755	522
Pressure	bar_g	9.3	9.3	9.3	9.3	8.8	8.8	91.0	71.2	91.0	7.6	5.2
Mass Flow	kg/h	82356.85	29194.58	289534.88	92836.71	92836.71	196698.17	80517.40	72509.32	7845.62	92836.71	196698.17
Molar Flow	kgmole/h	2545.47	899.18	9400.90	3899.75	3899.75	5501.15	3833.67	3452.38	373.55	3899.75	5501.15
Molecular Weight		32.4	32.5	30.8	23.8	23.8	35.8	21.0	21.0	21.0	23.8	35.8
Heat Flow	kW	-163516	-58456	-547951	-96398	-96398	-451503	-86559	-78265	-8434	-96081	-451835
Mass Heat Capacity	kJ/kg C	2.90	2.91	2.81	2.14	2.14	3.13	2.72	2.61	2.72	2.11	3.13
Mass Density	kg/m3	37.14	39.04	27.10	8.87	8.43	870.51	75.42	61.13	75.42	7.80	731.73
GAS PHASE												
Std Gas Flow	kNm3/h	17.74	5.99	87.21	87.24	87.24	0.01	85.76	77.23	8.36	85.60	0.23
Std Gas Flow	MMSCFD	15.89	5.36	78.12	78.15	78.15	0.02	76.83	69.19	7.49	76.91	0.21
Molar Flow	kgmole/h	792.94	267.56	3898.34	3899.75	3899.75	1.13	3833.67	3452.38	373.56	3837.74	10.47
Actual Gas Flow	ACT m3/h	2148.41	722.19	10461.79	10470.75	11011.23	3.19	1067.56	1186.11	104.02	11747.65	46.67
Mass Flow	kg/h	20061.87	6749.84	92780.89	92836.71	92836.71	27.22	80517.40	72509.32	7845.62	91652.63	286.14
Molecular Weight		25.3	25.2	23.8	23.8	23.8	24.1	21.0	21.0	21.0	23.9	27.3
Mass Heat Capacity	kJ/kg-C	2.13	2.12	2.14	2.14	2.14	2.14	2.72	2.61	2.72	2.06	2.06
Z Factor		0.97	0.97	0.97	0.97	0.97	0.97	0.86	0.86	0.86	0.97	0.97
Thermal Conductivity	W/m-K	0.034	0.034	0.035	0.035	0.035	0.035	0.047	0.043	0.047	0.033	0.037
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Mass Density	kg/m3	9.35	9.35	8.87	8.87	8.43	8.54	75.42	61.13	75.42	7.80	6.13
Cp/Cv (Gamma)		1.22	1.22	1.23	1.23	1.23	1.23	1.46	1.44	1.46	1.24	1.20
OIL PHASE												
Mass Flow	kg/h	33751.47	12159.37	107020.05	0.00	—	106954.00	—	—	—	80.05	106703.77
Liquid Vol Flow @Std Cond	m3/h	39.46	14.22	124.70	0.00	—	124.69	—	—	—	0.10	124.26
Liquid Vol Flow @Std Cond	barrel/day	5957	2147	18834	0	—	18823	—	—	—	18	18758
Actual Volume Flow	m3/h	41.47	14.93	130.61	0.00	—	130.51	—	—	—	0.11	129.94
Molecular Weight		200.7	200.3	205.1	205.3	—	205.6	—	—	—	110.1	206.7
Mass Heat Capacity	kJ/kg-C	2.14	2.13	2.12	2.12	—	2.12	—	—	—	2.09	2.11
Thermal Conductivity	W/m K	0.110	0.110	0.111	0.111	—	0.111	—	—	—	0.107	0.112
Viscosity	cP	1.55	1.56	1.72	1.72	—	1.72	—	—	—	0.49	1.79
Mass Density	kg/m3	813.88	814.31	819.41	819.38	—	819.51	—	—	—	733.22	821.21
Surface Tension	dyne/cm	14.75	14.78	15.11	15.10	—	15.13	—	—	—	16.73	15.41
AQUEOUS PHASE												
Mass Flow	kg/h	28543.51	10285.38	89733.03	0.00	—	89710.95	—	—	—	1101.03	89708.25
Liquid Vol Flow @Std Cond	m3/h	28.13	10.14	88.42	0.00	—	88.41	—	—	—	1.09	88.40
Liquid Vol Flow @Std Cond	barrel/day	4246	1530	13348	0	—	13345	—	—	—	164	13344
Actual Volume Flow	m3/h	29.45	10.60	92.26	0.00	—	92.26	—	—	—	1.12	92.20
Molecular Weight		18.0	18.0	18.0	18.0	—	18.0	—	—	—	18.0	18.0
Mass Heat Capacity	kJ/kg-C	4.35	4.34	4.34	4.34	—	4.34	—	—	—	4.32	4.34
Thermal Conductivity	W/m-K	0.666	0.665	0.663	0.663	—	0.663	—	—	—	0.646	0.662
Viscosity	cP	0.38	0.38	0.40	0.40	—	0.40	—	—	—	0.53	0.40
Mass Density	kg/m3	969.38	970.15	972.59	972.46	—	972.44	—	—	—	966.88	972.93
MIXTURE COMPOSITION (Mole Fraction)												
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0022	0.0021	0.0026	0.0068	0.0068	0.0000	0.0069	0.0069	0.0069	0.0068	0.0000
CO2		0.0040	0.0039	0.0044	0.0105	0.0105	0.0001	0.0093	0.0093	0.0093	0.0105	0.0001
Methane		0.2112	0.2026	0.3011	0.7225	0.7225	0.0023	0.8082	0.8082	0.8082	0.7225	0.0023
Ethane		0.0290	0.0278	0.0317	0.0799	0.0799	0.0010	0.0735	0.0735	0.0735	0.0799	0.0010
Propane		0.0274	0.0263	0.0297	0.0684	0.0684	0.0022	0.0574	0.0574	0.0574	0.0684	0.0022
i-Butane		0.0082	0.0079	0.0087	0.0190	0.0190	0.0013	0.0151	0.0151	0.0151	0.0190	0.0013
n-Butane		0.0109	0.0105	0.0112	0.0240	0.0240	0.0021	0.0178	0.0178	0.0178	0.0240	0.0021
i-Pentane		0.0053	0.0051	0.0053	0.0101	0.0101	0.0019	0.0051	0.0051	0.0051	0.0101	0.0019
n-Pentane		0.0044	0.0043	0.0043	0.0078	0.0078	0.0016	0.0032	0.0032	0.0032	0.0078	0.0016
Mcyclopentan		0.0014	0.0014	0.0014	0.0017	0.0017	0.0011	0.0007	0.0007	0.0007	0.0017	0.0011
Benzene		0.0004	0.0004	0.0003	0.0004	0.0004	0.0003	0.0000	0.0000	0.0000	0.0004	0.0003
Cyclohexane		0.0014	0.0014	0.0013	0.0015	0.0015	0.0012	0.0001	0.0001	0.0001	0.0015	0.0012
Mcyclohexane		0.0024	0.0024	0.0022	0.0017	0.0017	0.0025	0.0000	0.0000	0.0000	0.0017	0.0025
Toluene		0.0006	0.0006	0.0006	0.0004	0.0004	0.0007	0.0000	0.0000	0.0000	0.0004	0.0007
E-Benzene		0.0003	0.0003	0.0002	0.0001	0.0001	0.0004	0.0000	0.0000	0.0000	0.0001	0.0004
p-Xylene		0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
m-Xylene		0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
o-Xylene		0.0002	0.0002	0.0002	0.0001	0.0001	0.0003	0.0000	0.0000	0.0000	0.0001	0.0003
n-Pbenzene		0.0003	0.0003	0.0003	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0005
124-MBenzene		0.0004	0.0004	0.0004	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0006
C6*		0.0055	0.0054	0.0051	0.0007	0.0007	0.0040	0.0008	0.0008	0.0008	0.0007	0.0040
C7*		0.0040	0.0040	0.0035	0.0034	0.0034	0.0037	0.0002	0.0002	0.0002	0.0034	0.0037
C8*		0.0039	0.0040	0.0034	0.0018	0.0018	0.0046	0.0000	0.0000	0.0000	0.0018	0.0046
C9*		0.0030	0.0031	0.0027	0.0008	0.0008	0.0042	0.0000	0.0000	0.0000	0.0008	0.0040
C10-C15*		0.0160	0.0163	0.0140	0.0001	0.0001	0.0238	0.0000	0.0000	0.0000	0.0001	0.0238
C16-C19*		0.0070	0.0071	0.0061	0.0000	0.0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0104
C20-C27*		0.0076	0.0077	0.0066	0.0000	0.0000	0.0113	0.0000	0.0000	0.0000	0.0000	0.0113
C28-C37*		0.0044	0.0045	0.0039	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0066
C38-C80*		0.0032	0.0033	0.0028	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0048
H2O		0.6343	0.6456	0.5431	0.0318	0.0318	0.9055	0.0000	0.0000	0.0000	0.0318	0.9055
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

PSEUDO COMPONENT	LIQUID DENSITY (g/cm3)	Tc (°C)	Pc (bara)	ACENTRIC FACTOR	NBP (°C)	MOLECULAR WEIGHT (g/mol)	Vc (cm³/mol)
C6*	0.66	234.2	29.7	0.3	68.7	86.2	370.0
C7*	0.74	241.4	24.5	0.4	103.1	96.0	524.1
C8*	0.77	268.2	21.7	0.4	126.8	107.0	527.9
C9*	0.78	298.1	20.0	0.4	143.6	121.0	527.8
C10-C15*	0.82	419.6	18.1	0.6	220.7	171.6	716.7
C16-C19*	0.85	539.9	14.1	0.8	304.8	242.0	1019.3
C20-C27*	0.88	658.6	12.3	0.9	376.9	318.6	1381.5
C28-C37*	0.90	831.8	10.8	1.1	462.2	441.2	1979.7
C38-C80*	0.94	1081.1	0.7	1.0	579.2	669.1	3271.8

Approved For Construction

MASTER

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.1:
PROBABILITY OF FAILURE TO OPEN CALCULATION

PSV-2921

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.1 = Probabilty Of Failure To Open

PART 1 : CALCULATION OF PROBABILITY OF FAILURE TO OPEN

The fundamental calculation applied to PRDs for the fail to open case is the product of an estimated overpressure demand case frequency (or demand rate), the probability of the PRD failing to open on demand, and the probability that the protected equipment at higher overpressures will lose containment.

$$P_{f,j}^{prd} = P_{fod,j} \cdot DR_j . P_{f,j}$$ equation (1)

Dimana :

$P_{f,j}^{prd}$ = POF of a PRD overpressure demand case, (failures/year)

$P_{fod,j}$ = POFOD of a PRD (failures/demand)

DR_j = demand rate (demands/year)

$P_{f,j}$ = POF (loss of containment) (failures/year)

The subscript j in the above equation indicates that the POF for the PRD,P prd f , j. needs to be calculated for each of the applicable overpressure demand cases associated with the PRD

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 tahun see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service	:	Methane	
Typical Temperature	:	397 ^{o}F	
Fluid Severity	:	Mild	See Table 7.4
Design Type PRD	:	Conventional	
Discharge Location	:	discharge to flare with flare recovery system	

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fc,for conventional valves discharging to closed system or to flare

F_C = 0.75 for conventional valves discharging to closed system or flare

F_C = 1.00 for all other cases

STEP 4 Determine the environment adjustment factor, Fenv using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 1.0 (see data process condition)

STEP 5 The result of the procedure outlined above will be a modified characteristic life, ηmod, as defined in equation (2)

F_C = 0.75 see step 3

F_C = 1.00 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_C x F_{env} x η_{def} equation (1.14)

= 0.75 x 1.00 x 37.88

= 28.41

STEP 6 Assemble the PRD's inspection history, Grade each record using the inspection effectiveness table, part 2, Annex 2.c, Table 2.C.3.1. Record the result of each inspection record; PASS/FAIL and NO LEAK/LEAK and determine the confidence factors, Cfi, as applicable, for each inspection history based on the results of the test Determine the time duration, tdur,i of each inspection cycle

STEP 6.1 Each inspection record must be graded using the PRD inspection effectifeness table, part 2, annex 2.C, table 2.C.3.1

- Inspection effectiveness : part 2, annex 2.C, Table 2.C.3.1

Tabel 2.C.3.1- Inspeksi dan pengujian keefektifan untuk PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

STEP 6.2 Record the PASS/FAIL and NO LEAK/LEAK in order to determine the confidence factors, Cfi , as applicable , for each inspection history where a test was conducted

- Inspection Record = No Leak / Leak

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i = 0.5 see table 7.8

STEP 6.3 Determine the time duration , tdur,I ,between each inspection cycle

a. RBI Date $t_{dur,}i$ = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date $t_{dur,}i$ = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 6.4 Determine if the PRD was overhauled

- refer to section 7.7.2 and 7.7.3 ,as well as figure 7.7, for more information

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{14.69}{1464.9}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.009)}{0.90}\right)$$

$$= 0.11$$

P_S = 14.69

P_{Set} = 1464.9

$\frac{P_s}{P_{set}}$ = 0.01

STEP 7 Starting at the earliest inspection record, update the modifierd characteristic life ηmod ,determine in step 5 as follows

STEP 7.1 Calculate the prior POF using equation (3) . The time prior for use in equation (3) . Is the time duration of the inspection cycle , tdur,I as determine in step 6 . Note that for the first inspection record ,the modified characteristic life, ηmod, is used . sub sequent inspection record will use the update ed characteristic life ,ηupd,from step 7.5

$$P_{f,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.09714

STEP 7.2 Calculate the prior probability of passing using Equation (4)

$$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$$ equation (4)

A. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0289

$P_{p,Prior}^{prd}$ = 0.97108

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0971

$P_{p,Prior}^{prd}$ = 0.90286

STEP 7.3 Determine the condition POF and the conditional probability of pass using Equations (5)

$$P_{f,cond}^{prd} = (1\text{-}CF_{pass}).P_{p,prior}^{prd}$$ equation (5)

CF_{pass} = 0.5 step 6.2

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (BRI Plan Date) step 7.2

A. RBI Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48554

B. RBI Plan Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45143

step 7.4 Calculatethe weighted POF, $P_{f,wgt}^{prd}$ using the appropriate equation from table 7.9

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{f,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{f,wgt}^{prd}$ = 0.4855

B. RBI Plan Date

$P_{f,wgt}^{prd}$ = 0.4514

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (6) and the weighted POF

$$\eta_{upd} = \frac{t}{\left(-ln\left[1 - P_{f,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}}$$ equation (6)

η_{upd} = 10.62

STEP 7.6 Repeat step 7 for each of the inspection record available for the PRD until a final updated value for the characteristic life, , is determineη_{upd}

$$P_{f,Prior}^{prd} = 1 - \exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
ηupd	=	28.406	= η_{mod}	see step 6
ηupd	=	10.621		see step 7.5
β	=	1.80		see step 2

a. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.45143

STEP 8 The POFOD should be adjusted based on the overpressure scenario, The overpressure factor Fop,j, is an adjustment for overpressure scenarios higher than 1.3 times the set pressure

$F_{op,j}$ = 1.0 for $\frac{F_{op,j}}{P_{set}} < 1.3$

$F_{op,j}$ = 0.2 for $\frac{F_{op,j}}{P_{set}} > 4$

$F_{op,j}$ = $1 - \frac{1}{3.375} \cdot \left(\frac{F_{op,j}}{P_{set}} - 1.3 \right)$ for all other cases

$F_{op,j}$: overpressure likelyto accur as a result of a PRD failling to open upon demand ,associated with the J overprssure demand case,kPa(psig) = 1773 psig (see data process condition)

P_{set} : The set pressure of the PRD,kPa (psig) = 1465 psig (see data process condition)

$\frac{F_{op,j}}{P_{set}}$: $\frac{1772.5}{1464.9}$: 1.21

$F_{op,j}$: 1

$P_{fod,j} = P_{fod} \cdot F_{op,j}$

P_{fod} = 0.029 (RBI Date) see step 7.1

P_{fod} = 0.451 (RBI Plan Date) see step 7.1

$F_{op,j}$ = 1 see step 7

A. RBI Date

$P_{fod,j}$ = 0.0289 x 1

= 0.02892

B. RBI Plan Date

$P_{fod,j}$ = 0.451 x 1

= 0.45143

STEP 9 Estimates for the PRD initiating event frequencies, Efj, based on the various relief overpressure demand cases that the device is providing protection Examples of the initiating event frequencies are provided in Table 7.2 Additional background on the default initiating event frequencies is provided in Table 7. 3

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	EF_j (event/year)
Fire	1 per 250 years	0.004
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 10 Determine Credit for Other Layers of Protection. The concept of a demand rate reduction factor, DRRFj , is introduced here to account for the difference in the overpressure demand case event frequency and the demand rate on the PRD. demand rate reduction factor are provide in Table 7.2

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	$DRRF_f$
Fire	1 per 250 years	0.10
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 11 for each overpressure demand case, determine the demand rate placed on the PRD,DRj.The demand rate (DR) on the PRD is calculated as the product of the initiating event frequency and the DRRFj in accordance with Equation (1.12)

$$DR_j = EF_{j.} \; . DRRF_j$$ Equation (8)

EF (fire) = initiating fire frequencies = 0.004

DRRF (fire) = demand rate reduction factor = 0.10

DR (fire) = EF (fire) x DRRF (fire)

= 0.004 x 0.10

= 0.0004

EF (overfill) = initiating overfill frequencies = 0.10

DRRF (overfill) = demand rate reduction factor = 0.10

DR (overfill) = EF (overfill) x DRRF (overfill)

= 0.10 x 0.10

= 0.01

step 12 Determine the MAWP of the protected equipment

set pressure	=	1465 psig	see data
% Allowable Overpressure	=	21%	process
MAWP	=	1773 psig	

STEP 13 If an RBI Study has been completed for protected equipment, calculate its damage adjustment POF, Pf, using equation (1.1) since the DF for the protected equipment is a function of time ,the DF must be determined at the PRD inspection interval, t insp, specifide in step 1 . if a risk analysis for fix equipment has not been complated , a DF can be estimated using the values in table 7.10

Table 7. 10 – DF Classes for Protected Equipment

DF Class	DF	Description
None	1	New vessel or inspection shows little if any damage
Minimal	20	equipment has been in service for a reasonable amount of time and inspection shows evidence of minor damage . Damage mechanism have been identified and inspecton data is available.
Minor	200	One or more damage mechanisms have been identified, limited inspection data available and fairly moderate evidence of damage. Single damage mechanism identified, recent inspection indicates moderate evidence of damage.
Moderate	750	Moderate damage found during recent inspection. Low susceptible to one or more damage mechanisms, and limited inspection exists.
Severe	2000	One or more active damage mechanisms present without any recent inspection history. Limited inspection indicating high damage susceptibility

D_f = 20.0

STEP 14 Calculate the POF of the protected equipment at the elevated overpressure,Pf,j using equation (9).

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{(3.464837..\frac{Po,j}{MAWP})}$$ equation (9)

gff_{total}	=	0.0000306	see part 2 table 3.1
D_f	=	20	see step 13
F_{MS}	=	0.5	see part 2 section 3.5.4
$P_{o,j}$	=	14.69	data process condition
MAWP	=	1772.529	see step 12

$$Pf,j = (0.0312881x0.0000306x20x0.5)e^{3.464837..\frac{1319.8}{1772.53}}$$

Pf,j = 0.0000098531

STEP 15 Calculate the POF, ,using Equation (1.11)

A. RBI Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892051 x 0.0004 x 9.85E-06

= 1.14E-10

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892051 x 0.01 x 9.85E-06

= 2.85E-09

B. RBI Plan Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.0004 x 9.85E-06

= 1.78E-09

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.01 x 9.85E-06

= 4.45E-08

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.2:
PROBABILITY OF FAILURE TO LEAKAGE CALCULATION

PSV-2921

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
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			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

PART 2 : Calculation Procedure - POL at Specified Inspection Interval

The leakage case is different than the fail to open case since the POF is not a function of demand rate but rather is based on failure during continuous operation. The industry data associated with the probability of leakage,Pl , data is in per year units (failure/year). no multiplication by any demand rate is necessary

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 years see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service : Methane
Typical Temperature : 397 °F
Fluid Severity : Mild See Table 7.4
Design Type PRD : Conventional
Discharge Location : discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80
η_{def} : 50.5 - 25%*500.5 See note 1 table 7.5
: 37.875

STEP 3 Determine the adjustment factor, Fs using section 7.3.2.g).

F_s = 1.25 for soft seated design see data material
F_s = 1.00 for all other cases

STEP 4 Determine the environmenta adjustment factor, Fenv.using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 0.8 (see data process condition)

STEP 5 calculate the modified characteristic life, ηmod, using equation (11) and the factors obtain in step 3 and 4.

F_s = 1.25 see step 3

F_{env} = 0.80 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_s x F_{env} x η_{def} equation (11)

= 1.25 x 0.80 x 37.88

= 37.88

STEP 6 Assemble the the PRDs inspection history, grade each record using the inspection effectiveness table, part 2,annex 2.C, Table 2.C.3.1. Record the result of each inspection record.; NO LEAK/LEAK and determine the confidance factors, Cfi, as applicable, for each inspection history based on the result of the test . Determine the time duration, tdur.i. of each inspection cycle.

- Inspection effectiveness : part 2,annex 2.C, Table 2.C.3.1

Table 2.C.3.1- Inspection and testing efectiveness for PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

- Inspection Record : No LEAK / LEAK

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak,CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

  CF_i : 0.5

  $\boldsymbol{CF_i}$

- Determine the time duration, tdur,j. of each inspection cycle

  A. RBI Date

  $t_{dur,}i$ = RBI date - Last Inspection

  = 15/03/2020 - 17/06/2016

  = 4 year

  B. RBI Plan Date

  $t_{dur,}i$ = Plan date - Last Inspection

  = 15/03/2024 - 17/06/2016

  = 8 year

STEP 7 Starting at the earliest inspection record , update the modified characteristic life, ηmod, determine in step 5 as follows

STEP 7.1 Calculate the prior probability of leakage using equation (12). Note that for the first inspection record , the modified characteristic life,ηmod,is used subsequent inspection record will use the updated characteristic from STEP 7.5 below.

$$P_{l,Prior}^{prd}=1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right] \qquad \text{equation (12)}$$

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	37.88	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{l,Prior}^{prd}$ = 0.01733

B. RBI Plan Date

$P_{l,Prior}^{prd}$ = 0.05907

STEP 7.2 Calculate the prior probability of passing using equation (13)

$$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$$ equation (13)

A. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0173

$P_{p,Prior}^{prd}$ = 0.98267

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0591

$P_{p,Prior}^{prd}$ = 0.94093

STEP 7.3 Determine the conditional probability of leakage and conditional probability of pass using equation (14)

$$P_{l,cond}^{prd} = (1 - CF_{pass}).P_{p,prior}^{prd}$$ equation (14)

CF_{pass} : 0.5 step 6

$P_{p,Prior}^{prd}$ = 0.98267 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.94093 (RBI Plan Date) step 7.2

A. RBI Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.98267

= 0.49133

B. RBI Plan Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.94093

= 0.47046

STEP 7.4 calculate the weighted probability of leakage, $P_{l,wgt}^{prd}$, using the appropriate equation from table 7.9.

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{l,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{l,wgt}^{prd}$ = 0.49133

B. RBI Plan Date

$P_{l,wgt}^{prd}$ = 0.47046

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (15) and the weighted probability of leakage, $P_{l,wgt}^{prd}$ established in step 7.4

$$\eta upd = \frac{t}{(-\ln\left[1 - P_{f,wgt}^{prd}\right])^{\frac{1}{\beta}}}$$

η_{upd} = 10.29

STEP 8 Calculate the probability of leakage for the specific PRD in accordance with Equation (16)

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (16)

t	=	4	year	see step 6
t	=	8	year	see step 6
β	=	1.80		see step 2
η_{upd}	=	37.88 = η_{mod}		see step 5
η_{upd}	=	10.29		see step 7.5

A. RBI Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{4}{37.88}\right)^{1.80}\right]$

P_l^{prd} = 0.01733

B. RBI Plan Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{8}{10.29}\right)^{1.80}\right]$

P_l^{prd} = 0.47046

STEP 9

The Probability of leakage needs to be adjusted based on the closedness the system is operating near the set pressure with equation (17). The set pressure factor , F_{set} , is dependent on the PRD type.

$$P_{l,j}^{prd} = P_l^{prd} . F_{set}$$ equation (17)

PRD Type = Conventional see data general

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{14.69}{1465}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.009)}{0.90}\right)$$

$$= 0.11$$

$P_S =$ 14.69 see data

$P_{Set} =$ 1465 process

A. RBI Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.0173 step 8

F_{set} = 0.11 Table 7.7

$P_{l,j}^{prd}$ = 0.0173 x 0.11

= 0.0019

B. RBI Plan Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.47046 step 8

F_{set} = 0.11 Table 7.7

$P_{l,j}^{prd}$ = 0.4705 x 0.11

= 0.0518

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 3 :
CONSEQUENCE OF FAILURE CALCULATION

PSV-2921

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

PART 3 CONSEQUENCE CALCULATION of FAILURE to OPEN

STEP 1 Determine the list of overpressure scenarios applicable to the piece of equipment being protected by the PRD under evaluation. Table 7.2 provides a list of overpressure demand cases specific covered.

Overpressure Demand Case for PSV-2921

1 Fire see table 7.3

2 Liquid Overfillling without administrative controls in place

step 2 For each overpressure demand case, estimate the amount of overpressure, $p_{o,j}$ likely to occur during the overpressure event if the PRD were to fail to open.

Table 7.3 - Overpressure Scenario Project

Initiating Event	Equipment Type	PRD Demand rate reduction factor	Qualifier	over pressure potential	Background and comment
1. Overpressure Scenario					
1 per 250 years	All Equipment Type	0.1 industry experience justifies this value	N/A	4.0 x MAWP (RUPTURE)	see table 7.3
2. Overpressure scenario - liquid Overfilling					
1 per 100 years (admin control)	All Equipment including process tower	1.00	downsteam of positif displacement type rotating equipment	4.0 x MAWP	see table 7.3

$P_{0,fire}$ = 4 x MAWP
= 4 x 1773
= 7092 psig

$P_{o,overfilling}$ = 4 x MAWP
= 4 x 1773
= 7092 psig

STEP 3 For instalations that have multiple PRDs, determine the total amount of installed PRD orifice area , A_{total}^{prd}, including the area of the PRD being evaluated. Calculate the overpressure adjustment factor, , in accordance with equation (1.37) F_a

$$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \qquad \text{equation (1.37)}$$

A^{prd} = is the orifice area of the PRD, mm2

A_{total}^{prd} = is the total installed orifice area of a multiple device installation,mm2

multiple PRD ? no

F_a = 1

STEP 4 Reduce the overpressures determined in step 3 by the overpressure adjustment factor accordance with equation (1.38)

$$P_{o,j} = F_a \,.\, P_{o,j} \qquad \text{equation (1.38)}$$

F_a = 1 see step 3

$P_{0,fire}$	=	7092.0		$P_{o,overfilling}$	=	7092.0	
$P_{0,fire}$	=	7092.0 x	1	$P_{o,overfilling}$	=	7092.0 x	1
	=	7092.0 psig			=	7092.0 psig	

STEP 5 for each overpressure demand case, calculate the financial consequence ,....., C_{rel}^{prd} of loss containment from protected equipment using procedures developed in part 3. use the overpressure for demand cases as determine in STEP 4 in lieu of the operating pressure, P_s

STEP 1 Determine the Representative Fluid and Associated Properties

Fluid Properties

Sifat-sifat fluida yang dibutuhkan yang diperkirakan untuk masing-masing fluida representatif disediakan dalam Tabel 4.2 API 581 Bagian 3 COF dan tergantung pada fase simpanan fluida di bawah ini:

A). Stored Liquid	
1. Normal Boiling Point	(NBP)
2. Density	(ρt)
3. Auto-iIgnition Temperature	(AIT)
B). Stored Vapor or Gas	
1. Normal Boiling Point	(NBP)
2. Morcular Weight	(MW)
3. Ideal Gas Specific Heat Capacity Ratio	(k)
4. Constant Pressure Specific Heat	(Cp)
5. Auto-iIgnition Temperature	(AIT)

STEP 1.1 Select Representative fluid group Table 4.1

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

Fluid Composition Table

Well	Composition	Symbol	Amount	Unit
	Nitrogen	N_2	0.6	% mole
	Carbon Dioxide	CO_2	0.008	% mole
	Methane	CH_4	86.02	% mole
	Ethane	C_2H_6	4.36	% mole
	Propane	C_3H_8	5.74	% mole
`	i-Butane	i-C_4H_{10}	1.51	% mole
	n-Butane	n-C_4H_{10}	1.7	% mole
	i-Pentane	i-C_5H_{12}	0.01	% mole
	n-Pentane	n-C_5H_{12}	0.032	% mole
	Hexane Plus	C_6^+	0.02	% mole
		TOTAL	100.000	% mole

Chosen Representative Fluid : C1-C2

STEP 1.2 Determine the store fluid phase, liquid or vapor, if two phase , a level 2 consequence analysis should be performed

Stored fluid phase : Gas

Step 1.3 Determine the stored fluid properties

For a stored liquid

MW – Molecular weight, kg/kg-mol (lb/lb-mol), can be estimated from Table 4.2

k – Ideal gas specific heat ratio, can be estimated using Equation (3.1) and the C P values as determined using Table 4.2

AIT – Auto-ignition temperature, K (°R), can be estimated from Table 4.2

Table 4.2 - Properties of the Representative Fluids Used in Level 1 Consequence Analysis

Fluid	MW	Liquid Density (lb/ft^3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	CP				Auto ignition Temperature (°F)
						Ideal Gas Constant A	Ideal Gas Constant B	Ideal Gas Constant C	Ideal Gas Constant D	
C1-C2	23	15.64	-193	Gas	Note 1	12.3	1.15E-01	-2.87E-03	-1.30E-09	1036
C2-C3	51	33.61	-6.3	Gas	Note 1	2.632	0.3188	-1.35E-04	1.47E-08	696
C25+	422	56.19	981	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	396

1). Molecular Weight (MW), kg/kg-mol (lb/lb-mol)

The stored vapor Molecular Weight (MW) can be estimated from Table 4.2

MW = 23.00 (kg/kg-mol)

2). Auto-Ignition Temperature, K (^oR)

The stored liquid Auto-Ignition Temperature (AIT) can be estimated from Table 4.2 of API 581 Part 3 of COF.

AIT = 1036 (^oF)

AIT = 830.927778 (K)

AIT = 446.222222 (^oR)

3). Ideal gas specific heat ratio, k

Cp_A = 12.3 J/kmol-K

Cp_B = 1.15E-01 J/kmol-K

Cp_C = -2.87E-03 J/kmol-K

Cp_D = -1.30E-09 J/kmol-K

T = 72.9 C
T = 163.22 F
T = 346.05 K
R = 8.314 J/kg-mol-K

Cp $= A + BT + CT^2 + DT^3$ ..... equation (19)
= 12.3 + (0.015 x 344.15) + (-0.0000287 x 344.15)^2 + (-1.3^{-9} x 344.15)^3
= 53.0821237 J/kmol-K

k = $\frac{Cp}{Cp - R}$ ..... equation (20)
= $\frac{53.082}{53.082 - 8.314}$
= 1.1857125

STEP 1.4 Determine the steady state phase of the fluid after release to the atmosphere, using Table 4.3 and the phase of the fluid stored in the equipment as determine in STEP 1.2.

Table 4.3 - Level 1 Guidelines for Determining the phase of a fluid

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (After release) Condition	Determine of Final Phase for Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	model as gas usless the fluid boilling point at ambient condiitions is greater than 80 F , than model as liquid
Liquid	Liquid	Model as Liquid

The fluid is Gas in the vessel, its post release is Gas

STEP 2 Release Hole Size Selection

STEP 2.1 Based on component type and table 4.4, determine the release hole size diameters, d_n.

Table 4.4 - Release Hole Sizes and Areas Used in Level 1 and 2 Consequences Analysis

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	$d_1 = 0.25$
2	Medium	> 1/4 - 2	$d_2 = 1$
3	Large	> 2 - 6	$d_3 = 4$
4	Rupture	. 6	d_4 = min[D,16]

STEP 2.2 Determine the failure frequency, gff_n, for the nth release hole size from part 2, table 3.1, and the total generic failure frequency from this table or from equation (3.2)

$$gff_{total} = \sum_{n=1}^{4} gff_n \qquad (3.2)$$

Table 3.1 part 2, suggested component generic failure frequencies

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

Diameter = 300 mm = 11.82 inci

gff_{total} = 8.00E-06 failures/year

gff_{small} = 2.00E-05 failures/year

gff_{medium} = 2.00E-05 failures/year

gff_{large} = 6.00E-07 failures/year

$gff_{rupture}$ = 3.06E-05 failures/year

STEP 3 Release Rate Calculation

There are two regimes for flow gases through an orifice: aonic (choked) for higher internal pressure, and subssonic flow for lower pressure (nominally 15 psig (103.4 kPa) or less). The transition pressure at which the flow regime changes from sonic to subsonic is determined using below equation.

P_{atm} = 14.69 psi

k = 1.1857

$$P_{trans} = P_{atm}\left(\frac{k+1}{2}\right)^{\frac{k}{k-1}} \quad \text{.....} \quad \text{equation (21)}$$

$$P_{trans} = 14.69\left(\frac{1.1857+1}{2}\right)^{\frac{1.1857}{0.1857}}$$

= 18.0034792 psi

STEP 3.1 Select the appropriate release rate equation

$$W_n = \frac{Cd}{C2}\, x\, An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad \text{.....} \quad \text{equation 22)}$$

Abbreviation list :

C_d = Discharge coefficient, for turbulent liquid flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$

= 0.9

A_n = Release hole sized area

P_s	=	Storage operating pressure	=	7092	psi
P_{atm}	=	Atmosphere pressure	=	14.69	psi
k	=	Ideal gas specific heat capacity ratio	=	1.1857	
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	72.9	C
			=	163.22	F
			=	346.05	K

STEP 3.2 For every release hole size, calculate the release hole size area based on d_n

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

The release hole size area can be determined by formulating below equation:

$$An = \frac{\pi dn^2}{4} \quad \text{.....} \quad \text{equation (22)}$$

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

= 0.0064 m

π = 3.14

$$A1 = \frac{\pi d1^2}{4}$$

$$= \frac{3.14\ x\ (0.25)^2}{4}$$

= 0.0491 inch^2

= 3E-05 m^2

2). MEDIUM RELEASE HOLE SIZE AREA

d_1 = 1 inch

= 0.0254 m

π = 3.14

$$A2 = \frac{\pi d2^2}{4}$$

$$= \frac{3.14\ x\ (1)^2}{4}$$

= 0.785 inch^2

= 0.0005 m^2

3). LARGE RELEASE HOLE SIZE AREA

d_1 = 4 inch

= 0.1016 m

π = 3.14

$$A3 = \frac{\pi d3^2}{4}$$

= 12.56 $inch^2$

= 0.0081 m^2

4). RUPTURE RELEASE HOLE SIZE AREA

d_1 = 16 inch

= 0.4064 m

π = 3.14

$$A4 = \frac{\pi d4^2}{4}$$

$$= \frac{3.14\ x\ (16)^2}{4}$$

= 200.96 $inch^2$

= 0.1296 m^2

STEP 3.3 For liquid releases, for each release hole size, calculate the viscosity correction factor ($K_{v,n}$)

$$K_{v,n} = \left(0.9935 + \frac{2.878}{Ren^{0.5}} + \frac{342.75}{Ren^{1.5}}\right)^{-1} \quad \text{..... (equation 62)}$$

Because the store fluid phase determined in STEP 1.2 is gaseous or vapor phase, then, this step is no neeed to be considered.

STEP 3.4 For each hole size, calculate the release rate, W_n, for each release area A_n

$$W_n = \frac{Cd}{C2}\ x\ An\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Abbreviation List:

C_d = 0.9

k = 1.1857125

ρl = 250.51 kg/m^3

= 2.5051E-07 kg/mm^3

A_1 = 3.1645E-05 m^2

A_2 = 0.00050645 m^2

A_3 = 0.00810321 m^2

A_4	=	0.1296192	m^2
gc	=	1	kgm/Ns^2
	=	32.2	$lb_m ft/lb_f S^2$
Ps	=	48899.34	Kpa
P_{atm}	=	101.288	KPa
C_2	=	1	
R	=	8.314	J/(kg-mol-K)
g_c	=	9.8	m/s^2
T_s	=	346.05	K
MW	=	23.00	(kg/kg-mol)

1). SMALL RELEASE HOLE SIZE AREA

$$W_1 = \frac{Cd}{C2} x\ A1 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_1 = \frac{0.9}{C2} x\ 0.000031645 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 0.25171927 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$W_2 = \frac{Cd}{C2} x\ A2 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_2 = \frac{0.9}{C2} x\ 0.000506451 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 4.02850732 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$W_3 = \frac{Cd}{C2} x\ A3 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_3 = \frac{0.9}{C2} x\ 0.00810321 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 20.5897514 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$W_4 = \frac{Cd}{C2} x\ A4 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_4 = \frac{0.9}{C2} x\ 0.1296192 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 1031.04211 kg/s

STEP 4 Estimate the Fluid Inventory Available for Release

STEP 4.1 Group Component and equipment items into inventory groups (see annex 3.A)

only one component is given, and total inventory for the group

STEP 4.2 Calculate the fluid mass ,$mass_{comp}$, in the component being evaluated

ID	=	0.30	m
V_{tot}	=	7.065	m^3
	=	249.49812	ft^3
ρ_{gas}	=	75.42	kg/m^3
	=	4.7083167	lb/ft^3
L	=	100	m
$Mass_{comp}$	=	532.8423	kg

STEP 4.3 Calculate the fluid mass in each of the other components that are included in the inventory group, $mass_{comp,i}$

There are no other component, only an inventory group mass

STEP 4.4 Calculate the fluid mass in the inventory group, $mass_{inv}$, using equation (3.9)

$$mass_{inv} = \sum_{i=1}^{n} mass_{comp,i}$$

Where

$Mass_{comp}$ = is the inventory fluid mass for the component or piece of equipment being evaluated, kgs [lbs]

$Mass_{inv}$ = is the inventory group fluid mass, kgs [lbs]

= 532.8423 kg

STEP 4.5

Calculate the flow rate from a 203mm (8 inch) diameter hole, W_{max8}, using equation (3.3),(3.6)or (3.7) , as aplicable ,with A_n ,A8=32450 mm2 (50.3 inch2). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Where

C_d	=	Discharge coefficient, for turbulent gas flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$	=	0.9	
A_n	=	Release hole sized area	=	5.1031	$inch^2$
			=	129619	mm^2
			=	0.1296	m^2
P_s	=	Storage operating pressure	=	7092	psi
			=	48899	Kpa
P_{atm}	=	Atmosphere pressure	=	14.69	psi
			=	101.29	Kpa
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	72.9	C
			=	163.22	F
			=	346.05	K
C_2	=	SI and US customary conversion factors	=	1	
k	=	Ideal gas specific heat ratio	=	1.1857	

So,

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_{max8} = \frac{0.9}{1}\ x\ 0.1296 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 1031.04211 kg/s

STEP 4.6 For each release hole size, calculate the added fluid mass, $mass_{add,n}$, resulting from 3 (three) minutes of flow from the inventory group using equation (3.10) where Wn is the leakage rate for the release hole size being evaluated and $W_{max8,}$ is from step 4.5

$$mass_{add,n} = 180.\min\left[W_n, W_{\max 8}\right] \quad (3.10)$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[\text{W}_1 \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[0.2517, 1031.04\,]$$

$$= \quad 45.309 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add n}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 2}} = 180 \,.\, min[4.0285, 1031.04\,]$$

$$= \quad 725.13 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min\,[20.5898, 1031.04\,]$$

$$= \quad 3706.2 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[1031.042, 1031.04\,]$$

$$= \quad 185588 \text{ kgs}$$

STEP 4.7 For each release hole size, calculate the available mass for release using equation (3.11)

$$mass_{avail,n} = \min\left[\{mass_{comp} + \ mass_{add,n}\}, mass_{inv}\right]$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 1} = min\,.\,[\{532.842 + 45.31\}, 532.842\,]$$

$$= \quad 532.842 \quad \text{kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 2} = min\,.\,[\{532.842 + 725.1\}, 532.842\,]$$

$$= \quad 532.842 \quad \text{kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 3} = min.[\{532.842 + 3706\}, 532.842]$$

$$= 532.842 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 4} = min.[\{532.842 + 2E+05\}, 532.842]$$

$$= 532.842 \text{ kgs}$$

STEP 5 Determine the release type (continues or instantaneous)

STEP 5.1 For each release hole size, calculate the time required to release 4536kgs (10000 lbs) of fluid

$$t_n = \frac{C3}{W_n} \quad \text{.....} \quad \text{equation (24)}$$

Where

t_n = time required to release 4536 kgs (10000 lbs) of fluid

C_3 = SI and US customary conversion factors

= 4536 kgs

= 10000 lbs

W_n = Theoretical release rate associated with the nth release hole size, kg/s [lb/s]

W_1 = 0.2517 kg/s

W_2 = 4.0285 kg/s

W_3 = 20.5898 kg/s

W_4 = 1031.0421 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_1 = \frac{4536}{0.2517}$$

= 18020.0748 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_2 = \frac{4536}{4.0285}$$

= 1125.97536 s

3). LARGE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_3 = \frac{4536}{20.5898}$$

= 220.303777 s

4). RUPTURE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_4 = \frac{4536}{1031.042}$$

= 4.39943233 s

STEP 5.2 Determine the release type for each release hole size

For each release hole size, determine the release type either instataneous or continous using this following criteria:

a. If the release hole size is 6.35 mm(0.25 inch) or less, then the release type is continous

b. If t_n<180 sec and the releaase mass is gretaer than 4536 kgs (100000 lbs), then the release is instataneous: otherwise the release is continous

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 18020 s (Continous)

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1126 s (Continous)

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 220.3 s (Continous)

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.3994 s (Instataneous)

STEP6 Estimate The Impact of Detection and Isolation Systems on Release Magnitude

STEP 6.1 Determine the detection and isolation systems presents in the unit

STEP 6.2 Using table 4.5, select the appropriate classification (A,B,C) for the detection system.

Table 4.5 - Detection and Isolation system rating Guide

Type of Detection System	Detection Clssification
Instrumentation designed specifically to detect material losses by changes In operating conditions (i.e., loss of pressure or flow) in the system.	A
Suitable located detectors to determine when the material is present outside the pressure-containing envelope	B
Visual detection, cameras, or detectors with marginal coverage	C
Type of Isolation Sytem	**Isolation Classification**
Isolation or shutdown system activated directly process instrumentation or detection, with no operator intervention	A
Isolation or shutdown system activated by operators in the control room or other suitable locations remote from the leak	B
isolation dependent on manually-operated valves	C

Detection Is A

STEP 6.3 Using table 4.5, select the appropriate classification (a,b,c) for the isolation system

Isolation Is A

STEP 6.4 Determine the release reduction factor factdi using Table 4.6

Table 4.6 - Adjustment to Release Based on Detection and Isolation Systems

System Classification		Release Magnitude Adjustment	duction Factor, *fac*
Detection	Isolation		
A	A	Reduce release rate or mass by 25%	0.25
A	B	Reduce release rate or mass by 20%	0.20
A or B	C	Reduce release rate or mass by 10%	0.10
B	B	Reduce release rate or mass by 15%	0.15
C	C	No adjustment to release rate or mass	0.00

Release Magnitude Adjustment = Reduce release rate or mass by 25%

Reduction Factor, $fact_{di}$ = **0.25**

STEP 6.5 Determine the total leak durations for each release hole sizes using Table 4.7

Table 4.7 - Leak Durations Based on detection and Isolation Systems

Detection System Rating	Isolation System Rating	Maximum Leak Duration, ld_{max}
A	A	20 minutes for 1/4 inch leaks
		10 minutes for 1 inch leaks
		5 minutes for 4 inch leaks
A	B	30 minutes for 1/4 inch leaks
		20 minutes for 1 inch leaks
		10 minutes for 4 inch leaks
A	C	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	A or B	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	C	1 hour for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
C	A, B, or C	1 hour for 1/4 inch leaks
		40 minutes for 1 inch leaks
		20 minutes for 4 inch leaks

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 18020 s (Continous)

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1126 s (Continous)

$ld_{max,2}$ = 10 minutes for 1 inch leaks

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 220.3 s (Continous)

$ld_{max,3}$ = 5 minutes for 4 inch leaks

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.3994 s (Instataneous)

$ld_{max,4}$ = 5 minutes for 4 inch leaks

STEP7 Determine The Release Rate And Mass For Consequence of Failure

STEP 7.1 Calculate the adjusted release rate, raten for each release hole size

Reduction Factor, $fact_{di}$ = 0.25

W_1 = 0.2517 kg/s

W_2 = 4.0285 kg/s

W_3 = 20.5898 kg/s

W_4 = 1031.0421 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$Rate_1 = W_n\,(1 - fact_{di})$$

$$Rate_1 = 0.2517\,(1 - 0.25)$$

= 0.1888 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$Rate_2 = W_n\,(1 - fact_{di})$$

$$Rate_2 = 4.0285\,(1 - 0.25)$$

= 3.0214 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$Rate_3 = W_n\,(1 - fact_{di})$$

$$Rate_3 = 20.5898\,(1 - 0.25)$$

= 15.442 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$Rate_4 = W_n\,(1 - fact_{di})$$

$$Rate_4 = 1031.042\,(1 - 0.25)$$

= 773.28 kg/s

STEP7.2 Calculate the leak duration, ldn, for each release hole size

$$ld_n = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\,.\,ld_{max,n}\}] \quad \text{..... (equation)}$$

$ld_{max,1}$	=	20 minutes for 1/4 inch leaks	20	$Mass_{avail,1}$	=	532.84	kgs
$ld_{max,2}$	=	10 minutes for 1 inch leaks	10	$Mass_{avail,2}$	=	532.84	kgs
$ld_{max,3}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,3}$	=	532.84	kgs
$ld_{max,4}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,4}$	=	532.84	kgs

1). SMALL RELEASE HOLE SIZE AREA

$$ld_1 = min\,.\,[\{\frac{Mass_{avail,1}}{Rate_1}\},\{60\,.\,ld_{max,1}\}]$$

$$ld_1 = min\,.\,[\{\frac{532.84}{0.189}\},\{60\,.\,20\}]$$

= 1200 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2 = min\,.\,[\{\frac{Mass_{avail,2}}{Rate_2}\},\{60\,.\,ld_{max,2}\}]$$

$$ld_2 = min\,.\,[\{\frac{532.84}{3.021}\},\{60\,.\,10\}]$$

= 176.36 s

3). LARGE RELEASE HOLE SIZE AREA

$$ld_3 = min\ .\ [\{\frac{Mass_{avail,3}}{Rate_3}\},\{60\ .\ ld_{max,3}\}]$$

$$ld_3 = min\ .\ [\{\frac{532.84}{15.44}\},\{60\ .\ 5\}]$$

$$= 34.505\ s$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$ld_4 = min\ .\ [\{\frac{Mass_{avail,4}}{Rate_4}\},\{60\ .\ ld_{max,4}\}]$$

$$ld_4 = min\ .\ [\{\frac{532.84}{773.3}\},\{60\ .\ 5\}]$$

$$= 0.6891\ s$$

STEP 7.3 Calculate the release mass, $mass_n$, for each release hole size

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_1 = min\ .\ [\{Rate_1\ .\ ld_1\},Mass_{avail,n}]$$

$$Mass_1 = min\ .\ [\{0.189\ .\ 1200\},532.84]$$

$$= 226.547339\ kgs$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$Mass_2 = min\ .\ [\{Rate_2\ .\ ld_2\},Mass_{avail,n}]$$

$$Mass_2 = min\ .\ [\{3.021\ .\ 176.4\},532.84]$$

$$= 532.8423\ kgs$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_3 = min\ .\ [\{Rate_3\ .\ ld_3\},Mass_{avail,n}]$$

$$Mass_3 = min\ .\ [\{15.44\ .\ 34.51\},532.84]$$

$$= 532.8423\ kgs$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_4 = min\ .\ [\{Rate_4\ .\ ld_4\},Mass_{avail,n}]$$

$$Mass_4 = min\ .\ [\{773.3\ .\ 0.689\},532.84]$$

$$= 532.8423\ kgs$$

PART 8 : DETERMINE FLAMMABLE AND EXPLOSIVE CONSEQUENCE

8.1 CONSEQUENCE AREA EQUATIONS

1). CONTINOUS RELEASE

$CA_n^{CONT} = \alpha(rate_n)^b$ ..... equation (26)

2). INSTATANEOUS RELEASE

$CA_n^{CONT} = \alpha(mass_n)^b$ ..... equation (27)

STEP 8.1 Select the consequence area mitigation reduction factor, $fact_{mit}$, from Table 4.10

Mitigation System	Consequence Area Adjustemnet	Consequence Area Reduction Factor, factor mit
Inventory blowdown , couple with isolation system classification B or higher	Reduce consequence area by 25%	0.25
Fire water deluge system and monitors	Reduce consequence area by 20%	0.2
Fire water monitor only	Reduce consequence area by 5%	0.05
Foam spray system	Reduce consequence area by 15%	0.15

Mitigation system = Inventory blowdown , couple with isolation system classification B or higher *

Consequence Area = Reducer consequence area by 25 % *

$fact_{mit}$ = 0.25

STEP 8.2 Calculate the energy efficiency, $eneff_n$, for each hole size using equation mentioned below.

C_4 = 2205 1/kg

$eneff_n = 4.log_{10}[C_4 . mass_n] - 15$ ..... equation (28)

$Mass_1$ = 226.547 kgs

$Mass_2$ = 532.842 kgs

$Mass_3$ = 532.842 kgs

$Mass_4$ = 532.842 kgs

1. SMALL RELEASE HOLE SIZE AREA

$eneff_1 = 4 . log_{10} [C_{4A} . mass_1] - 15$

$eneff_1 = 4 . log_{10} [2205 . 226.547] - 15$

$eneff_1 = 7.794270$

2. MEDIUM RELEASE HOLE SIZE AREA

$$eneff_2 = 4 . log_{10} [C_{4A} . mass_2] - 15$$
$$eneff_2 = 4 . log_{10} [2205 . 532.842] - 15$$
$$eneff_2 = 9.280029$$

3. LARGE RELEASE HOLE SIZE AREA

$$eneff_3 = 4 . log_{10} [C_{4A} . mass_3] - 15$$
$$eneff_3 = 4 . log_{10} [2205 . 532.842] - 15$$
$$eneff_3 = 9.280029$$

4. RUPTURE RELEASE HOLE SIZE AREA

$$eneff_4 = 4 . log_{10} [C_{4A} . mass_4] - 15$$
$$eneff_4 = 4 . log_{10} [2205 . 532.842] - 15$$
$$eneff_4 = 9.28003$$

STEP 8.3 Determine the fluid type

Determine the fluid type, either TYPE 0 or TYPE 1 based on Table 4.1 of API RP 581 Part 3 of COF.

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

C_1-C_2	=	TYPE 0	AIT	=	446.222222 (^oR)
MW	=	23 (kg/kg-mol)	T	=	72.9 (^oC)
AIT	=	1036 (^oF)	T	=	163.22 (^oF)
AIT	=	830.927778 (K)	T	=	346.05 (K)

STEP 8.4 For each release hole size, calculate the component damage consequence areas for Auto-Ignition Not Likely, Continous Release (AINT-CONT), $CA^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

Table 4.8 - Component Damage Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	8.7	0.98			55	0.95			6.5	0.67			164	0.62		
C3-C4	10.1	1.0			64	1.0			4.7	0.7			80	0.63		

$\alpha = \alpha_{cmd,n}^{AINL-CONT} =$ 8.7 $\quad$ $b = b_{cmd}^{AINL-CONT} =$ 0.98

2). Calculate the consequence of area using equation below

$Rate_1 = 0.189$ kg/s

$Rate_2 = 3.0210$ kg/s

$Rate_3 = 15.4400$ kg/s

Rate4 = 773.30 kg/s

$$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit}) \quad \text{..... equation (29)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-CONT} = \alpha(rate_1)^b \cdot (1 - fact_{mit})$$

$= 1.275$ m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$$

$= 19.281$ m^2

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$$

$= 95.379$ m^2

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$$

$= 4417.3$ m^2

STEP 8.5 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Continous Release (AIL-CONT), $CA^{AIL\text{-}CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-CONT} =$ 55.0 b $= b_{cmd}^{AIL-CONT} =$ 0.95

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$ ..... equation (30)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$

$= 8.4735\ m^2$

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$

$= 117.91\ m^2$

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-CONT} = \alpha(rate_n)^b \,.(1 - fact_{mit})$

$= 555.44\ m^2$

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-CONT} = \alpha\,(rate_4)^b.(1 - fact_{mit})$

$= 22875\ m^2$

STEP 8.6 For each release hole size, calculate the component damage consequence areas for Auto-ignition Not Likely, Instaneous Release, (AINL-INST), $CA^{AINL\text{-}INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AINL-INST} =$ 6.5 b $= b_{cmd}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \,.\left(\frac{1-fact_{mit}}{eneff_n}\right)$ ..... equation (31)

From step 7, know that :

$Mass_1$	=	226.547	kgs	$eneff_1$	=	7.794
$Mass_2$	=	532.842	kgs	$eneff_2$	=	9.280
$Mass_3$	=	532.842	kgs	$eneff_3$	=	9.280
$Mass_4$	=	532.842	kgs	$eneff_4$	=	9.280

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 6{,}469\,(226.547)^{0{,}67}.\left(\frac{1-0{,}25}{7.794}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 23.67\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 6{,}469(532.842)^{0{,}67}.\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 35.26\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 6{,}469\,(532.842)^{0{,}67}.\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 35.26\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 6{,}469\,(532.842)^{0{,}67}.\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 35.26\ \text{m}^2$$

STEP 8.7 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Instataneous Release (AIL-INST), $CA^{AIL-INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-INST} =$ 164.0 b $= b_{cmd}^{AIL-INST} =$ 0.62

2). Calculate the consequence of area using equation below

$$CA_{cmd,n}^{AIL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{.....} \quad \text{equation (32)}$$

From step 7, know that :

$Mass_1$	=	226.547	kgs	$eneff_1$	=	7.794
$Mass_2$	=	532.842	kgs	$eneff_2$	=	9.280
$Mass_3$	=	532.842	kgs	$eneff_3$	=	9.280
$Mass_4$	=	532.842	kgs	$eneff_4$	=	9.280

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AIL-INST} = \alpha\,(mass_1)^b \cdot \left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 164\,(226.547)^{0,62} \cdot \left(\frac{1-0,25}{7.794}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 455.33 \text{ m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AIL-INST} = \alpha\,(mass_2)^b \cdot \left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 164\,(532.842)^{0,62} \cdot \left(\frac{1-0,25}{9.280}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 649.90 \text{ m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AIL-INST} = \alpha\,(mass_3)^b \cdot \left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 164\,(532.842)^{0,62} \cdot \left(\frac{1-0,25}{9.280}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 649.90 \text{ m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AIL-INST} = \alpha\,(mass_4)^b \cdot \left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 164\,(532.842)^{0,62} \cdot \left(\frac{1-0,25}{9.280}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 649.90 \text{ m}^2$$

STEP 8.8 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Continous Release (AINL-CONT), $CA_{inj,n}^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

Table 4.9 - Personnel Injury Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	21.8	1.00			143	0.92			12.5	0.67			474	0.63		
C3-C4	25.6	1.0			171	1.0			9.7	0.7			270	0.63		

$\alpha = \alpha_{inj,n}^{AINL-CONT} =$ **21.8** $\quad b = b_{inj,n}^{AINL-CONT} =$ **1.00**

2). Calculate the consequence of area using equation below

$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1 - fact_{mit})$ ….. (equation)

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-CONT} = \left[\alpha.\left(rate_1^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 3.0944 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-CONT} = \left[\alpha.\left(rate_2^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 49.461 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-CONT} = \left[\alpha.\left(rate_3^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 252.79 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-CONT} = \left[\alpha.\left(rate_4^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 12661 \text{ m}^2$$

STEP 8.9 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Continous Release (AIL-CONT), $CA_{inj,n}^{AIL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-CONT} =$ 143.2 b $= b_{inj,n}^{AIL-CONT} =$ 0.92

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1 - fact_{mit}) \quad \text{..... equation (34)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-CONT} = \left[\alpha.\left(rate_1^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 23.193 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-CONT} = \left[\alpha.\left(rate_2^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 296.99 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-CONT} = \left[\alpha.\left(rate_3^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 1332.2 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-CONT} = \left[\alpha.\left(rate_4^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 48785 \text{ m}^2$$

STEP 8.10 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Instataneous Release (AINL-INST), $CA_{inj,n}^{AINL-INST}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AINL-INST} =$ 12.5 b $= b_{inj,n}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (35)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-INST} = \left[a.\left(mass_1^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AINL-INST} = [12{,}46\ (226.547)^{0{,}67}].\left(\frac{1-0{,}25}{7.794}\right)$$

$$CA_{inj,1}^{AINL-INST} = 45.37\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-INST} = \left[a.\left(mass_2^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AINL-INST} = [12{,}46.(532.842)^{0{,}67}].\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{inj,2}^{AINL-INST} = 67.59\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-INST} = \left[a.\left(mass_3^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AINL-INST} = [12{,}46.(532.842)^{0{,}67}].\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{inj,3}^{AINL-INST} = 67.59\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-INST} = \left[a.\left(mass_4^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AINL-INST} = [12{,}46.(532.842)^{0{,}67}].\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{inj,4}^{AINL-INST} = 67.59\ \text{m}^2$$

STEP 8.11 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Instataneous Release (AIL-INST),

$$CA_{inj,n}^{AIL-INST}$$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-INST} =$ 473.9 b $= b_{inj,n}^{AIL-INST} =$ 0.63

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \ldots\ldots\ldots \text{equation (36)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-INST} = \left[a.\left(mass_1^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AIL-INST} = [473{,}9.(226.547)^{0{,}63}].\left(\frac{1-0{,}25}{7.794}\right)$$

$$CA_{inj,1}^{AIL-INST} = 1389.07 \quad m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-INST} = \left[a.\left(mass_2^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AIL-INST} = [473{,}9.(532.842)^{0{,}63}].\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{inj,2}^{AIL-INST} = 1999.66 \quad m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-INST} = \left[a.\left(mass_3^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AIL-INST} = [473{,}9.(532.842)^{0{,}63}].\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{inj,3}^{AIL-INST} = 1999.66 \quad m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-INST} = \left[a.\left(mass_4^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AIL-INST} = [473{,}9.(532.842)^{0{,}63}].\left(\frac{1-0{,}25}{9.280}\right)$$

$$CA_{inj,4}^{AIL-INST} = 1999.66 \quad m^2$$

8.12 STEP 8.12 For each release hole size, calculate the instataneous / continous blending factor, factn^{IC}.

1). FOR CONTINOUS RELEASE

$C_5 = 25.2$ kg/s

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad \text{.....equation (37)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$fact_1^{IC} = \min\left[\left\{\frac{rate_1}{C_5}\right\}, 1.0\right]$$

$$= 0.0075$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$fact_2^{IC} = \min\left[\left\{\frac{rate_2}{C_5}\right\}, 1.0\right]$$

$$= 0.11988095$$

C). LARGE RELEASE HOLE SIZE AREA

$$fact_3^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$

$$= 0.61269841$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$fact_4^{IC} = \min\left[\left\{\frac{rate_4}{C_5}\right\}, 1.0\right]$$

$$= 1$$

2). FOR INSTATANEOUS RELEASE

$$fact_4^{IC} = 1$$

8.13 Calculate the AIT blending factor, $fact^{AIT}$, using these optional equation below.

$$fact^{AIT} = 0 \quad \text{for } T_S + C_6 \leq AIT \quad \text{equation (38)}$$

$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2 \,.\, C_6} \quad \text{for } T_S + C_6 > AIT > T_S - C_6$$

$$fact^{AIT} = 1 \quad \text{for } T_S - C_6 \geq AIT \quad \text{equation (39)}$$

Ts	=	72.9 (^{o}C)	AIT	=	1036 (^{o}F)
Ts	=	163.22 (^{o}F)	AIT	=	830.927778 (K)
Ts	=	346.05 (K)	AIT	=	446.222222 (^{o}R)
C_6	=	55.6 (K)			

$T_s + C_6$	=	401.65 (K)
$T_s - C_6$	=	290.45 (K)
$\frac{(T_s - AIT + C_6)}{2 \,.\, C_6}$	=	-3.8604 (K)

$fact^{AIT}$ = 0

STEP 8.14 Calculate the continuous/instantaneous blended consequence area for the component using equation (3.53) through (3.56) based on the consequence areas calculated in previous steps $fact_n^{IC}$

A. Componen demage for auto-ignition Likely, Continous - Instataneous release

$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} . fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} . (1 - fact_n^{IC})$ equation (40)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-INST}$	=	23.67	m^2
$fact_1^{IC}$	=	0.0075	
$CA_{cmd,1}^{AIL-CONT}$	=	1.2750085	m^2
$CA_{cmd,1}^{AIL}$	=	1.4429535	m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-INST}$	=	35.26	m^2
$fact_2^{IC}$	=	0.119881	
$CA_{cmd,2}^{AIL-CONT}$	=	19.280941	m^2
$CA_{cmd,2}^{AIL}$	=	21.196176	m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-INST}$	=	35.26	m^2
$fact_3^{IC}$	=	0.612698	
$CA_{cmd,3}^{AIL-CONT}$	=	95.379461	m^2
$CA_{cmd,3}^{AIL}$	=	58.542577	m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-INST}$ = 35.26 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AIL-CONT}$ = 4417.35 m^2

$CA_{cmd,4}^{AIL}$ = 35.257085 m^2

B. Personal Injury for auto-ignition Likely, Continous - Instataneous release

$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} . fact_n^{IC} + CA_{inj,n}^{AIL-CONT} . (1 - fact_n^{IC})$.....equation (41)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AIL-INST}$ = 1389.07 m^2

$fact_{n1}^{IC}$ = 0.0075

$CA_{inj,1}^{AIL-CONT}$ = 23.192584 m^2

$CA_{inj,1}^{AIL}$ = 33.436629 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AIL-INST}$ = 1999.66 m^2

$fact_{n2}^{IC}$ = 0.1198810

$CA_{inj,2}^{AIL-CONT}$ = 296.99077 m^2

$CA_{inj,2}^{AIL}$ = 501.10818 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AIL-INST}$ = 1999.66 m^2

$fact_{n3}^{IC}$ = 0.6126984

$CA_{inj,3}^{AIL-CONT}$ = 1332.1704 m^2

$CA_{inj,3}^{AIL}$ = 1741.1392 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AIL-INST}$ = 1999.66 m^2

$fact_{n4}^{IC}$ = 1

$CA_{inj,4}^{AIL-CONT}$ = 48784.791 m^2

$CA_{inj,4}^{AIL}$ = 1999.6584 m^2

C. Componen demage for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST} . fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (42)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,n}^{AINL-INST}$ = 23.67 m^2

$fact_1^{IC}$ = 0.0075

$CA_{cmd,1}^{AINL-CONT}$ = 1.2750085 m^2

$CA_{cmd,1}^{AINL}$ = 1.4429535 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,n}^{AINL-INST}$ = 35.26 m^2

$fact_2^{IC}$ = 0.119881

$CA_{cmd,2}^{AINL-CONT}$ = 19.280941 m^2

$CA_{cmd,2}^{AINL}$ = 21.196176 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-INST}$ = 35.26 m^2

$fact_3^{IC}$ = 0.6127

$CA_{cmd,3}^{AINL-CONT}$ = 95.379461 m^2

$CA_{cmd,3}^{AINL}$ = 58.542577 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-INST}$ = 35.26 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AINL-CONT}$ = 4417.35 m^2

$CA_{cmd,4}^{AINL}$ = 35.257085 m^2

D. Personal Injury for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} . fact_n^{IC} + CA_{inj,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (43)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AINL-INST}$ = 45.37 m^2

$fact_1^{IC}$ = 0.0075

$CA_{inj,1}^{AINL-CONT}$ = 3.0944025 m^2

$CA_{inj,1}^{AINL}$ = 3.4114629 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AINL-INST}$ = 67.59 m^2

$fact_2^{IC}$ = 0.119881

$CA_{inj,2}^{AINL-CONT}$ = 49.461323 m^2

$CA_{inj,2}^{AINL}$ = 51.634021 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AINL-INST}$ = 67.59 m^2

$fact_3^{IC}$ = 0.6127

$CA_{inj,3}^{AINL-CONT}$ = 252.7914 m^2

$CA_{inj,3}^{AINL}$ = 139.31581 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AINL-INST}$ = 67.59 m^2

$fact_4^{IC}$ = 1

$CA_{inj,4}^{AINL-CONT}$ = 12660.854 m^2

$CA_{inj,4}^{AINL}$ = 67.58512 m^2

STEP 8.15 Calculate the AIT blended consequence areas for the component using equations (3.57) and (3.58) based on the consequence areas determined in step 8.14 and the AIT blending factors, , calculate in step 8.13. the resulting consequence areas are the component damage and personnel injury flammable consequence areas, and for each release hole size selected in step 2.2 $CA_{cmd,n}^{flam}$ $CA_{inj,n}^{flam}$

A. Componen Demage

$CA_{cmd,n}^{flam} = CA_{smd,n}^{AIL} . fact^{AIT} + CA_{cmd,n}^{AINL} . (1 - fact^{AIT})$ ..... equation (44)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL}$ = 1.4429535 m^2

$fact^{AIT}$ = 0

$CA_{cmd,1}^{AINL}$ = 1.4429535 m^2

$CA_{cmd,1}^{flam}$ = 1.4429535 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL}$ = 21.196176 m^2

$fact^{AIT}$ = 0

$CA_{cmd,2}^{AINL}$ = 21.196176 m^2

$CA_{cmd,2}^{flam}$ = 21.196176 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL}$ = 58.542577 m^2

$fact^{AIT}$ = 0

$CA_{cmd,3}^{AINL}$ = 58.542577 m^2

$CA_{cmd,3}^{flam}$ = 58.542577 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL}$ = 35.257085 m^2

$fact^{AIT}$ = 0

$CA_{cmd,4}^{AINL}$ = 35.257085 m^2

$CA_{cmd,4}^{flam}$ = 35.257085 m^2

B. Personal Injury

$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} . fact^{AIT} + CA_{inj,n}^{AINL} . (1 - fact^{AIT})$…….. equation (45)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{flam-AIL}$ = 33.436629 m^2

$fact^{AIT}$ = 0

$CA_{inj,1}^{AINL}$ = 3.4114629 m^2

$CA_{inj,1}^{flam}$ = 3.4114629 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{flam-AIL}$ = 501.10818 m^2

$fact^{AIT}$ = 0

$CA_{inj,2}^{AINL}$ = 51.634021 m^2

$CA_{inj,2}^{flam}$ = 51.634021 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{flam-AIL}$ = 1741.1392 m^2

$fact^{AIT}$ = 0

$CA_{inj,3}^{AINL}$ = 139.31581 m^2

$CA_{inj,3}^{flam}$ = 139.31581 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{flam-AIL}$ = 1999.6584 m^2

$fact^{AIT}$ = 0

$CA_{inj,4}^{AINL}$ = 67.58512 m^2

$CA_{inj,4}^{flam}$ = 67.58512 m^2

STEP 8.16 Determine the consequence areas (probability weighted on release hole size) for component damage and personnel injury using equations (3.59) and (3.60) based on the consequence area from step 8.15

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

CONSEQUENCE AREA FOR COMPONENT DAMAGE

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad \text{.....(equation)}$$

$$CA_{cmd}^{flam} = \left(\frac{(gff_{1.}\, CA_{cmd,1}^{flam}) + (gff_{2.}\, CA_{cmd,2}^{flam}) + (gff_{3.}\, CA_{cmd,3}^{flam}) + (gff_{4.}\, CA_{cmd,4}^{flam})}{gff_{total}} \right)$$

$$= 53.19\ m^2$$

CONSEQUENCE AREA FOR PERSONNEL INJURY

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad \text{(equation 94)}$$

$$CA_{inj}^{flam} = \left(\frac{\left(gff_1 \cdot CA_{inj,1}^{flam}\right) + \left(gff_2 \cdot CA_{inj,2}^{flam}\right) + \left(gff_3 \cdot CA_{inj,3}^{flam}\right) + \left(gff_4 \cdot CA_{inj,4}^{flam}\right)}{gff_{total}} \right.$$

$$= \left. 127.021\ m^2 \right.$$

PART 9 : CALCULATE THE TOXIC CONSEQUENCES AREA

Table 4.113 Continuous Gas and Liquid Release Toxic Consequence Equation Constantsfor Miscellaneous Chemicals

Chemical	Release Duration (minutes)	Gas Release Constants		Liquid Release Constants	
		e	f	e	f
Aluminum Chloride (Alcl3)	ALL	17.663	0.9411	N/A	N/A
Carbon Monoxide (CO)	3	41.412	1.15	N/A	N/A
	5	279.79	1.06	N/A	N/A
	10	834.48	1.13	N/A	N/A
	20	2915.9	1.11	N/A	N/A
	40	5346.8	1.17	N/A	N/A
	60	6293.7	1.21	N/A	N/A
Hydrogen Chloride (HCL)	3	215.48	1.09	N/A	N/A
	5	536.28	1.15	N/A	N/A
	10	2397.5	1.1	N/A	N/A
	20	4027	1.18	N/A	N/A
	40	7534.5	1.2	N/A	N/A
	60	8625.1	1.23	N/A	N/A
Nitric Acid	3	53.013	1.25	5110	1.08
	5	68.7	1.25	9640.8	1.02
	10	96.325	1.24	12.453	1.06
	20	126.942	1.23	19.149	1.06
	40	146.941	1.22	31.145	1.06
	60	156.345	1.22	41.999	1.12
Nitrogen Dioxide (NO2)	3	6633.1	0.7	2132.9	0.98
	5	9221.4	0.68	2887	1.04
	10	11.965	0.68	6194.4	1.07
	20	14.248	0.72	13.843	1.08
	40	22.411	0.7	27.134	1.12
	60	24.994	0.71	41.657	1.13

Phosgene	3	12.902	1.2	3414.8	1.06
	5	22.976	1.29	6857.1	1.1
	10	48.985	1.24	21.215	1.12
	20	108.298	1.27	63.361	1.16
	40	244.67	1.3	178.841	1.2
	60	367.877	1.31	314.608	1.23
Toluene Diisocyanate (TDI)	3	N/A	N/A	3692.5	1.06
	5	N/A	N/A	3849.2	1.09
	10	N/A	N/A	4564.9	1.1
	20	N/A	N/A	4777.5	1.06
	40	N/A	N/A	4953.2	1.06
	60	N/A	N/A	5972.1	1.03
Ethylene Glycol Monoethyl Ether (EE)	1.5	3.819	1.171	N/A	N/A
	3	7.438	1.181	N/A	N/A
	5	17.735	1.122	N/A	N/A
	10	33.721	1.111	3.081	1.105
	20	122.68	0.971	16.877	1.065
	40	153.03	0.995	43.292	1.132
	60	315.57	0.899	105.74	1.104

Because of no chemical toxic in this equipment, so this step not calculate.

PART 10 : CALCULATE THE NON-FLAMMABLE, NON-TOXIC CA

Step 10.1 For each release hole size, calculate the non-flammable , non-toxic For steam-calculate $CA_{inj,N}^{CONT}$ using equation (43) and $CA_{inj,N}^{INST}$

1). FOR STEAM

Steam represents a hazard to personnel who are exposed to it at high temperatures. In general, steam is at 100oC (212oF) immediately after exiting a hole in an equipment item. Within a few feet, the steam will begin to mix with air cool, and condensed. The approach used here is that injury occurs above 60oC (140oF). In this case of Production Separator, the temperatur inside the presssure vessel is maximally working at 100oC (212oF). So, steam leaks is potentially occur at this situation.

$Mass_1$ = 226.5473 kgs
$Mass_2$ = 532.8423 kgs
$Mass_3$ = 532.8423 kgs
$Mass_4$ = 532.8423 kgs
$Rate_1$ = 0.1890 kg/s
$Rate_2$ = 3.0210 kg/s
$Rate_3$ = 15.4400 kg/s
$Rate_4$ = 773.3000 kg/s
C_9 = 0.123 m^2.sec/kg
C_{10} = 9.744 $m^2/kg^{0.06384}$
$fact_1^{IC}$ = 0.0075
$fact_2^{IC}$ = 0.119881
$fact_3^{IC}$ = 0.6126984
$fact_4^{IC}$ = 1

$CA_{inj,n}^{CONT} = C_9 . Rate_n)$ ..... equation (48)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{CONT} = C_9 . Rate_1)$
= 0.02325 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{CONT} = C_9 . Rate_2)$
= 0.37158 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{CONT} = C_9 . Rate_3)$
= 1.89912 m^2

$CA_{inj,n}^{INST} = C_{10} . Mass_n)^{0.6384}$ ..... equation (49)

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{INST} = C_{10} . Mass_4)^{0.6384}$
= 235.43471 m^2

2). FOR ACIDS AND CAUSTIC

For Acids or caustics- compute, $CA_{inj,n}^{CONT}$ using equation (3.72), (3.73), (3.74). Note that the data is not provided for an instantaneous release ; therefore,

No acid or caustic, thus value are 0.

Step 10.2 For each release hole size, calculate the instantaneous/continuous blending factor, $fact_n^{IC}$ For steam, use equation (3.71).
for acids or caustics, $fact_n^{IC}$ =0.0

Step 10.3 For each release hole size , compute the blended non-flammable , non-toxic personnel injury consequence area for steam or acid leaks, $CA_{cmd,n}^{leak}$, using equation (3.76) based on the consequence are from step 10.1 and the blending factor , $fact_n^{IC}$ from step 10.2 note that there is no need to calculate component damage area for the level 1 non-flammable release (steam or acid/caustic) :

$CA_{cmd,n}^{leak}$ = 0 m^2

$CA_{inj,n}^{leak} = CA_{inj,n}^{INST}.\ fact_n^{IC} + CA_{inj,n}^{CONT}.(1 - fact_n^{IC})$ ..... equation (50)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{leak} = CA_{inj,1}^{INST}.\ fact_1^{IC} + CA_{inj,1}^{CONT}.(1 - fact_1^{IC})$

= 0.0230726 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{leak} = CA_{inj,2}^{INST}.\ fact_2^{IC} + CA_{inj,2}^{CONT}.(1 - fact_2^{IC})$

= 0.3270373 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{leak} = CA_{inj,3}^{INST}.\ fact_3^{IC} + CA_{inj,3}^{CONT}.(1 - fact_3^{IC})$

= 0.73553219 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{leak} = CA_{inj,4}^{INST}.\ fact_4^{IC} + CA_{inj,4}^{CONT}.(1 - fact_4^{IC})$

= 235.43471 m^2

Step 10.4 Determine the final non-flammable, non toxic consequence areas for personnil injury, CA_{icmd}^{nfnt} using equation (3.80) based on consequence areas calculated for each release hole size in step 10.3 . Note that there is no need to calculate a final-flammable, non-toxic consequence area for component damage area for the level 1 non-flammable release (steam or acid/caustic, or :

$CA_{cmd,n}^{lnfnt} = 0 \ m^2$

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}} \right) \quad \text{..... (equation)}$$

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

$$CA_{inj}^{nfnt} = \left(\frac{(gff_1 \cdot CA_{inj,1}^{leak}) + (gff_2 \cdot CA_{inj,2}^{leak}) + (gff_3 \cdot CA_{inj,3}^{leak}) + (gff_4 \cdot CA_{inj,4}^{leak})}{gff_{total}} \right)$$

$= 5.31689 \ m^2$

PART 11 : CALCULATION OF FINAL CONSEQUENCE AREA

Step 11.1 Calculate the final component damage consequence area, Cacmd

Note that since the component damage consequence areas for toxic releases, CAcmd^{tox}, and non-flammable, non-toxic releases, CAcmd^{nfnt}, are both equal to zero. Then, the final component damage consequence area is equal to the consequence area calculated for flammable releases, CAcmd^{flam}.

CA_{cmd}= CA_{cmd}^{flam} ..... equation (52)

= 53.19 m^2

Step 11.2 Calculate the final personnel injury consequence area, CA_{inj}

CA_{inj} = max $\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$ ..... equation (53)

CA_{inj}^{flam} = 127.021 m^2

CA_{inj}^{tox} = 0.00 m^2

CA_{inj}^{nfnt} = 5.31689 m^2

CA_{inj} = max $\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$

= 127.020893 m^2

Step 11.3 Calculate the final consequence area, CA, using equation below:

CA=max$\left[CA_{cmd}, CA_{inj}\right]$

= 127.02 m^2

= 1367.24151 ft^2

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 4 :

INSPECTION PLANNING AND RECOMMENDATION

PSV-2921

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 4 = Inspection Planning and Recommendation

STEP 1 CALCULATION OF RISK ANALYSIS

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (54)

dimana :

$Risk^{prd}$ = total risiko PRD

$Risk_f^{prd}$ = risiko PRD gagal membuka

$Risk_l^{prd}$ = risiko PRD bocor

STEP 1 Menghitung resiko dari peluang kegagalan PRD untuk gagal membuka

$Risk_{f.j}^{prd}$

A. RBI Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 1.14E-10 $Risk_{f.j}^{prd}$ = 1E-10 x 127.02

$C_{f,j}^{prd}$ = 127.02 m^2 = 1.448E-08

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 2.85E-09 $Risk_{f.j}^{prd}$ = 3E-09 x 127.02

$C_{f,j}^{prd}$ = 127.02 m^2 = 3.6201E-07

A. RBI Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 1.78E-09 $Risk_{f.j}^{prd}$ = 2E-09 x 127.02

$C_{f,j}^{prd}$ = 127.02 m^2 = 2.261E-07

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 4.45E-08 $Risk_{f.j}^{prd}$ = 4E-08 x 127.02

$C_{f,j}^{prd}$ = 127.02 m^2 = 5.6524E-06

$$Risk_f^{prd} = \sum_{j=1}^{ndc} P_{f,j}^{prd} . C_{f,j}^{prd}$$

A. RBI Date

$Risk_f^{prd}$ = 1E-08 + 4E-07

= 3.7649E-07

B. RBI Plan Date

$Risk_f^{prd}$ = 2E-07 + 6E-06

= 5.8785E-06

STEP 1.2 Hitung risiko untuk kasus kebocoran PRD $Risk_l^{prd}$

$$Risk_l^{prd} = P_l^{prd} . C_l^{prd}$$ equation (56)

Dimana :

P_l^{prd} = 0.0019 (RBI Date)

P_l^{prd} = 0.0518 (RBI Plan Date)

C_l^{prd} = 127.02 m^2

A. RBI Date

$Risk_l^{prd}$ = 0.0019 x 127.02

= 0.2413

B. RBI Plan Date

$Risk_l^{prd}$ = 0.0518 x 127.02

= 6.5797

STEP 1.3 Menghitung total risiko menggunakan persamaan (57)

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (57)

A. Risk at RBI Date

$Risk^{prd}$ = 0.2413 $m^2/year$

= 2.5978 $ft^2/year$

B. Risk at RBI Plan Date

$Risk^{prd}$ = 6.5797 $m^2/year$

= 70.823 $ft^2/year$

STEP 2 Risk Matrix

Probabilty Score at RBI Date = 1E-10 + 3E-09 + 0.0019

= 1.90E-03

Probabilty Score at Plan Date = 2E-09 + 4E-08 + 0.0518

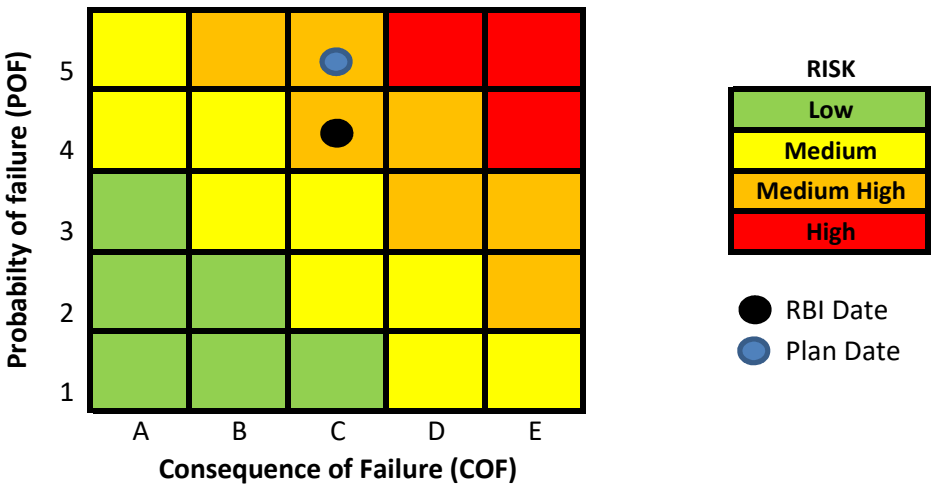
= 5.18E-02

Consequence Score = 127.02 m^2

= 1367.2 ft^2

Table 4.1 Numerical Values Associated with POF and Area-Based COF Categories

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t,I_E) \leq 3.06E-05$	$D_{ftotal} \leq 1$	A	$CA \leq 100$
2	$3.06E-05 < P_f(t,I_E) \leq 3.06E-04$	$1 < D_{ftotal} \leq 10$	B	$100 < CA \leq 1.000$
3	$3.06E-04 < P_f(t,I_E) \leq 3.06E-03$	$10 < D_{ftotal} \leq 100$	C	$1.000 < CA \leq 10.000$
4	$3.06E-03 < P_f(t,I_E) \leq 3.06E-02$	$100 < D_{ftotal} \leq 1000$	D	$10.000 < CA \leq 100.000$
5	$P_f(t,I_E) > 3.06E-02$	$D_{ftotal} > 1000$	E	$CA > 100.000$



STEP 3 Inspection Date

Target date dapat dihitung dengan cara melakukan interpolasi nilai RBI Date dan PRBI Plan Date

Dalam menentukan target date, digunakan nilai risk target sebesar 40ft^2 (3.71 m^2) untuk menentukan tahun inspection date.

Data	Date	Age	Risk (m^2/yr)
RBI Date	15/03/2020	0	0.241
Risk Target	?	?	3.710
Plan Date	15/3/2024	11	6.580

$$\frac{Y - Y_1}{Y_2 - Y_1} = \frac{X - X_1}{X_2 - X_1}$$

$$Y = Y_1 + \left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)$$

$$Y = 0 + \left(\frac{3.71 - 0.241}{6.580 - 0.241}\right)(11 - 0)$$

Y = 6.0197482 Year

Y = 2197.2081 Hari

= 21/03/2026

Interval inspeksi equipment berikutnya berdasarkan hasil inspeksi berbasis risiko yaitu pada tanggal 21 Maret 2026

STEP 4 Recommendation

1 Inspection Category

Inspection Effectiveness	Description of Inspection	Date
C	Inspeksi visual telah dilakukan tanpa tes pop, di mana dokumentasi terperinci tentang kondisi internal PRD komponen dibuat.	21/03/2026
Fairly Effective	Tes trevitest atau in-situ telah dilakukan di tempat yang sebenarnya cairan proses tidak digunakan untuk memberi tekanan pada sistem.	

Berdasarkan standart API 581 Direkomendasikan menggunakan inspection effectiveness kategori C dengan mengaplikasikan Visual on-stream inspection

2 Inspection Strategy

Berdasarkan Standart API 576 berikut rekomendasi record visual inspeksi Pressure Relief Device

Unit	Location		Set Pressure	Test Interval
Make		:		
Style		:		
Body and bonnet material		:		
Nozzle and disk material		:		
Trim material		:		
Spring material		:		
Spring no		:		
Flange sizes				
	Inlet	:		
	Outlet	:		
Spring set pressure		:		
Relieving pressure		:		
normal operating temp		:		
Remark				

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 1:

DATA PRESSURE RELIEF DEVICE

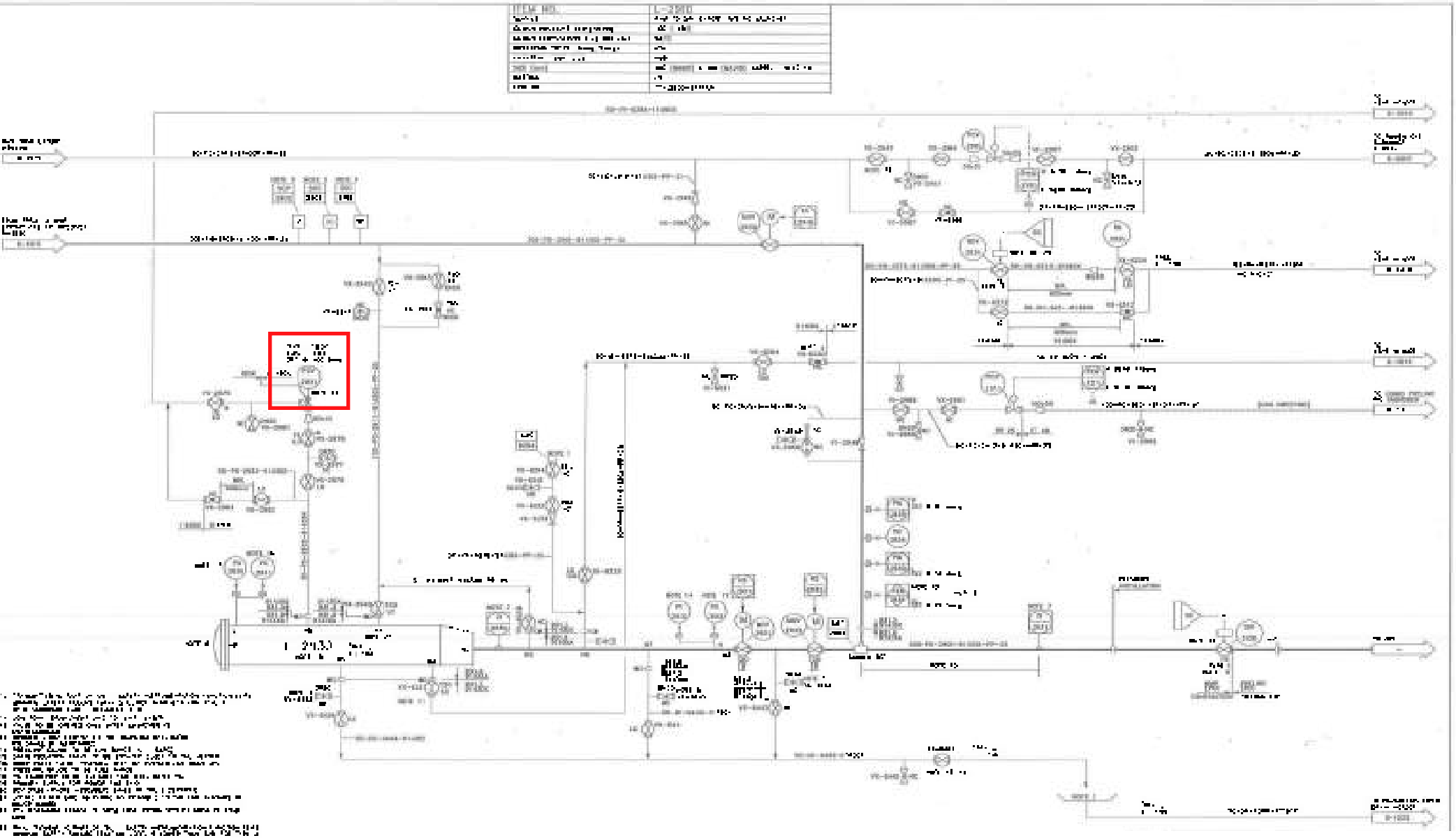
PSV-2931

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

Lampiran 1 = Data Pressure Relief Device

1 GENERAL				
Tag Number		:	PSV-2931	
Service		:	WHP to ORF Export Gas Pig Launcher	
Noozle (full/semi)		:	FULL	
PID No.		:	BTJT-A-B-1016	
Design		:	SAFETY-RELIEF	
Type		:	Conventional	
Bonnet Type		:	Closed	
Nace Requirement		:	Yes	
2 PROCESS CONDITIONS				
Fluid		:	Hydrocarbon	
State		:	Gas	
Required Capacity		:	1660	lb/h
Molecular Weight		:	21	
Operating Pressure		:	14.69	psig
Set Pressure		:	1465	psig
Operating Temperatur		:	614.1	^{o}F
Reliefing Temperatur		:	614.1	^{o}F
Back Pressure	Constant	:	0	psig
	Variable	:	0	psi
	Total	:	108.3	psig
% Allowable Overpressure		:	21%	
Overpressure Factor		:	-	
Compressible Factor		:	1.005	
Laten Heat of Vaporation		:	-	Btu/lb
Ratio of Specific Heats (Cp/C		:	1.192	
Relief Density		:	-	Lb/ft^2
Relief Viscosity		:	-	cP
Barometric Pressure		:	14.7	psia
3 DESIGN CONDITION				
Design Pressure		:	1465	psig
Design Temperatur		:	1000	^{o}F



CASE 1 : MAXIMUM GAS FLOW RATE (AUGUST 2016)

Stream Name		1	1A	1B	1C	1D	1E	2	2A	2B	2C
Description		Wellhead Flowline U/S of choke - NAG	Wellhead Flowline (BT2_A_P) U/S of choke - Long String	Wellhead Flowline (BT4_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_D_P) U/S of choke - Long String	Wellhead Flowline (BT2_C_P1) U/S of choke - Long String	Wellhead Flowline (BT4_E_P) U/S of choke - Long String	Wellhead Flowline D/S of choke - Short String (NAG)	Wellhead Flowline (BT2_A_P) D/S of choke - Long String	Wellhead Flowline (BT4_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_D_P) D/S of choke - Long String
MIXTURE											
Vapour Fraction		1.0000	0.2955	0.4203	0.2920	0.3095	0.2956	1.0000	0.3159	0.4223	0.2840
Temperature	C	75.0	75.0	71.0	72.0	75.0	74.0	66.4	69.2	70.2	71.4
Pressure	kPag	2959	2959	1034	1034	1034	1034	930	930	930	930
Pressure	bar_g	29.6	29.6	10.3	10.3	10.3	10.3	9.3	9.3	9.3	9.3
Mass Flow	kg/h	8478.39	26300.60	110228.76	22227.17	83356.85	29194.58	8478.39	26300.60	110228.76	22227.17
Molar Flow	kgmole/h	449.11	841.38	3550.51	685.06	2545.47	899.18	449.11	841.38	3550.51	685.06
Molecular Weight		18.9	31.3	31.0	32.4	32.4	32.5	18.9	31.3	31.0	32.4
Heat Flow	kW	-9821	-53720	-205650	-44662	-163516	-58456	-9821	-53720	-205650	-44662
Mass Heat Capacity	kJ/kg C	2.40	2.88	2.80	2.91	2.91	2.92	2.27	2.92	2.79	2.91
Mass Density	kg/m3	21.04	108.95	29.76	43.88	41.06	43.17	7.04	35.86	29.94	39.70
GAS PHASE											
Std Gas Flow	MNm3/h	10.05	5.56	33.39	4.46	17.62	5.95	10.05	5.95	33.54	4.51
Std Gas Flow	MMSCFD	9.00	4.98	29.91	4.01	15.79	5.33	9.00	5.33	30.05	4.04
Molar Flow	kgmole/h	449.11	248.67	1492.34	200.05	787.71	265.75	449.11	265.61	1499.40	201.38
Actual Gas Flow	ACT m3/h	403.02	217.58	3621.21	486.87	1934.34	650.60	1205.17	710.89	4009.69	540.38
Mass Flow	kg/h	8478.39	5617.70	37106.48	4989.82	19834.55	6670.73	8478.39	6309.08	37411.64	5048.85
Molecular Weight		18.9	22.6	24.9	24.9	25.2	25.1	18.9	23.7	25.0	25.1
Mass Heat Capacity	kJ/kg C	2.40	2.30	2.13	2.13	2.14	2.14	2.27	2.13	2.12	2.12
Z Factor		0.95	0.93	0.96	0.96	0.96	0.96	0.98	0.97	0.97	0.97
Thermal Conductivity	W/m K	0.041	0.038	0.034	0.034	0.035	0.035	0.038	0.035	0.034	0.034
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mass Density	kg/m3	21.04	26.82	10.25	10.25	10.25	10.25	7.04	6.86	9.33	9.34
Cp/Cv (Gamma)		1.32	1.30	1.23	1.23	1.22	1.22	1.27	1.23	1.22	1.22
OIL PHASE											
Mass Flow	kg/h	—	11155.91	39678.59	9354.61	33942.01	12226.33	—	10545.33	39426.24	9304.07
Liquid Vol Flow @Std Cond	m3/h	—	13.25	46.51	10.96	39.75	14.32	—	12.29	46.14	10.88
Liquid Vol Flow @Std Cond	barrel/day	—	2000	7021	1656	6000	2162	—	1855	6965	1643
Actual Volume Flow	m3/h	—	13.99	48.76	11.50	41.81	15.05	—	12.85	48.32	11.41
Molecular Weight		—	174.5	196.6	197.0	198.1	197.7	—	205.6	199.4	199.5
Mass Heat Capacity	kJ/kg C	—	2.10	2.13	2.13	2.14	2.14	—	2.11	2.12	2.13
Thermal Conductivity	W/m K	—	0.103	0.109	0.109	0.109	0.109	—	0.111	0.110	0.110
Viscosity	cP	—	1.20	1.56	1.54	1.50	1.51	—	1.76	1.62	1.60
Mass Density	kg/m3	—	787.60	813.74	813.27	811.86	812.33	—	820.69	815.97	815.22
Surface Tension	dyne/cm	—	12.91	14.73	14.88	14.57	14.61	—	15.18	14.92	14.80
AQUEOUS PHASE											
Mass Flow	kg/h	—	9526.98	33443.69	7882.74	28580.29	10297.52	—	9445.29	33390.88	7874.25
Liquid Vol Flow @Std Cond	m3/h	—	9.33	32.98	7.77	28.19	10.15	—	9.31	32.90	7.76
Liquid Vol Flow @Std Cond	barrel/day	—	1417	4975	1173	4251	1532	—	1406	4967	1171
Actual Volume Flow	m3/h	—	9.83	34.40	8.12	29.50	10.62	—	9.70	34.33	8.10
Molecular Weight		—	18.0	18.0	18.0	18.0	18.0	—	18.0	18.0	18.0
Mass Heat Capacity	kJ/kg C	—	4.34	4.34	4.34	4.35	4.35	—	4.34	4.34	4.34
Thermal Conductivity	W/m K	—	0.666	0.663	0.664	0.666	0.665	—	0.662	0.663	0.663
Viscosity	cP	—	0.37	0.39	0.39	0.37	0.38	—	0.41	0.40	0.39
Mass Density	kg/m3	—	969.63	972.09	971.29	968.88	969.68	—	973.51	972.66	971.73
MIXTURE COMPOSITION (Mole Fraction)											
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005
Nitrogen		0.0055	0.0025	0.0031	0.0021	0.0022	0.0021	0.0055	0.0025	0.0031	0.0021
CO2		0.0031	0.0040	0.0055	0.0038	0.0040	0.0039	0.0031	0.0040	0.0055	0.0038
Methane		0.6627	0.2283	0.2901	0.2016	0.2112	0.2026	0.6627	0.2283	0.2901	0.2016
Ethane		0.0453	0.0283	0.0393	0.0276	0.0290	0.0278	0.0453	0.0283	0.0393	0.0276
Propane		0.0262	0.0236	0.0361	0.0260	0.0274	0.0263	0.0262	0.0236	0.0361	0.0260
i-Butane		0.0072	0.0065	0.0104	0.0078	0.0082	0.0078	0.0072	0.0065	0.0104	0.0078
n-Butane		0.0081	0.0084	0.0135	0.0103	0.0109	0.0105	0.0081	0.0084	0.0135	0.0103
i-Pentane		0.0038	0.0040	0.0062	0.0050	0.0053	0.0051	0.0038	0.0040	0.0062	0.0050
n-Pentane		0.0025	0.0034	0.0050	0.0042	0.0044	0.0043	0.0025	0.0034	0.0050	0.0042
Mcyclopentan		0.0007	0.0012	0.0015	0.0014	0.0014	0.0014	0.0007	0.0012	0.0015	0.0014
Benzene		0.0000	0.0003	0.0004	0.0004	0.0004	0.0004	0.0000	0.0003	0.0004	0.0004
Cyclohexane		0.0004	0.0012	0.0014	0.0014	0.0014	0.0014	0.0004	0.0012	0.0014	0.0014
Mcyclohexane		0.0006	0.0021	0.0023	0.0024	0.0024	0.0024	0.0000	0.0021	0.0023	0.0024
Toluene		0.0000	0.0006	0.0006	0.0006	0.0006	0.0006	0.0000	0.0006	0.0006	0.0006
E-Benzene		0.0000	0.0003	0.0002	0.0003	0.0003	0.0003	0.0000	0.0003	0.0002	0.0003
p-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
m-Xylene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
o-Xylene		0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002	0.0002
n-Pbenzene		0.0000	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0003	0.0003
124-MBenzene		0.0000	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0004	0.0004	0.0004
C6*		0.0024	0.0045	0.0056	0.0053	0.0055	0.0054	0.0024	0.0045	0.0056	0.0053
C7*		0.0000	0.0035	0.0038	0.0039	0.0040	0.0040	0.0000	0.0035	0.0038	0.0039
C8*		0.0000	0.0036	0.0035	0.0039	0.0039	0.0040	0.0000	0.0036	0.0035	0.0039
C9*		0.0000	0.0026	0.0020	0.0031	0.0030	0.0031	0.0000	0.0026	0.0026	0.0031
C10-C15*		0.0000	0.0154	0.0134	0.0164	0.0160	0.0163	0.0000	0.0154	0.0134	0.0164
C16-C19*		0.0000	0.0057	0.0056	0.0071	0.0070	0.0071	0.0000	0.0057	0.0056	0.0071
C20-C27*		0.0000	0.0073	0.0063	0.0078	0.0076	0.0077	0.0000	0.0073	0.0063	0.0078
C28-C37*		0.0000	0.0043	0.0037	0.0045	0.0044	0.0045	0.0000	0.0043	0.0037	0.0045
C38-C80*		0.0000	0.0031	0.0027	0.0033	0.0032	0.0033	0.0000	0.0031	0.0027	0.0033
H2O		0.0115	0.6328	0.5354	0.6479	0.6343	0.6456	0.0115	0.6328	0.5354	0.6479
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Stream Name		2D	2E	3	4	4A	5	6	7	8	9	10
Description		Wellhead Flowline (BT2_C_P1) D/S of choke - Long String	Wellhead Flowline (BT4_E_P) D/S of choke - Long String	Inlet to Production Separator	Production Separator Gas Outlet	Gas Pipeline to FPSO	Liquid Pipeline to FPSO	Export Gas from FPSO to WHP (Note 7)	Export Gas from WHP to ORF (Note 6)	Gas Lift	Gas Inlet to FPSO (Note 6)	Liquid Inlet to FPSO (Note 6)
MIXTURE												
Vapour Fraction		0.3115	0.2976	0.4147	1.0000	1.0000	0.0002	1.0000	1.0000	1.0000	0.0841	0.0010
Temperature	C	74.3	73.4	70.3	70.5	70.2	70.5	65.8	22.9	65.8	32.1	69.7
Pressure	kPag	930	930	930	930	880	880	9101	7120	9101	755	522
Pressure	bar_g	9.3	9.3	9.3	9.3	8.8	8.8	91.0	71.2	91.0	7.6	5.2
Mass Flow	kg/h	83356.85	29194.58	289534.88	92836.71	92836.71	196698.17	80517.40	72509.32	7845.62	92836.71	196698.17
Molar Flow	kgmole/h	2545.47	899.18	9400.90	3899.75	3899.75	5501.15	3833.67	3452.38	373.55	3899.75	5501.15
Molecular Weight		32.4	32.5	30.8	23.8	23.8	35.8	21.0	21.0	21.0	23.8	35.8
Heat Flow	kW	-163516	-58456	-547951	-96398	-96398	-451503	-86559	-78265	-8434	-98081	-451835
Mass Heat Capacity	kJ/kg C	2.80	2.81	2.81	2.14	2.14	3.13	2.72	2.61	2.72	2.11	3.13
Mass Density	kg/m3	37.14	39.04	27.10	8.87	8.43	870.51	75.42	61.13	75.42	7.80	731.73
GAS PHASE												
Std Gas Flow	MNm3/h	17.74	5.99	87.21	87.24	87.24	0.01	85.76	77.23	8.36	85.80	0.23
Std Gas Flow	MMSCFD	15.89	5.36	78.12	78.15	78.15	0.02	76.83	69.19	7.49	76.91	0.21
Molar Flow	kgmole/h	792.94	267.56	3898.34	3899.75	3899.75	1.13	3833.67	3452.38	373.55	3837.74	10.47
Actual Gas Flow	ACT m3/h	2148.41	722.19	10461.79	10470.75	11011.23	3.19	1067.56	1186.11	104.02	11747.65	46.67
Mass Flow	kg/h	20061.87	8749.84	92780.89	92836.71	92836.71	27.22	80517.40	72509.32	7845.62	91652.63	286.14
Molecular Weight		25.3	25.2	23.8	23.8	23.8	24.1	21.0	21.0	21.0	23.9	27.3
Mass Heat Capacity	kJ/kg C	2.13	2.12	2.14	2.14	2.14	2.14	2.72	2.61	2.72	2.06	2.06
Z Factor		0.97	0.97	0.97	0.97	0.97	0.97	0.86	0.86	0.86	0.97	0.97
Thermal Conductivity	W/m K	0.034	0.034	0.035	0.035	0.035	0.035	0.047	0.043	0.047	0.033	0.037
Viscosity	cP	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Mass Density	kg/m3	9.35	9.35	8.87	8.87	8.43	8.54	75.42	61.13	75.42	7.80	6.13
Cp/Cv (Gamma)		1.22	1.22	1.23	1.23	1.23	1.23	1.46	1.44	1.46	1.24	1.20
OIL PHASE												
Mass Flow	kg/h	33751.47	12159.37	107020.05	0.00	—	106954.00	—	—	—	80.05	106703.77
Liquid Vol Flow @Std Cond	m3/h	39.46	14.22	124.70	0.00	—	124.69	—	—	—	0.10	124.26
Liquid Vol Flow @Std Cond	barrel/day	5957	2147	18838	0	—	18823	—	—	—	16	18758
Actual Volume Flow	m3/h	41.47	14.93	130.61	0.00	—	130.51	—	—	—	0.11	129.94
Molecular Weight		200.7	200.3	205.1	205.3	—	205.6	—	—	—	110.1	206.7
Mass Heat Capacity	kJ/kg C	2.14	2.13	2.12	2.12	—	2.12	—	—	—	2.09	2.11
Thermal Conductivity	W/m K	0.110	0.110	0.111	0.111	—	0.111	—	—	—	0.107	0.112
Viscosity	cP	1.55	1.56	1.72	1.72	—	1.72	—	—	—	0.49	1.79
Mass Density	kg/m3	813.88	814.31	819.41	819.38	—	819.51	—	—	—	733.22	821.21
Surface Tension	dyne/cm	14.75	14.78	15.11	15.10	—	15.13	—	—	—	16.73	15.41
AQUEOUS PHASE												
Mass Flow	kg/h	28543.51	10285.38	89733.93	0.00	—	89718.95	—	—	—	1101.03	89708.25
Liquid Vol Flow @Std Cond	m3/h	28.13	10.14	88.42	0.00	—	88.41	—	—	—	1.09	88.40
Liquid Vol Flow @Std Cond	barrel/day	4246	1530	13348	0	—	13345	—	—	—	164	13344
Actual Volume Flow	m3/h	29.45	10.60	92.26	0.00	—	92.26	—	—	—	1.12	92.20
Molecular Weight		18.0	18.0	18.0	18.0	—	18.0	—	—	—	18.0	18.0
Mass Heat Capacity	kJ/kg C	4.35	4.34	4.34	4.34	—	4.34	—	—	—	4.32	4.34
Thermal Conductivity	W/m K	0.666	0.665	0.663	0.663	—	0.663	—	—	—	0.646	0.662
Viscosity	cP	0.38	0.38	0.40	0.40	—	0.40	—	—	—	0.53	0.40
Mass Density	kg/m3	969.38	970.15	972.59	972.46	—	972.44	—	—	—	968.88	972.93
MIXTURE COMPOSITION (Mole Fraction)												
H2S		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen		0.0022	0.0021	0.0026	0.0068	0.0068	0.0000	0.0089	0.0089	0.0089	0.0068	0.0000
CO2		0.0040	0.0039	0.0044	0.0105	0.0105	0.0001	0.0093	0.0093	0.0093	0.0105	0.0001
Methane		0.2112	0.2026	0.3011	0.7225	0.7225	0.0023	0.8082	0.8082	0.8082	0.7225	0.0023
Ethane		0.0290	0.0278	0.0337	0.0799	0.0799	0.0010	0.0735	0.0735	0.0735	0.0799	0.0010
Propane		0.0274	0.0263	0.0297	0.0684	0.0684	0.0022	0.0574	0.0574	0.0574	0.0684	0.0022
i-Butane		0.0082	0.0079	0.0087	0.0190	0.0190	0.0013	0.0151	0.0151	0.0151	0.0190	0.0013
n-Butane		0.0109	0.0105	0.0112	0.0240	0.0240	0.0021	0.0178	0.0178	0.0178	0.0240	0.0021
i-Pentane		0.0053	0.0051	0.0053	0.0101	0.0101	0.0019	0.0051	0.0051	0.0051	0.0101	0.0019
n-Pentane		0.0044	0.0043	0.0043	0.0078	0.0078	0.0016	0.0032	0.0032	0.0032	0.0078	0.0016
Mcyclopentan		0.0014	0.0014	0.0014	0.0017	0.0017	0.0011	0.0007	0.0007	0.0007	0.0017	0.0011
Benzene		0.0004	0.0004	0.0003	0.0004	0.0004	0.0003	0.0000	0.0000	0.0000	0.0004	0.0003
Cyclohexane		0.0014	0.0014	0.0013	0.0015	0.0015	0.0012	0.0001	0.0001	0.0001	0.0015	0.0012
Mcyclohexane		0.0024	0.0024	0.0022	0.0017	0.0017	0.0025	0.0000	0.0000	0.0000	0.0017	0.0025
Toluene		0.0006	0.0006	0.0000	0.0004	0.0004	0.0007	0.0000	0.0000	0.0000	0.0004	0.0007
E-Benzene		0.0003	0.0003	0.0002	0.0001	0.0001	0.0004	0.0000	0.0000	0.0000	0.0001	0.0004
p-Xylene		0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
m-Xylene		0.0004	0.0004	0.0004	0.0001	0.0001	0.0005	0.0000	0.0000	0.0000	0.0001	0.0005
o-Xylene		0.0002	0.0002	0.0002	0.0001	0.0001	0.0003	0.0000	0.0000	0.0000	0.0001	0.0003
n-Pbenzene		0.0003	0.0003	0.0003	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0005
124-MBenzene		0.0004	0.0004	0.0004	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0006
C6*		0.0055	0.0054	0.0051	0.0007	0.0007	0.0040	0.0008	0.0008	0.0008	0.0007	0.0040
C7*		0.0040	0.0040	0.0035	0.0034	0.0034	0.0037	0.0002	0.0002	0.0002	0.0034	0.0037
C8*		0.0039	0.0040	0.0034	0.0018	0.0018	0.0046	0.0000	0.0000	0.0000	0.0018	0.0046
C9*		0.0030	0.0031	0.0027	0.0008	0.0008	0.0040	0.0000	0.0000	0.0000	0.0008	0.0040
C10-C15*		0.0160	0.0163	0.0140	0.0001	0.0001	0.0238	0.0000	0.0000	0.0000	0.0001	0.0238
C16-C19*		0.0070	0.0071	0.0061	0.0000	0.0000	0.0104	0.0000	0.0000	0.0000	0.0000	0.0101
C20-C27*		0.0076	0.0077	0.0066	0.0000	0.0000	0.0113	0.0000	0.0000	0.0000	0.0000	0.0113
C28-C37*		0.0044	0.0045	0.0039	0.0000	0.0000	0.0066	0.0000	0.0000	0.0000	0.0000	0.0066
C38-C80*		0.0032	0.0033	0.0028	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0048
H2O		0.6343	0.6456	0.5431	0.0318	0.0318	0.5055	0.0000	0.0000	0.0000	0.0318	0.5055
Total		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

PSEUDO COMPONENT	LIQUID DENSITY (g/cm3)	Tc (°C)	Pc (bara)	ACENTRIC FACTOR	NBP (°C)	MOLECULAR WEIGHT (g/mol)	Vc (cm^3/mol)
C6*	0.66	234.2	29.7	0.3	68.7	86.2	370.0
C7*	0.74	241.4	24.5	0.4	103.1	96.0	524.1
C8*	0.77	268.2	21.7	0.4	126.8	107.0	527.9
C9*	0.78	298.1	20.0	0.4	143.6	121.0	527.8
C10-C15*	0.82	419.6	18.1	0.6	220.7	171.6	716.7
C16-C19*	0.85	539.9	14.1	0.8	304.8	242.0	1019.3
C20-C27*	0.88	658.6	12.3	0.9	376.9	318.6	1381.5
C28-C37*	0.90	831.8	10.8	1.1	462.2	441.2	1979.7
C38-C80*	0.94	1084.1	9.7	1.0	579.2	669.1	3271.8

Approved For Construction

MASTER

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.1:
PROBABILITY OF FAILURE TO OPEN CALCULATION

PSV-2931

REV.	DATE	Explanation	Done By		Approved by	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.1 = Probabilty Of Failure To Open

PART 1 : CALCULATION OF PROBABILITY OF FAILURE TO OPEN

The fundamental calculation applied to PRDs for the fail to open case is the product of an estimated overpressure demand case frequency (or demand rate), the probability of the PRD failing to open on demand, and the probability that the protected equipment at higher overpressures will lose containment.

$$P_{f,j}^{prd} = P_{fod,j} \cdot DR_j . P_{f,j}$$ equation (1)

Dimana :

$P_{f,j}^{prd}$ = POF of a PRD overpressure demand case, (failures/year)

$P_{fod,j}$ = POFOD of a PRD (failures/demand)

DR_j = demand rate (demands/year)

$P_{f,j}$ = POF (loss of containment) (failures/year)

The subscript j in the above equation indicates that the POF for the PRD,P prd f , j. needs to be calculated for each of the applicable overpressure demand cases associated with the PRD

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 tahun see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service	:	Methane	
Typical Temperature	:	614.1 ^{o}F	
Fluid Severity	:	Mild	See Table 7.4
Design Type PRD	:	Conventional	
Discharge Location	:	discharge to flare with flare recovery system	

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fc,for conventional valves discharging to closed system or to flare

F_C = 0.75 for conventional valves discharging to closed system or flare

F_C = 1.00 for all other cases

STEP 4 Determine the environment adjustment factor, Fenv using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 1.0 (see data process condition)

STEP 5 The result of the procedure outlined above will be a modified characteristic life, ηmod, as defined in equation (2)

F_C = 0.75 see step 3

F_C = 1.00 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_C x F_{env} x η_{def} equation (2)

= 0.75 x 1.00 x 37.88

= 28.41

STEP 6 Assemble the PRD's inspection history, Grade each record using the inspection effectiveness table, part 2, Annex 2.c, Table 2.C.3.1. Record the result of each inspection record; PASS/FAIL and NO LEAK/LEAK and determine the confidence factors, Cfi, as applicable, for each inspection history based on the results of the test Determine the time duration, tdur,i of each inspection cycle

STEP 6.1 Each inspection record must be graded using the PRD inspection effectifeness table, part 2, annex 2.C, table 2.C.3.1

- Inspection effectiveness : part 2, annex 2.C, Table 2.C.3.1

Tabel 2.C.3.1- Inspeksi dan pengujian keefektifan untuk PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

STEP 6.2 Record the PASS/FAIL and NO LEAK/LEAK in order to determine the confidence factors, Cfi , as applicable , for each inspection history where a test was conducted

- Inspection Record = No Leak / Leak

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

CF_i = 0.5 see table 7.8

STEP 6.3 Determine the time duration , tdur,I ,between each inspection cycle

a. RBI Date $t_{dur,}i$ = RBI date - Last Inspection

= 15/03/2020 - 17/06/2016

= 4 year

B. RBI Plan Date $t_{dur,}i$ = Plan date - Last Inspection

= 15/03/2024 - 17/06/2016

= 8 year

STEP 6.4 Determine if the PRD was overhauled

- refer to section 7.7.2 and 7.7.3 ,as well as figure 7.7, for more information

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{14.69}{1464.9}\right)}{0.90}\right)$$

P_S = 14.69

P_{Set} = 1464.9

$$= 1 - \left(\frac{0.90 - \min(0.009)}{0.90}\right)$$

= 0.11

STEP 7 Starting at the earliest inspection record, update the modifierd characteristic life ηmod ,determine in step 5 as follows

STEP 7.1 Calculate the prior POF using equation (3) . The time prior for use in equation (3) . Is the time duration of the inspection cycle , tdur,I as determine in step 6 . Note that for the first inspection record ,the modified characteristic life, ηmod, is used . sub sequent inspection record will use the update ed characteristic life ,ηupd,from step 7.5

$$P_{f,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.09714

STEP 7.2 Calculate the prior probability of passing using Equation (4)

$$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$$ equation (4)

A. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0289

= 0.97108

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{f,prior}^{prd}$

$P_{p,Prior}^{prd}$ = 1 - 0.0971

= 0.90286

STEP 7.3 Determine the condition POF and the conditional probability of pass using Equations (5)

$$P_{f,cond}^{prd} = (1\text{-}CF_{pass}).P_{p,prior}^{prd}$$ equation (5)

CF_{pass} = 0.5 step 6.2

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (BRI Plan Date) step 7.2

A. RBI Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48553975

B. RBI Plan Date

$P_{f,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45142809

step 7.4 Calculatethe weighted POF, $P_{f,wgt}^{prd}$ using the appropriate equation from table 7.9

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.\ P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.\ P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.\ P_{f,prior}^{prd} + 0.5.\ P_{f,cond}^{prd}$

$P_{f,wgt}^{prd}$ = $P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{f,wgt}^{prd}$ = 0.4855

B. RBI Plan Date

$P_{f,wgt}^{prd}$ = 0.4514

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (6) and the weighted POF

$$\eta_{upd} = \frac{t}{\left(-ln\left[1 - P_{f,wgt}^{prd}\right]\right)^{\frac{1}{\beta}}}$$

η_{upd} = 10.62

STEP 7.6 Repeat step 7 for each of the inspection record available for the PRD until a final updated value for the characteristic life, , is determine.η_{upd}

$$P_{f,Prior}^{prd} = 1 - \exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (3)

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
ηupd	=	28.406	= η_{mod}	see step 5
ηupd	=	10.621		see step 7.5
β	=	1.80		see step 2

A. RBI Date

$P_{f,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{f,Prior}^{prd}$ = 0.45143

STEP 8 The POFOD should be adjusted based on the overpressure scenario, The overpressure factor Fop,j, is an adjustment for overpressure scenarios higher than 1.3 times the set pressure

$F_{op,j}$ = 1.0 for $\frac{F_{op,j}}{P_{set}} < 1.3$

$F_{op,j}$ = 0.2 for $\frac{F_{op,j}}{P_{set}} > 4$

$F_{op,j}$ = $1 - \frac{1}{3.375} \cdot \left(\frac{F_{op,j}}{P_{set}} - 1.3 \right)$ for all other cases

$F_{op,j}$: overpressure likelyto accur as a result of a PRD failling to open upon demand ,associated with the J overprssure demand case,kPa(psig) = 1773 psig (see data process condition)

P_{set} : The set pressure of the PRD,kPa (psig) = 1465 psig (see data process condition)

$\frac{F_{op,j}}{P_{set}}$: $\frac{1772.5}{1464.9}$: 1.21

$F_{op,j}$: 1

$P_{fod,j} = P_{fod} \cdot F_{op,j}$ equation (7)

P_{fod} = 0.029 see step 7.1

P_{fod} = 0.451 see step 7.1

$F_{op,j}$ = 1 see step 7

A. RBI Date

$P_{fod,j}$ = 0.029 x 1

= 0.02892

B. RBI Plan Date

$P_{fod,j}$ = 0.451 x 1

= 0.45143

STEP 9 Estimates for the PRD initiating event frequencies, Efj, based on the various relief overpressure demand cases that the device is providing protection Examples of the initiating event frequencies are provided in Table 7.2 Additional background on the default initiating event frequencies is provided in Table 7. 3

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	EF_j (event/year)
Fire	1 per 250 years	0.004
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 10 Determine Credit for Other Layers of Protection. The concept of a demand rate reduction factor, DRRFj , is introduced here to account for the difference in the overpressure demand case event frequency and the demand rate on the PRD. demand rate reduction factor are provide in Table 7.2

Table 7.2 – Default Initiating Event Frequencies

OverPressurre Demand Case	Event Frequency	$DRRF_f$
Fire	1 per 250 years	0.10
Liquid Overfilling without administrative controls	1 per 10 years	0.10

STEP 11 for each overpressure demand case, determine the demand rate placed on the PRD,DRj.The demand rate (DR) on the PRD is calculated as the product of the initiating event frequency and the DRRFj in accordance with Equation (1.12)

$$DR_j = EF_{j.} \; . DRRF_j$$ Equation (8)

EF (fire) = initiating fire frequencies = 0.004

DRRF (fire) = demand rate reduction factor = 0.10

DR (fire) = EF (fire) x DRRF (fire)

= 0.004 x 0.10

= 0.0004

EF (overfill) = initiating overfill frequencies = 0.10

DRRF (overfill) = demand rate reduction factor = 0.10

DR (overfill) = EF (overfill) x DRRF (overfill)

= 0.10 x 0.10

= 0.01

step 12 Determine the MAWP of the protected equipment

set pressure	=	1465 psig	see data
% Allowable Overpressure	=	21%	process
MAWP	=	1773 psig	

STEP 13 If an RBI Study has been completed for protected equipment, calculate its damage adjustment POF, Pf, using equation (1.1) since the DF for the protected equipment is a function of time ,the DF must be determined at the PRD inspection interval, t insp, specifide in step 1 . if a risk analysis for fix equipment has not been complated , a DF can be estimated using the values in table 7.10

Table 7. 10 – DF Classes for Protected Equipment

DF Class	DF	Description
None	1	New vessel or inspection shows little if any damage
Minimal	20	equipment has been in service for a reasonable amount of time and inspection shows evidence of minor damage . Damage mechanism have been identified and inspecton data is available.
Minor	200	One or more damage mechanisms have been identified, limited inspection data available and fairly moderate evidence of damage. Single damage mechanism identified, recent inspection indicates moderate evidence of damage.
Moderate	750	Moderate damage found during recent inspection. Low susceptible to one or more damage mechanisms, and limited inspection exists.
Severe	2000	One or more active damage mechanisms present without any recent inspection history. Limited inspection indicating high damage susceptibility

D_f = 20.0

STEP 14 Calculate the POF of the protected equipment at the elevated overpressure,Pf,j using equation (9).

$$Pf,j = (0.0312881.gfftotal.Df.Fms)e^{(3.464837..\frac{Po,j}{MAWP})}$$ equation (9)

gff_{total}	=	0.0000306	see part 2 table 3.1
D_f	=	20	see step 13
F_{MS}	=	0.5	see part 2 section 3.5.4
$P_{o,j}$	=	14.69	data process condition
MAWP	=	1772.529	see step 12

$$Pf,j = (0.0312881x0.0000306x20x0.5)e^{3.464837..\frac{1029.8}{1772.53}}$$

Pf,j = | 0.0000098531

STEP 15 Calculate the POF, ,using Equation (1.11)

A. RBI Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892 x 0.0004 x 9.8531E-06

= | 1.14E-10

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.02892051 x 0.01 x 9.85E-06

= | 2.85E-09

B. RBI Plan Date

FIRE CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.0004 x 9.85E-06

= | 1.78E-09

OVERFILLING CASE

$$P_{f,j}^{prd} = P_{fod,j}.DR_j.P_{f,j}$$ equation (10)

$P_{f,j}^{prd}$ = 0.45143 x 0.01 x 9.85E-06

= | 4.45E-08

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 2.2:
PROBABILITY OF FAILURE TO LEAKAGE CALCULATION

PSV-2931

REV.	DATE	Explanation	Done By		Approved by	
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	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 2.2 = Probabilty Of Failure To Leakage

PART 2 : Calculation Procedure - POL at Specified Inspection Interval

The leakage case is different than the fail to open case since the POF is not a function of demand rate but rather is based on failure during continuous operation. The industry data associated with the probability of leakage,Pl , data is in per year units (failure/year). no multiplication by any demand rate is necessary

STEP 1 Select an inspection Interval, tinsp

t_{insp} = 4 years see data planning

STEP 2 Determine the dafault value for the weibull parameters,β and ηdef using table 7.5

Fluid Service : Methane

Typical Temperature : 614.1 °F

Fluid Severity : Mild See Table 7.4

Design Type PRD : Conventional

Discharge Location : discharge to flare with flare recovery system

Table. 7.5- Default Weibull Parameters for POFOD

Fluid Severity	Conventional and Balanced Bellows PRV		Pilot-Operated PRV		Rupture Disk	
	β	ηdef	β	ηdef	β	ηdef
Mild	1.8	50.5	1.8	33.7	1.8	50.5
Moderate	1.8	23.9	1.8	8.00	1.8	50.5
Severe	1.8	17.6	1.8	3.5	1.8	50.5

Table Information : β : 1.80

η_{def} : 50.5 - 25%*50.5 See note 1 table 7.5

: 37.875

STEP 3 Determine the adjustment factor, Fs using section 7.3.2.g).

F_s = 1.25 for soft seated design see data material

F_s = 1.00 for all other cases

STEP 4 Determine the environmenta adjustment factor, Fenv.using table 7.6

Table 7.6-Environment adjustment Factors to weibull η parameter

Environment Modifier	Adjustment to POFOD η parameter	Adjustment to POL η parameter
Operating Temperatur 200<T<500°F	1.0	0.8
Operating Temperatur >500°F	1.0	0.6
Operating Ratio >90% for spring-loaded PRVs or >95% for pilot-operated PRVs	1.0	0.5

F_{env} = 0.6 (see data process condition)

STEP 5 calculate the modified characteristic life, ηmod, using equation (11) and the factors obtain in step 3 and 4.

F_s = 1.25 see step 3

F_{env} = 0.60 see step 4

η_{def} = 37.88 see step 2

η_{mod} = F_s x F_{env} x η_{def} equation (11)

= 1.25 x 0.60 x 37.88

= 28.41

STEP 6 Assemble the the PRDs inspection history, grade each record using the inspection effectiveness table, part 2,annex 2.C, Table 2.C.3.1. Record the result of each inspection record.; NO LEAK/LEAK and determine the confidance factors, Cfi, as applicable, for each inspection history based on the result of the test . Determine the time duration, tdur.i. of each inspection cycle.

- Inspection effectiveness : part 2,annex 2.C, Table 2.C.3.1

Table 2.C.3.1- Inspection and testing efectiveness for PRD

Inspection Effectiveness	Component Type	Description of Inspection
Inefective D	Pressure Relief Device	Valve overhaul performed ; no pop test conducted/documented
	Rupture Disk	No details of the internal component were documented

- Inspection Record : No LEAK/ LEAK

Table 7. 8 – Level of Inspection Confidence Factors

Inspection Result	Confidence Factor That Inspection Result Determines the True Damage State, CF			
	Ineffective	Fairly Effective	Usually Effective	Highly Effective
Pass, CF_{pass}	No credit	0.5	0.7	0.9
Fail, CF_{fail}	No credit	0.7	0.95	0.95
No Leak, CF_{noleak}	No credit	0.5	0.7	0.9
Leak, CF_{leak}	No credit	0.7	0.95	0.95

- Determine the confidence factors, CF_i

  CF_i : 0.5

- Determine the time duration, tdur,j. of each inspection cycle

  A. RBI Date

  $t_{dur,i}$ = RBI date - Last Inspection

  = 15/03/2020 - 17/06/2016

  = 4 year

  B. RBI Plan Date

  $t_{dur,i}$ = Plan date - Last Inspection

  = 15/03/2024 - 17/06/2016

  = 8 year

STEP 7 Starting at the earliest inspection record , update the modified characteristic life, ηmod, determine in step 5 as follows

STEP 7.1 Calculate the prior probability of leakage using equation (12). Note that for the first inspection record , the modified characteristic life,ηmod,is used subsequent inspection record will use the updated characteristic from STEP 7.5 below.

$$P_{l,Prior}^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta_{mod}}\right)^{\beta}\right] \qquad \text{equation (12)}$$

t	=	4	(RBI Date)	see step 6
t	=	8	(RBI Plan Date)	see step 6
η_{mod}	=	28.41	for the first inspection record	see step 5
β	=	1.80		see step 2

A. RBI Date

$P_{l,Prior}^{prd}$ = 0.02892

B. RBI Plan Date

$P_{l,Prior}^{prd}$ = 0.09714

STEP 7.2 Calculate the prior probability of passing using equation (13)

$$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd} \quad \text{equation (13)}$$

A. RBI Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd} = 1 - 0.0289$

$P_{p,Prior}^{prd} = 0.97108$

B. RBI Plan Date

$P_{p,Prior}^{prd} = 1 - P_{l,prior}^{prd}$

$P_{p,Prior}^{prd} = 1 - 0.0971$

$P_{p,Prior}^{prd} = 0.90286$

STEP 7.3 Determine the conditional probability of leakage and conditional probability of pass using equation (14)

$$P_{l,cond}^{prd} = (1\text{-}CF_{pass}).P_{p,prior}^{prd} \quad \text{equation (14)}$$

CF_{pass} : 0.5 step 6

$P_{p,Prior}^{prd}$ = 0.97108 (RBI Date) step 7.2

$P_{p,Prior}^{prd}$ = 0.90286 (RBI Plan Date) step 7.2

A. RBI Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.97108

= 0.48554

B. RBI Plan Date

$P_{l,cond}^{prd}$ = (1-0.5) x 0.90286

= 0.45143

STEP 7.4 calculate the weighted probability of leakage, $P_{l,wgt}^{prd}$, using the appropriate equation from table 7.9.

Table 7. 9 - Inspection Updating Equations

PRV Type	Set Pressure Factor
Highly Effective Pass	$P_{f,wgt}^{prd} = P_{f,prior}^{prd} - 0.2.P_{f,prior}^{prd}\left(\frac{t}{\eta}\right) + 0.2.P_{f,cond}^{prd}\left(\frac{t}{\eta}\right)$
Usually Effective Pass	
Fairly Effective Pass	
Highly Effective Fail	$P_{f,wgt}^{prd} = P_{f,cond}^{prd}$
Usually Effective Fail	
Fairly Effective Fail	$P_{f,wgt}^{prd} = 0.5.P_{f,prior}^{prd} + 0.5.P_{f,cond}^{prd}$

$P_{l,wgt}^{prd} = P_{f,cond}^{prd}$ choose equation from table 7.9

A. RBI Date

$P_{l,wgt}^{prd}$ = 0.48554

B. RBI Plan Date

$P_{l,wgt}^{prd}$ = 0.45143

STEP 7.5 Determine the updated characteristic life ,ηupd, using equation (15) and the weighted probability of leakage, $P_{l,wgt}^{prd}$ established in step 7.4

$$\eta upd = \frac{t}{(-\ln\left[1 - P_{f,wgt}^{prd}\right])^{\frac{1}{\beta}}}$$ equation (15)

η_{upd} = 10.62

STEP 8 Calculate the probability of leakage for the specific PRD in accordance with Equation (16)

$$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{t}{\eta upd}\right)^{\beta}\right]$$ equation (16)

t = 4 year see step 6

t = 8 year see step 6

β = 1.80 see step 2

η_{upd} = 28.41 = η_{mod} see step 5

η_{upd} = 10.62 see step 7.5

A. RBI Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{4}{28.41}\right)^{1.80}\right]$

P_l^{prd} = 0.02892

B. RBI Plan Date

$P_l^{prd} = 1\text{-}\exp\left[-\left(\frac{8}{10.62}\right)^{1.80}\right]$

P_l^{prd} = 0.45143

STEP 9

The Probability of leakage needs to be adjusted based on the closedness the system is operating near the set pressure with equation (1.36). The set pressure factor , F_{set} , is dependent on the PRD type.

$$P_{l,j}^{prd} = P_l^{prd} . F_{set}$$ equation (1.36)

PRD Type = Conventional see data general

Tabel 7.7 Set Pressure Factor

PRV Type	Set Pressure Factor
Pilot Operated PRVs	$F_{Set} = 1 - \left(\frac{0.95 - min\left(0.95.\frac{P_S}{P_{set}}\right)}{0.95}\right)$
Rupture Disks	$P_{Set} = 1$
Conventional PRVs and Balanced Bellows PRVs	$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{P_S}{P_{set}}\right)}{0.90}\right)$
Notes : 1. Ps denotes the operating pressure and Pset denotes the set preesure	

$$F_{Set} = 1 - \left(\frac{0.90 - min\left(0.90.\frac{14.69}{1465}\right)}{0.90}\right)$$

$$= 1 - \left(\frac{0.90 - \min(0.009)}{0.90}\right)$$

$$= 0.11$$

$P_S =$ 14.69 see data

$P_{Set} =$ 1465 process

A. RBI Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.0289 step 8

F_{set} = 0.11 Table 7.7

$P_{l,j}^{prd}$ = 0.0289 x 0.11

= 0.0032

B. RBI Plan Date

$P_{l,j}^{prd} = P_l^{prd} . F_{set}$ Equation (18)

P_l^{prd} = 0.45143 step 8

F_{set} = 0.11 Table 7.7

$P_{l,j}^{prd}$ = 0.4514 x 0.11

= 0.0497

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 3 :
CONSEQUENCE OF FAILURE CALCULATION

PSV-2931

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

PART 3 CONSEQUENCE CALCULATION of FAILURE to OPEN

STEP 1 Determine the list of overpressure scenarios applicable to the piece of equipment being protected by the PRD under evaluation. Table 7.2 provides a list of overpressure demand cases specific covered.

Overpressure Demand Case for PSV-2931

1 Fire see table 7.3

2 Liquid Overfillling without administrative controls in place

step 2 For each overpressure demand case, estimate the amount of overpressure, $p_{o,j}$ likely to occur during the overpressure event if the PRD were to fail to open.

Table 7.3 - Overpressure Scenario Project

Initiating Event	Equipment Type	PRD Demand rate reduction factor	Qualifier	over pressure potential	Background and comment
1. Overpressure Scenario					
1 per 250 years	All Equipment Type	0.1 industry experience justifies this value	N/A	4.0 x MAWP (RUPTURE)	see table 7.3
2. Overpressure scenario - liquid Overfilling					
1 per 100 years (admin control)	All Equipment including process tower	1.00	downsteam of positif displacement type rotating equipment	4.0 x MAWP	see table 7.3

$P_{0,fire}$ = 4 x MAWP
= 4 x 1773
= 7092 psig

$P_{o,overfilling}$ = 4 x MAWP
= 4 x 1773
= 7092 psig

STEP 3 For instalations that have multiple PRDs, determine the total amount of installed PRD orifice area , A_{total}^{prd}, including the area of the PRD being evaluated. Calculate the overpressure adjustment factor, , in accordance with equation (1.37) F_a

$$F_a = \sqrt{\frac{A^{prd}}{A_{total}^{prd}}} \qquad \text{equation (1.37)}$$

A^{prd} = is the orifice area of the PRD, mm2

A_{total}^{prd} = is the total installed orifice area of a multiple device installation,mm2

multiple PRD ? no

F_a = 1

STEP 4 Reduce the overpressures determined in step 3 by the overpressure adjustment factor accordance with equation (1.38)

$$P_{o,j} = F_a \,.\, P_{o,j} \qquad \text{equation (1.38)}$$

F_a = 1 see step 3

$P_{0,fire}$	=	7092.0		$P_{o,overfilling}$	=	7092.0	
$P_{0,fire}$	=	7092.0 x	1	$P_{o,overfilling}$	=	7092.0 x	1
	=	7092.0 psig			=	7092.0 psig	

STEP 5 for each overpressure demand case, calculate the financial consequence ,....., C_{rel}^{prd} of loss containment from protected equipment using procedures developed in part 3. use the overpressure for demand cases as determine in STEP 4 in lieu of the operating pressure, P_s

STEP 1 Determine the Representative Fluid and Associated Properties

Fluid Properties

Sifat-sifat fluida yang dibutuhkan yang diperkirakan untuk masing-masing fluida representatif disediakan dalam Tabel 4.2 API 581 Bagian 3 COF dan tergantung pada fase simpanan fluida di bawah ini:

A). Stored Liquid	
1. Normal Boiling Point	(NBP)
2. Density	(ρt)
3. Auto-iIgnition Temperature	(AIT)
B). Stored Vapor or Gas	
1. Normal Boiling Point	(NBP)
2. Morcular Weight	(MW)
3. Ideal Gas Specific Heat Capacity Ratio	(k)
4. Constant Pressure Specific Heat	(Cp)
5. Auto-iIgnition Temperature	(AIT)

STEP 1.1 Select Representative fluid group Table 4.1

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

Fluid Composition Table

Well	Composition	Symbol	Amount	Unit
	Nitrogen	N_2	0	% mole
	Carbon Dioxide	CO_2	0.23	% mole
	Methane	CH_4	85.82	% mole
	Ethane	C_2H_6	1.35	% mole
	Propane	C_3H_8	5.74	% mole
`	i-Butane	i-C_4H_{10}	1.51	% mole
	n-Butane	n-C_4H_{10}	1.78	% mole
	i-Pentane	i-C_5H_{12}	3.52	% mole
	n-Pentane	n-C_5H_{12}	0.03	% mole
	Hexane Plus	C_6^+	0.02	% mole
	TOTAL		100.000	% mole

Chosen Representative Fluid : C1-C2

STEP 1.2 Determine the store fluid phase, liquid or vapor, if two phase , a level 2 consequence analysis should be performed

Stored fluid phase : Gas

Step 1.3 Determine the stored fluid properties

For a stored liquid

MW – Molecular weight, kg/kg-mol (lb/lb-mol), can be estimated from Table 4.2

k – Ideal gas specific heat ratio, can be estimated using Equation (3.1) and the C P values as determined using Table 4.2

AIT – Auto-ignition temperature, K (°R), can be estimated from Table 4.2

Table 4.2 - Properties of the Representative Fluids Used in Level 1 Consequence Analysis

Fluid	MW	Liquid Density (lb/ft^3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	CP				Auto ignition Temperature (°F)
						Ideal Gas Constant A	Ideal Gas Constant B	Ideal Gas Constant C	Ideal Gas Constant D	
C1-C2	23	15.64	-193	Gas	Note 1	12.3	1.15E-01	-2.87E-03	-1.30E-09	1036
C2-C3	51	33.61	-6.3	Gas	Note 1	2.632	0.3188	-1.35E-04	1.47E-08	696
C25+	422	56.19	981	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	396

1). Molecular Weight (MW), kg/kg-mol (lb/lb-mol)

The stored vapor Molecular Weight (MW) can be estimated from Table 4.2

MW = 23.00 (kg/kg-mol)

2). Auto-Ignition Temperature, K (^{o}R)

The stored liquid Auto-Ignition Temperature (AIT) can be estimated from Table 4.2 of API 581 Part 3 of COF.

AIT = 1036 (^{o}F)

AIT = 830.927778 (K)

AIT = 446.222222 (^{o}R)

3). Ideal gas specific heat ratio, k

Cp_A = 12.3 J/kmol-K

Cp_B = 1.15E-01 J/kmol-K

Cp_C = -2.87E-03 J/kmol-K

Cp_D = -1.30E-09 J/kmol-K

T = 72.9 C
T = 163.22 F
T = 346.05 K
R = 8.314 J/kg-mol-K

Cp $= A + BT + CT^2 + DT^3$ ..... equation (19)

= 12.3 + (0.015 x 344.15) + (-0.0000287 x 344.15)^2 + (-1.3^{-9} x 344.15)^3

= 53.0821237 J/kmol-K

k = $\frac{Cp}{Cp - R}$ ..... equation (20)

= $\frac{53.082}{53.082 - 8.314}$

= 1.1857125

STEP 1.4 Determine the steady state phase of the fluid after release to the atmosphere, using Table 4.3 and the phase of the fluid stored in the equipment as determine in STEP 1.2.

Table 4.3 - Level 1 Guidelines for Determining the phase of a fluid

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (After release) Condition	Determine of Final Phase for Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	model as gas usless the fluid boilling point at ambient condiitions is greater than 80 F , than model as liquid
Liquid	Liquid	Model as Liquid

The fluid is Gas in the vessel, its post release is Gas

STEP 2 Release Hole Size Selection

STEP 2.1 Based on component type and table 4.4, determine the release hole size diameters, d_n.

Table 4.4 - Release Hole Sizes and Areas Used in Level 1 and 2 Consequences Analysis

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

STEP 2.2 Determine the failure frequency, gff_n, for the nth release hole size from part 2, table 3.1, and the total generic failure frequency from this table or from equation (3.2)

$$gff_{total} = \sum_{n=1}^{4} gff_n \qquad (3.2)$$

Table 3.1 part 2, suggested component generic failure frequencies

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

Diameter = 300 mm = 11.82 inci

gff_{total} = 8.00E-06 failures/year

gff_{small} = 2.00E-05 failures/year

gff_{medium} = 2.00E-05 failures/year

gff_{large} = 6.00E-07 failures/year

$gff_{rupture}$ = 3.06E-05 failures/year

STEP 3 Release Rate Calculation

There are two regimes for flow gases through an orifice: aonic (choked) for higher internal pressure, and subssonic flow for lower pressure (nominally 15 psig (103.4 kPa) or less). The transition pressure at which the flow regime changes from sonic to subsonic is determined using below equation.

P_{atm} = 14.69 psi

k = 1.1857

$$P_{trans} = P_{atm}\left(\frac{k+1}{2}\right)^{\frac{k}{k-1}} \quad \text{..... equation (21)}$$

$$P_{trans} = 14.69\left(\frac{1.1857+1}{2}\right)^{\frac{1.1857}{0.1857}}$$

= 18.0034792 psi

STEP 3.1 Select the appropriate release rate equation

$$W_n = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad \text{..... equation 22)}$$

Abbreviation list :

C_d = Discharge coefficient, for turbulent liquid flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$

= 0.9

A_n = Release hole sized area

P_s	=	Storage operating pressure	=	7092	psi
P_{atm}	=	Atmosphere pressure	=	14.69	psi
k	=	Ideal gas specific heat capacity ratio	=	1.1857	
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	72.9	C
			=	163.22	F
			=	346.05	K

STEP 3.2 For every release hole size, calculate the release hole size area based on d_n

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 - 1/4	d_1 = 0.25
2	Medium	> 1/4 - 2	d_2 = 1
3	Large	> 2 - 6	d_3 = 4
4	Rupture	. 6	d_4 = min[D,16]

The release hole size area can be determined by formulating below equation:

$$An = \frac{\pi dn^2}{4} \quad \text{.....} \quad \text{equation (22)}$$

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

= 0.0064 m

π = 3.14

$$A1 = \frac{\pi d1^2}{4}$$

$$= \frac{3.14\ x\ (0.25)^2}{4}$$

= 0.0491 $inch^2$

= 3E-05 m^2

2). MEDIUM RELEASE HOLE SIZE AREA

d_1 = 1 inch

= 0.0254 m

π = 3.14

$$A2 = \frac{\pi d2^2}{4}$$

$$= \frac{3.14\ x\ (1)^2}{4}$$

= 0.785 $inch^2$

= 0.0005 m^2

3). LARGE RELEASE HOLE SIZE AREA

d_1 = 4 inch

= 0.1016 m

π = 3.14

$$A3 = \frac{\pi d3^2}{4}$$

= 12.56 $inch^2$

= 0.0081 m^2

4). RUPTURE RELEASE HOLE SIZE AREA

d_1 = 16 inch

= 0.4064 m

π = 3.14

$$A4 = \frac{\pi d4^2}{4}$$

$$= \frac{3.14\ x\ (16)^2}{4}$$

= 200.96 $inch^2$

= 0.1296 m^2

STEP 3.3 For liquid releases, for each release hole size, calculate the viscosity correction factor ($K_{v,n}$)

$$K_{v,n} = \left(0.9935 + \frac{2.878}{Ren^{0.5}} + \frac{342.75}{Ren^{1.5}}\right)^{-1} \quad \text{.....} \quad \text{equation (23)}$$

Because the store fluid phase determined in STEP 1.2 is gaseous or vapor phase, then, this step is no neeed to be considered.

STEP 3.4 For each hole size, calculate the release rate, W_n, for each release area A_n

$$W_n = \frac{Cd}{C2}\ x\ An\ \text{x Ps}\ \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Abbreviation List:

C_d = 0.9

k = 1.1857125

ρl = 250.51 kg/m^3

= 2.5051E-07 kg/mm^3

A_1 = 3.1645E-05 m^2

A_2 = 0.00050645 m^2

A_3 = 0.00810321 m^2

A_4	=	0.1296192	m^2
gc	=	1	kgm/Ns^2
	=	32.2	$lb_m ft/lb_f S^2$
Ps	=	48899.34	Kpa
P_{atm}	=	101.288	KPa
C_2	=	1	
R	=	8.314	J/(kg-mol-K)
g_c	=	9.8	m/s^2
T_s	=	346.05	K
MW	=	23.00	(kg/kg-mol)

1). SMALL RELEASE HOLE SIZE AREA

$$W_1 = \frac{Cd}{C2} x\ A1 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_1 = \frac{0.9}{C2} x\ 0.000031645 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 0.25171927 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$W_2 = \frac{Cd}{C2} x\ A2 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_2 = \frac{0.9}{C2} x\ 0.000506451 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 4.02850732 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$W_3 = \frac{Cd}{C2} x\ A3 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_3 = \frac{0.9}{C2} x\ 0.00810321 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 20.5897514 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$W_4 = \frac{Cd}{C2} x\ A4 \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_4 = \frac{0.9}{C2} x\ 0.1296192 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 1031.04211 kg/s

STEP 4 Estimate the Fluid Inventory Available for Release

STEP 4.1 Group Component and equipment items into inventory groups (see annex 3.A)

only one component is given, and total inventory for the group

STEP 4.2 Calculate the fluid mass ,$mass_{comp}$, in the component being evaluated

ID	=	0.30	m
V_{tot}	=	7.065	m^3
	=	249.49812	ft^3
ρ_{gas}	=	61.13	kg/m^3
	=	3.8162212	lb/ft^3
L	=	100	m
$Mass_{comp}$	=	431.88345	kg

STEP 4.3 Calculate the fluid mass in each of the other components that are included in the inventory group, $mass_{comp,i}$

There are no other component, only an inventory group mass

STEP 4.4 Calculate the fluid mass in the inventory group, $mass_{inv}$, using equation (3.9)

$$mass_{inv} = \sum_{i=1}^{n} mass_{comp,i}$$

Where

$Mass_{comp}$ = is the inventory fluid mass for the component or piece of equipment being evaluated, kgs [lbs]

$Mass_{inv}$ = is the inventory group fluid mass, kgs [lbs]

= 431.8835 kg

STEP 4.5

Calculate the flow rate from a 203mm (8 inch) diameter hole, W_{max8}, using equation (3.3),(3.6)or (3.7) , as aplicable ,with A_n ,A8=32450 mm2 (50.3 inch2). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Where

C_d	=	Discharge coefficient, for turbulent gas flow from the sharp-edge orifices in the range of $0.85 \le C_d \le 1.00$	=	0.9	
A_n	=	Release hole sized area	=	5.1031	$inch^2$
			=	129619	mm^2
			=	0.1296	m^2
P_s	=	Storage operating pressure	=	7092	psi
			=	48899	Kpa
P_{atm}	=	Atmosphere pressure	=	14.69	psi
			=	101.29	Kpa
MW	=	Molecular weight	=	23.00	(kg/kg-mol)
g_c	=	Gravitational constant	=	9.8	m/s^2
R	=	Universal gas constant	=	8.314	J/(kg-mol-K)
T_s	=	Storage or normal operating temperatur	=	72.9	C
			=	163.22	F
			=	346.05	K
C_2	=	SI and US customary conversion factors	=	1	
k	=	Ideal gas specific heat ratio	=	1.1857	

So,

$$W_{max8} = \frac{Cd}{C2}\ x\ An \text{ x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_{max8} = \frac{0.9}{1}\ x\ 0.1296 \text{ x } 48899.3 \sqrt{\left(\frac{1.1857\ x\ 23\ x\ 9.8}{8.314\ x\ 346.05}\right)\left(\frac{2}{1.1857+1}\right)^{\frac{1.1857+1}{1.1857-1}}}$$

= 1031.04211 kg/s

STEP 4.6 For each release hole size, calculate the added fluid mass, $mass_{add,n}$, resulting from 3 (three) minutes of flow from the inventory group using equation (3.10) where Wn is the leakage rate for the release hole size being evaluated and $W_{max8,}$ is from step 4.5

$$mass_{add,n} = 180.\min\left[W_n, W_{\max 8}\right] \quad (3.10)$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[\text{W}_1 \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 1}} = 180 \,.\, min[0.2517, 1031.04\,]$$

$$= \quad 45.309 \text{ kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add n}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 2}} = 180 \,.\, min[4.0285, 1031.04\,]$$

$$= \quad 725.13 \text{ kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 3}} = 180 \,.\, min\,[20.5898, 1031.04\,]$$

$$= \quad 3706.2 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[\text{W}_n \,, \text{W}_{\text{max8}}\,]$$

$$\text{Mass}_{\text{add 4}} = 180 \,.\, min[1031.04, 1031.04\,]$$

$$= \quad 185588 \text{ kgs}$$

STEP 4.7 For each release hole size, calculate the available mass for release using equation (3.11)

$$mass_{avail,n} = \min\left[\{mass_{comp} + \ mass_{add,n}\}, mass_{inv}\right]$$

1). SMALL RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\,\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 1} = min\,.\,[\{431.883 + 45.31\,\}, 431.883\,]$$

$$= \quad 431.883 \quad \text{kgs}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$\text{Mass}_{avail\ n} = min\,.\,[\{\text{Mass}_{\text{comp}} + \text{Mass}_{\text{add,n}}\,\}, \text{Mass}_{\text{inv}}\,]$$

$$\text{Mass}_{avail\ 2} = min\,.\,[\{431.883 + 725.1\,\}, 431.883\,]$$

$$= \quad 431.883 \quad \text{kgs}$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 3} = min.[\{431.883 + 3706\}, 431.883]$$

$$= 431.883 \text{ kgs}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$$

$$Mass_{avail\ 4} = min.[\{431.883 + 2E+05\}, 431.883]$$

$$= 431.883 \text{ kgs}$$

STEP 5 Determine the release type (continues or instantaneous)

STEP 5.1 For each release hole size, calculate the time required to release 4536kgs (10000 lbs) of fluid

$$t_n = \frac{C3}{W_n} \quad \text{.....} \quad \text{equation (24)}$$

Where

t_n = time required to release 4536 kgs (10000 lbs) of fluid

C_3 = SI and US customary conversion factors

= 4536 kgs

= 10000 lbs

W_n = Theoretical release rate associated with the nth release hole size, kg/s [lb/s]

W_1 = 0.252 kg/s

W_2 = 4.029 kg/s

W_3 = 20.590 kg/s

W_4 = 1031.042 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_1 = \frac{4536}{0.252}$$

= 18020.0748 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_2 = \frac{4536}{4.029}$$

= 1125.97536 s

3). LARGE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_3 = \frac{4536}{20.590}$$

= 220.303777 s

4). RUPTURE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_4 = \frac{4536}{1031.042}$$

= 4.39943233 s

STEP 5.2 Determine the release type for each release hole size

For each release hole size, determine the release type either instataneous or continous using this following criteria:

a. If the release hole size is 6.35 mm(0.25 inch) or less, then the release type is continous

b. If t_n<180 sec and the releaase mass is gretaer than 4536 kgs (100000 lbs), then the release is instataneous: otherwise the release is continous

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 18020 s (Continous)

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1126 s (Continous)

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 220.3 s (Continous)

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.3994 s (Instataneous)

STEP6 Estimate The Impact of Detection and Isolation Systems on Release Magnitude

STEP 6.1 Determine the detection and isolation systems presents in the unit

STEP 6.2 Using table 4.5, select the appropriate classification (A,B,C) for the detection system.

Table 4.5 - Detection and Isolation system rating Guide

Type of Detection System	Detection Clssification
Instrumentation designed specifically to detect material losses by changes In operating conditions (i.e., loss of pressure or flow) in the system.	A
Suitable located detectors to determine when the material is present outside the pressure-containing envelope	B
Visual detection, cameras, or detectors with marginal coverage	C
Type of Isolation Sytem	**Isolation Classification**
Isolation or shutdown system activated directly process instrumentation or detection, with no operator intervention	A
Isolation or shutdown system activated by operators in the control room or other suitable locations remote from the leak	B
isolation dependent on manually-operated valves	C

Detection Is A

STEP 6.3 Using table 4.5, select the appropriate classification (a,b,c) for the isolation system

Isolation Is A

STEP 6.4 Determine the release reduction factor factdi using Table 4.6

Table 4.6 - Adjustment to Release Based on Detection and Isolation Systems

System Classification		Release Magnitude Adjustment	duction Factor, *fac*
Detection	Isolation		
A	A	Reduce release rate or mass by 25%	0.25
A	B	Reduce release rate or mass by 20%	0.20
A or B	C	Reduce release rate or mass by 10%	0.10
B	B	Reduce release rate or mass by 15%	0.15
C	C	No adjustment to release rate or mass	0.00

Release Magnitude Adjustment	=	Reduce release rate or mass by 25%
Reduction Factor, $fact_{di}$	=	**0.25**

STEP 6.5 Determine the total leak durations for each release hole sizes using Table 4.7

Table 4.7 - Leak Durations Based on detection and Isolation Systems

Detection System Rating	Isolation System Rating	Maximum Leak Duration, ld_{max}
A	A	20 minutes for 1/4 inch leaks
		10 minutes for 1 inch leaks
		5 minutes for 4 inch leaks
A	B	30 minutes for 1/4 inch leaks
		20 minutes for 1 inch leaks
		10 minutes for 4 inch leaks
A	C	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	A or B	40 minutes for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
B	C	1 hour for 1/4 inch leaks
		30 minutes for 1 inch leaks
		20 minutes for 4 inch leaks
C	A, B, or C	1 hour for 1/4 inch leaks
		40 minutes for 1 inch leaks
		20 minutes for 4 inch leaks

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0.25 inch

t_1 = 18020 s (Continous)

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 1126 s (Continous)

$ld_{max,2}$ = 10 minutes for 1 inch leaks

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 220.3 s (Continous)

$ld_{max,3}$ = 5 minutes for 4 inch leaks

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 4.3994 s (Instataneous)

$ld_{max,4}$ = 5 minutes for 4 inch leaks

STEP7 Determine The Release Rate And Mass For Consequence of Failure

STEP 7.1 Calculate the adjusted release rate, raten for each release hole size

Reduction Factor, $fact_{di}$ = 0.25

W_1 = 0.252 kg/s

W_2 = 4.029 kg/s

W_3 = 20.590 kg/s

W_4 = 1031.042 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$Rate_1 = W_n\,(1 - fact_{di})$$

$$Rate_1 = 0.252\,(1 - 0.25)$$

= 0.1888 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$Rate_2 = W_n\,(1 - fact_{di})$$

$$Rate_2 = 4.029\,(1 - 0.25)$$

= 3.0214 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$Rate_3 = W_n\,(1 - fact_{di})$$

$$Rate_3 = 20.590\,(1 - 0.25)$$

= 15.442 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$Rate_4 = W_n\,(1 - fact_{di})$$

$$Rate_4 = 1031.042\,(1 - 0.25)$$

= 773.28 kg/s

STEP7.2 Calculate the leak duration, ldn, for each release hole size

$$ld_n = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\,.\,ld_{max,n}\}] \quad \text{.....} \quad \text{equation (25)}$$

$ld_{max,1}$	=	20 minutes for 1/4 inch leaks	20	$Mass_{avail,1}$	=	431.88	kgs
$ld_{max,2}$	=	10 minutes for 1 inch leaks	10	$Mass_{avail,2}$	=	431.88	kgs
$ld_{max,3}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,3}$	=	431.88	kgs
$ld_{max,4}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,4}$	=	431.88	kgs

1). SMALL RELEASE HOLE SIZE AREA

$$ld_1 = min\,.\,[\{\frac{Mass_{avail,1}}{Rate_1}\},\{60\,.\,ld_{max,1}\}]$$

$$ld_1 = min\,.\,[\{\frac{431.883}{0.189}\},\{60\,.\,20\}]$$

= 1200 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2 = min\,.\,[\{\frac{Mass_{avail,2}}{Rate_2}\},\{60\,.\,ld_{max,2}\}]$$

$$ld_2 = min\,.\,[\{\frac{431.883}{3.021}\},\{60\,.\,10\}]$$

= 142.94 s

3). LARGE RELEASE HOLE SIZE AREA

$$ld_3 = min\ .\ [\{\frac{Mass_{avail,3}}{Rate_3}\},\{60\ .\ ld_{max,3}\}]$$

$$ld_3 = min\ .\ [\{\frac{431.883}{15.44}\},\{60\ .\ 5\}]$$

$$= \quad 27.968\ s$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$ld_4 = min\ .\ [\{\frac{Mass_{avail,4}}{Rate_4}\},\{60\ .\ ld_{max,4}\}]$$

$$ld_4 = min\ .\ [\{\frac{431.883}{773.3}\},\{60\ .\ 5\}]$$

$$= \quad 0.5585\ s$$

STEP 7.3 Calculate the release mass, $mass_n$, for each release hole size

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_1 = min\ .\ [\{Rate_1\ .\ ld_1\},Mass_{avail,n}]$$

$$Mass_1 = min\ .\ [\{0.189\ .\ 1200\},431.883]$$

$$= \quad 226.547339\ kgs$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$Mass_2 = min\ .\ [\{Rate_2\ .\ ld_2\},Mass_{avail,n}]$$

$$Mass_2 = min\ .\ [\{3.021\ .\ 142.9\},431.883]$$

$$= \quad 431.88345\ kgs$$

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_3 = min\ .\ [\{Rate_3\ .\ ld_3\},Mass_{avail,n}]$$

$$Mass_3 = min\ .\ [\{15.44\ .\ 27.97\},431.883]$$

$$= \quad 431.88345\ kgs$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_4 = min\ .\ [\{Rate_4\ .\ ld_4\},Mass_{avail,n}]$$

$$Mass_4 = min\ .\ [\{773.3\ .\ 0.559\},431.883]$$

$$= \quad 431.88345\ kgs$$

PART 8 : DETERMINE FLAMMABLE AND EXPLOSIVE CONSEQUENCE

8.1 CONSEQUENCE AREA EQUATIONS

1). CONTINOUS RELEASE

$CA_n^{CONT} = \alpha(rate_n)^b$ ..... equation (26)

2). INSTATANEOUS RELEASE

$CA_n^{CONT} = \alpha(mass_n)^b$ ..... equation (27)

STEP 8.1 Select the consequence area mitigation reduction factor, $fact_{mit}$, from Table 4.10

Mitigation System	Consequence Area Adjustemnet	Consequence Area Reduction Factor, factor mit
Inventory blowdown , couple with isolation system classification B or higher	Reduce consequence area by 25%	0.25
Fire water deluge system and monitors	Reduce consequence area by 20%	0.2
Fire water monitor only	Reduce consequence area by 5%	0.05
Foam spray system	Reduce consequence area by 15%	0.15

Mitigation system = Inventory blowdown , couple with isolation system classification B or higher *

Consequence Area = Reducer consequence area by 25 % *

$fact_{mit}$ = 0.25

STEP 8.2 Calculate the energy efficiency, $eneff_n$, for each hole size using equation mentioned below.

C_4 = 2205 1/kg

$eneff_n = 4.log_{10}[C_4 . mass_n] - 15$ ..... equation (28)

$Mass_1$ = 226.547 kgs

$Mass_2$ = 431.883 kgs

$Mass_3$ = 431.883 kgs

$Mass_4$ = 431.883 kgs

1. SMALL RELEASE HOLE SIZE AREA

$eneff_1 = 4 . log_{10} [C_{4A} . mass_1] - 15$

$eneff_1 = 4 . log_{10} [2205 . 226.547] - 15$

$eneff_1 = 7.794270$

2. MEDIUM RELEASE HOLE SIZE AREA

$$eneff_2 = 4 . log_{10} [C_{4A} . mass_2] - 15$$
$$eneff_2 = 4 . log_{10} [2205 . 431.883] - 15$$
$$eneff_2 = 8.915101$$

3. LARGE RELEASE HOLE SIZE AREA

$$eneff_3 = 4 . log_{10} [C_{4A} . mass_3] - 15$$
$$eneff_3 = 4 . log_{10} [2205 . 431.883] - 15$$
$$eneff_3 = 8.915101$$

4. RUPTURE RELEASE HOLE SIZE AREA

$$eneff_4 = 4 . log_{10} [C_{4A} . mass_4] - 15$$
$$eneff_4 = 4 . log_{10} [2205 . 431.883] - 15$$
$$eneff_4 = 8.91510$$

STEP 8.3 Determine the fluid type

Determine the fluid type, either TYPE 0 or TYPE 1 based on Table 4.1 of API RP 581 Part 3 of COF.

Table 4.1- List of Representative Fluid Available for level 1 Analysis

Representative Fluid	Fluid Type (see 4.1.5)	Example of Aplicable Material
C1-C2	TYPE 0	Methane,Ethan,Ethylane,LNG,Fuel gas
C3-C4	TYPE 0	Propan,Butane,Isobitane,LPG
C25+	TYPE 0	Residum, Heavy Crude, Lube Oil, Seal Oil

C_1-C_2	=	TYPE 0	AIT	=	446.222222 (^oR)
MW	=	23 (kg/kg-mol)	T	=	72.9 (^oC)
AIT	=	1036 (^oF)	T	=	163.22 (^oF)
AIT	=	830.927778 (K)	T	=	346.05 (K)

STEP 8.4 For each release hole size, calculate the component damage consequence areas for Auto-Ignition Not Likely, Continous Release (AINT-CONT), $CA^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

Table 4.8 - Component Damage Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	8.7	0.98			55	0.95			6.5	0.67			164	0.62		
C3-C4	10.1	1.0			64	1.0			4.7	0.7			80	0.63		

$\alpha = \alpha_{cmd,n}^{AINL-CONT} =$ 8.7 b $= b_{cmd}^{AINL-CONT} =$ 0.98

2). Calculate the consequence of area using equation below

$Rate_1$ = 0.189 kg/s

$Rate_2$ = 3.0210 kg/s

$Rate_3$ = 15.4400 kg/s

Rate4 = 773.30 kg/s

$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b . (1 - fact_{mit})$ ..... equation (29)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AINL-CONT} = \alpha(rate_1)^b . (1 - fact_{mit})$

= 1.275 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AINL-CONT} = \alpha(rate_n)^b . (1 - fact_{mit})$

= 19.281 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-CONT} = \alpha(rate_n)^b . (1 - fact_{mit})$

= 95.379 m^2

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-CONT} = \alpha\,(rate_4)^b . (1 - fact_{mit})$

= 4417 m^2

STEP 8.5 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Continous Release (AIL-CONT), $CA^{AIL\text{-}CONT}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-CONT} =$ 55.0 b $= b_{cmd}^{AIL-CONT} =$ 0.95

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$ ..... equation (30)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 8.4735\ m^2$

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 117.91\ m^2$

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-CONT} = \alpha(rate_n)^b \cdot (1 - fact_{mit})$

$= 555.44\ m^2$

D. RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-CONT} = \alpha\,(rate_4)^b \cdot (1 - fact_{mit})$

$= 22875\ m^2$

STEP 8.6 For each release hole size, calculate the component damage consequence areas for Auto-ignition Not Likely, Instaneous Release, (AINL-INST), $CA^{AINL\text{-}INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AINL-INST} =$ 6.5 b $= b_{cmd}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right)$ ..... equation (31)

From step 7, know that :

$Mass_1$	=	226.547	kgs	$eneff_1$	=	7.794
$Mass_2$	=	431.883	kgs	$eneff_2$	=	8.915
$Mass_3$	=	431.883	kgs	$eneff_3$	=	8.915
$Mass_4$	=	431.883	kgs	$eneff_4$	=	8.915

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha\,(mass_1)^b.\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 6{,}469\,(226.547)^{0{,}67}.\left(\frac{1-0{,}25}{7.794}\right)$$

$$CA_{cmd,1}^{AINL-INST} = 23.67\ m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha\,(mass_2)^b.\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 6{,}469(431.883)^{0{,}67}.\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{cmd,2}^{AINL-INST} = 31.88\ m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha\,(mass_3)^b.\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 6{,}469\,(431.883)^{0{,}67}.\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{cmd,3}^{AINL-INST} = 31.88\ m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-INST} = \alpha\,(mass_4)^b.\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 6{,}469\,(431.883)^{0{,}67}.\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{cmd,4}^{AINL-INST} = 31.88\ m^2$$

STEP 8.7 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Instataneous Release (AIL-INST), $CA^{AIL-INST}$

1). Determine the appropriate constant a and b from the Table 4.8

$\alpha = \alpha_{cmd,n}^{AIL-INST} =$ 164.0 b = $b_{cmd}^{AIL-INST} =$ 0.62

2). Calculate the consequence of area using equation below

$$CA_{cmd,n}^{AIL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{.....} \quad \text{equation (32)}$$

From step 7, know that :

$Mass_1$	=	226.547	kgs	$eneff_1$	=	7.794
$Mass_2$	=	431.883	kgs	$eneff_2$	=	8.915
$Mass_3$	=	431.883	kgs	$eneff_3$	=	8.915
$Mass_4$	=	431.883	kgs	$eneff_4$	=	8.915

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AIL-INST} = \alpha\,(mass_1)^b \cdot \left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 164\,(226.547)^{0,62} \cdot \left(\frac{1-0,25}{7.794}\right)$$

$$CA_{cmd,1}^{AIL-INST} = 455.33 \text{ m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AIL-INST} = \alpha\,(mass_2)^b \cdot \left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 164\,(431.883)^{0,62} \cdot \left(\frac{1-0,25}{8.915}\right)$$

$$CA_{cmd,2}^{AIL-INST} = 593.89 \text{ m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AIL-INST} = \alpha\,(mass_3)^b \cdot \left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 164\,(431.883)^{0,62} \cdot \left(\frac{1-0,25}{8.915}\right)$$

$$CA_{cmd,3}^{AIL-INST} = 593.89 \text{ m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AIL-INST} = \alpha\,(mass_4)^b \cdot \left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 164\,(431.883)^{0,62} \cdot \left(\frac{1-0,25}{8.915}\right)$$

$$CA_{cmd,4}^{AIL-INST} = 593.89 \text{ m}^2$$

STEP 8.8 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Continous Release (AINL-CONT), $CA_{inj,n}^{AINL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

Table 4.9 - Personnel Injury Flammable Consequence Equation Constants

Fluid	Continuous Release Constant								Instantaneous Release Constant							
	Auto Ignition Not Likely (CAINL)				Auto Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	α	b	α	b	α	b	α	b	α	b	α	b	α	b	α	b
C1-C2	21.8	1.00			143	0.92			12.5	0.67			474	0.63		
C3-C4	25.6	1.0			171	1.0			9.7	0.7			270	0.63		

$\alpha = \alpha_{inj,n}^{AINL-CONT} =$ **21.8** $\quad b = b_{inj,n}^{AINL-CONT} =$ **1.00**

2). Calculate the consequence of area using equation below

$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1 - fact_{mit})$ ….. equation (33)

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-CONT} = \left[\alpha.\left(rate_1^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 3.0944 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-CONT} = \left[\alpha.\left(rate_2^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 49.461 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-CONT} = \left[\alpha.\left(rate_3^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 252.79 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-CONT} = \left[\alpha.\left(rate_4^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 12661 \text{ m}^2$$

STEP 8.9 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Continous Release (AIL-CONT), $CA_{inj,n}^{AIL-CONT}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-CONT} =$ 143.2 b $= b_{inj,n}^{AIL-CONT} =$ 0.92

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1 - fact_{mit}) \quad \text{..... equation (34)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-CONT} = \left[\alpha.\left(rate_1^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 23.193 \text{ m}^2$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-CONT} = \left[\alpha.\left(rate_2^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 296.99 \text{ m}^2$$

C). LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-CONT} = \left[\alpha.\left(rate_3^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 1332.2 \text{ m}^2$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-CONT} = \left[\alpha.\left(rate_4^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

$$= 48785 \text{ m}^2$$

STEP 8.10 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Not Likely, Instataneous Release (AINL-INST), $CA_{inj,n}^{AINL-INST}$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AINL-INST} =$ 12.5 b $= b_{inj,n}^{AINL-INST} =$ 0.67

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (35)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-INST} = \left[a.\left(mass_1^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AINL-INST} = [12{,}46\ (226.547)^{0{,}67}].\left(\frac{1-0{,}25}{7.794}\right)$$

$$CA_{inj,1}^{AINL-INST} = 45.37\ \text{m}^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-INST} = \left[a.\left(mass_2^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AINL-INST} = [12{,}46\ .(431.883)^{0{,}67}].\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{inj,2}^{AINL-INST} = 61.12\ \text{m}^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-INST} = \left[a.\left(mass_3^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AINL-INST} = [12{,}46\ .(431.883)^{0{,}67}].\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{inj,3}^{AINL-INST} = 61.12\ \text{m}^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-INST} = \left[a.\left(mass_4^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AINL-INST} = [12{,}46\ .(431.883)^{0{,}67}].\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{inj,4}^{AINL-INST} = 61.12\ \text{m}^2$$

STEP 8.11 For each release hole size, calculate the personnel injury consequence areas for Auto-ignition Likely, Instataneous Release (AIL-INST),

$$CA_{inj,n}^{AIL-INST}$$

1). Determine the appropriate constant a and b from the Table 4.9 from API RP 581 Part 3. The release phas as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

$\alpha = \alpha_{inj,n}^{AIL-INST} =$ 473.9 b $= b_{inj,n}^{AIL-INST} =$ 0.63

2). Calculate the consequence of area using equation below

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad \text{..... equation (36)}$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-INST} = \left[a.\left(mass_1^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

$$CA_{inj,1}^{AIL-INST} = [473{,}9.(226.547)^{0{,}63}].\left(\frac{1-0{,}25}{7.794}\right)$$

$$CA_{inj,1}^{AIL-INST} = 1389.07 \quad m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-INST} = \left[a.\left(mass_2^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

$$CA_{inj,2}^{AIL-INST} = [473{,}9.(431.883)^{0{,}63}].\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{inj,2}^{AIL-INST} = 1823.49 \quad m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-INST} = \left[a.\left(mass_3^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

$$CA_{inj,3}^{AIL-INST} = [473{,}9.(431.883)^{0{,}63}].\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{inj,3}^{AIL-INST} = 1823.49 \quad m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-INST} = \left[a.\left(mass_4^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

$$CA_{inj,4}^{AIL-INST} = [473{,}9.(431.883)^{0{,}63}].\left(\frac{1-0{,}25}{8.915}\right)$$

$$CA_{inj,4}^{AIL-INST} = 1823.49 \quad m^2$$

8.12 STEP 8.12 For each release hole size, calculate the instataneous / continous blending factor, factn^{IC}.

1). FOR CONTINOUS RELEASE

$C_5 = 25.2$ kg/s

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad \text{.....equation (37)}$$

A). SMALL RELEASE HOLE SIZE AREA

$$fact_1^{IC} = \min\left[\left\{\frac{rate_1}{C_5}\right\}, 1.0\right]$$
$$= 0.0075$$

B). MEDIUM RELEASE HOLE SIZE AREA

$$fact_2^{IC} = \min\left[\left\{\frac{rate_2}{C_5}\right\}, 1.0\right]$$
$$= 0.11988095$$

C). LARGE RELEASE HOLE SIZE AREA

$$fact_3^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$
$$= 0.61269841$$

D). RUPTURE RELEASE HOLE SIZE AREA

$$fact_4^{IC} = \min\left[\left\{\frac{rate_4}{C_5}\right\}, 1.0\right]$$
$$= 1$$

2). FOR INSTATANEOUS RELEASE

$$fact_4^{IC} = 1$$

8.13 Calculate the AIT blending factor, $fact^{AIT}$, using these optional equation below.

$$fact^{AIT} = 0 \quad \text{for } T_S + C_6 \leq AIT \quad \text{equation (38)}$$

$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2 \,.\, C_6} \quad \text{for } T_S + C_6 > AIT > T_S - C_6$$

$$fact^{AIT} = 1 \quad \text{for } T_S - C_6 \geq AIT \quad \text{equation (39)}$$

Ts = 72.9 (^{o}C)
Ts = 163.22 (^{o}F)
Ts = 346.05 (K)
C_6 = 55.6 (K)

AIT = 1036 (^{o}F)
AIT = 830.927778 (K)
AIT = 446.222222 (^{o}R)

$T_s + C_6$ = 401.65 (K)
$T_s - C_6$ = 290.45 (K)
$\frac{(T_s - AIT + C_6)}{2 \,.\, C_6}$ = -3.8604 (K)

$fact^{AIT}$ = 0

STEP 8.14 Calculate the continuous/instantaneous blended consequence area for the component using equation (3.53) through (3.56) based on the consequence areas calculated in previous steps $fact_n^{IC}$

A. Componen demage for auto-ignition Likely, Continous - Instataneous release

$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} . fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} . (1 - fact_n^{IC})$ equation (40)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL-INST}$ = 23.67 m^2
$fact_1^{IC}$ = 0.0075
$CA_{cmd,1}^{AIL-CONT}$ = 1.2750085 m^2
$CA_{cmd,1}^{AIL}$ = 1.4429535 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL-INST}$ = 31.88 m^2
$fact_2^{IC}$ = 0.119881
$CA_{cmd,2}^{AIL-CONT}$ = 19.280941 m^2
$CA_{cmd,2}^{AIL}$ = 20.791554 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL-INST}$ = 31.88 m^2
$fact_3^{IC}$ = 0.612698
$CA_{cmd,3}^{AIL-CONT}$ = 95.379461 m^2
$CA_{cmd,3}^{AIL}$ = 56.474596 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL-INST}$ = 31.88 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AIL-CONT}$ = 4417.35 m^2

$CA_{cmd,4}^{AIL}$ = 31.881883 m^2

B. Personal Injury for auto-ignition Likely, Continous - Instataneous release

$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} . fact_n^{IC} + CA_{inj,n}^{AIL-CONT} . (1 - fact_n^{IC})$.....equation (41)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AIL-INST}$ = 1389.07 m^2

$fact_{n1}^{IC}$ = 0.0075

$CA_{inj,1}^{AIL-CONT}$ = 23.192584 m^2

$CA_{inj,1}^{AIL}$ = 33.436629 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AIL-INST}$ = 1823.49 m^2

$fact_{n2}^{IC}$ = 0.1198810

$CA_{inj,2}^{AIL-CONT}$ = 296.99077 m^2

$CA_{inj,2}^{AIL}$ = 479.98858 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AIL-INST}$ = 1823.49 m^2

$fact_{n3}^{IC}$ = 0.6126984

$CA_{inj,3}^{AIL-CONT}$ = 1332.1704 m^2

$CA_{inj,3}^{AIL}$ = 1633.1993 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AIL-INST}$ = 1823.49 m^2

$fact_{n4}^{IC}$ = 1

$CA_{inj,4}^{AIL-CONT}$ = 48784.791 m^2

$CA_{inj,4}^{AIL}$ = 1823.4869 m^2

C. Componen demage for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST} . fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (42)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,n}^{AINL-INST}$ = 23.67 m^2

$fact_1^{IC}$ = 0.0075

$CA_{cmd,1}^{AINL-CONT}$ = 1.2750085 m^2

$CA_{cmd,1}^{AINL}$ = 1.4429535 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,n}^{AINL-INST}$ = 31.88 m^2

$fact_2^{IC}$ = 0.119881

$CA_{cmd,2}^{AINL-CONT}$ = 19.280941 m^2

$CA_{cmd,2}^{AINL}$ = 20.791554 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AINL-INST}$ = 31.88 m^2

$fact_3^{IC}$ = 0.6127

$CA_{cmd,3}^{AINL-CONT}$ = 95.379461 m^2

$CA_{cmd,3}^{AINL}$ = 56.474596 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AINL-INST}$ = 31.88 m^2

$fact_4^{IC}$ = 1

$CA_{cmd,4}^{AINL-CONT}$ = 4417.35 m^2

$CA_{cmd,4}^{AINL}$ = 31.881883 m^2

D. Personal Injury for auto-ignition Not Likely, Continous - Instataneous release

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} . fact_n^{IC} + CA_{inj,n}^{AINL-CONT} . (1 - fact_n^{IC})$$ equation (43)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{AINL-INST}$ = 45.37 m^2

$fact_1^{IC}$ = 0.0075

$CA_{inj,1}^{AINL-CONT}$ = 3.0944025 m^2

$CA_{inj,1}^{AINL}$ = 3.4114629 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{AINL-INST}$ = 61.12 m^2

$fact_2^{IC}$ = 0.119881

$CA_{inj,2}^{AINL-CONT}$ = 49.461323 m^2

$CA_{inj,2}^{AINL}$ = 50.858391 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{AINL-INST}$ = 61.12 m^2

$fact_3^{IC}$ = 0.6127

$CA_{inj,3}^{AINL-CONT}$ = 252.7914 m^2

$CA_{inj,3}^{AINL}$ = 135.35165 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{AINL-INST}$ = 61.12 m^2

$fact_4^{IC}$ = 1

$CA_{inj,4}^{AINL-CONT}$ = 12660.854 m^2

$CA_{inj,4}^{AINL}$ = 61.115118 m^2

STEP 8.15 Calculate the AIT blended consequence areas for the component using equations (3.57) and (3.58) based on the consequence areas determined in step 8.14 and the AIT blending factors, , calculate in step 8.13. the resulting consequence areas are the component damage and personnel injury flammable consequence areas, and for each release hole size selected in step 2.2

$CA_{cmd,n}^{flam}$ $CA_{inj,n}^{flam}$

A. Componen Demage

$CA_{cmd,n}^{flam} = CA_{smd,n}^{AIL} . fact^{AIT} + CA_{cmd,n}^{AINL} . (1 - fact^{AIT})$ .....equation (44)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{cmd,1}^{AIL}$ = 1.4429535 m^2

$fact^{AIT}$ = 0

$CA_{cmd,1}^{AINL}$ = 1.4429535 m^2

$CA_{cmd,1}^{flam}$ = 1.4429535 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{cmd,2}^{AIL}$ = 20.791554 m^2

$fact^{AIT}$ = 0

$CA_{cmd,2}^{AINL}$ = 20.791554 m^2

$CA_{cmd,2}^{flam}$ = 20.791554 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{cmd,3}^{AIL}$ = 56.474596 m^2

$fact^{AIT}$ = 0

$CA_{cmd,3}^{AINL}$ = 56.474596 m^2

$CA_{cmd,3}^{flam}$ = 56.474596 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{cmd,4}^{AIL}$ = 31.881883 m^2

$fact^{AIT}$ = 0

$CA_{cmd,4}^{AINL}$ = 31.881883 m^2

$CA_{cmd,4}^{flam}$ = 31.881883 m^2

B. Personal Injury

$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} . fact^{AIT} + CA_{inj,n}^{AINL} . (1 - fact^{AIT})$ …….. equation (45)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{flam-AIL}$ = 33.436629 m^2

$fact^{AIT}$ = 0

$CA_{inj,1}^{AINL}$ = 3.4114629 m^2

$CA_{inj,1}^{flam}$ = 3.4114629 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{flam-AIL}$ = 479.98858 m^2

$fact^{AIT}$ = 0

$CA_{inj,2}^{AINL}$ = 50.858391 m^2

$CA_{inj,2}^{flam}$ = 50.858391 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{flam-AIL}$ = 1633.1993 m^2

$fact^{AIT}$ = 0

$CA_{inj,3}^{AINL}$ = 135.35165 m^2

$CA_{inj,3}^{flam}$ = 135.35165 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{flam-AIL}$ = 1823.4869 m^2

$fact^{AIT}$ = 0

$CA_{inj,4}^{AINL}$ = 61.115118 m^2

$CA_{inj,4}^{flam}$ = 61.115118 m^2

STEP 8.16 Determine the consequence areas (probability weighted on release hole size) for component damage and personnel injury using equations (3.59) and (3.60) based on the consequence area from step 8.15

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

CONSEQUENCE AREA FOR COMPONENT DAMAGE

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad \text{.....(equation)}$$

$$CA_{cmd}^{flam} = \left(\frac{(gff_{1.}\, CA_{cmd,1}^{flam}) + (gff_{2.}\, CA_{cmd,2}^{flam}) + (gff_{3.}\, CA_{cmd,3}^{flam}) + (gff_{4.}\, CA_{cmd,4}^{flam})}{gff_{total}} \right)$$

$$= 51.50\ m^2$$

CONSEQUENCE AREA FOR PERSONNEL INJURY

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad \text{(equation 94)}$$

$$CA_{inj}^{flam} = \left(\frac{\left(gff_1 \cdot CA_{inj,1}^{flam}\right) + \left(gff_2 \cdot CA_{inj,2}^{flam}\right) + \left(gff_3 \cdot CA_{inj,3}^{flam}\right) + \left(gff_4 \cdot CA_{inj,4}^{flam}\right)}{gff_{total}} \right.$$

$$= \left. 123.796\ m^2 \right.$$

PART 9 : CALCULATE THE TOXIC CONSEQUENCES AREA

Table 4.113 Continuous Gas and Liquid Release Toxic Consequence Equation Constantsfor Miscellaneous Chemicals

Chemical	Release Duration (minutes)	Gas Release Constants		Liquid Release Constants	
		e	f	e	f
Aluminum Chloride (Alcl3)	ALL	17.663	0.9411	N/A	N/A
Carbon Monoxide (CO)	3	41.412	1.15	N/A	N/A
	5	279.79	1.06	N/A	N/A
	10	834.48	1.13	N/A	N/A
	20	2915.9	1.11	N/A	N/A
	40	5346.8	1.17	N/A	N/A
	60	6293.7	1.21	N/A	N/A
Hydrogen Chloride (HCL)	3	215.48	1.09	N/A	N/A
	5	536.28	1.15	N/A	N/A
	10	2397.5	1.1	N/A	N/A
	20	4027	1.18	N/A	N/A
	40	7534.5	1.2	N/A	N/A
	60	8625.1	1.23	N/A	N/A
Nitric Acid	3	53.013	1.25	5110	1.08
	5	68.7	1.25	9640.8	1.02
	10	96.325	1.24	12.453	1.06
	20	126.942	1.23	19.149	1.06
	40	146.941	1.22	31.145	1.06
	60	156.345	1.22	41.999	1.12
Nitrogen Dioxide (NO2)	3	6633.1	0.7	2132.9	0.98
	5	9221.4	0.68	2887	1.04
	10	11.965	0.68	6194.4	1.07
	20	14.248	0.72	13.843	1.08
	40	22.411	0.7	27.134	1.12
	60	24.994	0.71	41.657	1.13

Phosgene	3	12.902	1.2	3414.8	1.06
	5	22.976	1.29	6857.1	1.1
	10	48.985	1.24	21.215	1.12
	20	108.298	1.27	63.361	1.16
	40	244.67	1.3	178.841	1.2
	60	367.877	1.31	314.608	1.23
Toluene Diisocyanate (TDI)	3	N/A	N/A	3692.5	1.06
	5	N/A	N/A	3849.2	1.09
	10	N/A	N/A	4564.9	1.1
	20	N/A	N/A	4777.5	1.06
	40	N/A	N/A	4953.2	1.06
	60	N/A	N/A	5972.1	1.03
Ethylene Glycol Monoethyl Ether (EE)	1.5	3.819	1.171	N/A	N/A
	3	7.438	1.181	N/A	N/A
	5	17.735	1.122	N/A	N/A
	10	33.721	1.111	3.081	1.105
	20	122.68	0.971	16.877	1.065
	40	153.03	0.995	43.292	1.132
	60	315.57	0.899	105.74	1.104

Because of no chemical toxic in this equipment, so this step not calculate.

PART 10 : CALCULATE THE NON-FLAMMABLE, NON-TOXIC CA

Step 10.1 For each release hole size, calculate the non-flammable , non-toxic For steam-calculate $CA_{inj,N}^{CONT}$ using equation (43) and $CA_{inj,N}^{INST}$

1). FOR STEAM

Steam represents a hazard to personnel who are exposed to it at high temperatures. In general, steam is at 100oC (212oF) immediately after exiting a hole in an equipment item. Within a few feet, the steam will begin to mix with air cool, and condensed. The approach used here is that injury occurs above 60oC (140oF). In this case of Production Separator, the temperatur inside the presssure vessel is maximally working at 100oC (212oF). So, steam leaks is potentially occur at this situation.

$Mass_1$ = 226.5473 kgs
$Mass_2$ = 431.8835 kgs
$Mass_3$ = 431.8835 kgs
$Mass_4$ = 431.8835 kgs
$Rate_1$ = 0.1890 kg/s
$Rate_2$ = 3.0210 kg/s
$Rate_3$ = 15.4400 kg/s
$Rate_4$ = 773.3000 kg/s
C_9 = 0.123 m^2.sec/kg
C_{10} = 9.744 $m^2/kg^{0.06384}$
$fact_1^{IC}$ = 0.0075
$fact_2^{IC}$ = 0.119881
$fact_3^{IC}$ = 0.6126984
$fact_4^{IC}$ = 1

$CA_{inj,n}^{CONT} = C_9 . Rate_n)$ ..... equation (48)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{CONT} = C_9 . Rate_1)$
= 0.02325 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{CONT} = C_9 . Rate_2)$
= 0.37158 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{CONT} = C_9 . Rate_3)$
= 1.89912 m^2

$CA_{inj,n}^{INST} = C_{10} . Mass_n)^{0.6384}$ ..... equation (49)

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{INST} = C_{10} . Mass_4)^{0.6384}$
= 205.88651 m^2

2). FOR ACIDS AND CAUSTIC

For Acids or caustics- compute, $CA_{inj,n}^{CONT}$ using equation (3.72), (3.73), (3.74). Note that the data is not provided for an instantaneous release ; therefore,

No acid or caustic, thus value are 0.

Step 10.2 For each release hole size, calculate the instantaneous/continuous blending factor, $fact_n^{IC}$ For steam, use equation (3.71).
for acids or caustics, $fact_n^{IC}$ =0.0

Step 10.3 For each release hole size , compute the blended non-flammable , non-toxic personnel injury consequence area for steam or acid leaks, $CA_{inj,n}^{leak}$, using equation (3.76) based on the consequence are from step 10.1 and the blending factor , $fact_n^{IC}$, from step 10.2 note that there is no need to calculate component damage area for the level 1 non-flammable release (steam or acid/caustic) :

$CA_{cmd,n}^{leak}$ = 0 m²

$CA_{inj,n}^{leak} = CA_{inj,n}^{INST}.\ fact_n^{IC} + CA_{inj,n}^{CONT}.(1 - fact_n^{IC})$ ..... equation (50)

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{leak} = CA_{inj,1}^{INST}.\ fact_1^{IC} + CA_{inj,1}^{CONT}.(1 - fact_1^{IC})$

= 0.0230726 m^2

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{leak} = CA_{inj,2}^{INST}.\ fact_2^{IC} + CA_{inj,2}^{CONT}.(1 - fact_2^{IC})$

= 0.3270373 m^2

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{leak} = CA_{inj,3}^{INST}.\ fact_3^{IC} + CA_{inj,3}^{CONT}.(1 - fact_3^{IC})$

= 0.73553219 m^2

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{leak} = CA_{inj,4}^{INST}.\ fact_4^{IC} + CA_{inj,4}^{CONT}.(1 - fact_4^{IC})$

= 205.88651 m^2

Step 10.4 Determine the final non-flammable, non toxic consequence areas for personnil injury, CA_{icmd}^{nfnt} using equation (3.80) based on consequence areas calculated for each release hole size in step 10.3 . Note that there is no need to calculate a final-flammable, non-toxic consequence area for component damage area for the level 1 non-flammable release (steam or acid/caustic, or :

$CA_{cmd,n}^{lnfnt} = 0 \ m^2$

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}} \right) \quad \text{..... (equation)}$$

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		small	medium	large	rupture	
Pipe	Pipe-1	2.80E-05	0	0	2.60E-06	3.06E-05
	Pipe-2					
Pipe	Pipe-4	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
	Pipe-6					
Pipe	Pipe-8	8.00E-06	2.00E-05	2.00E-05	6.00E-07	3.06E-05
	Pipe-10					
	Pipe-12					
	Pipe-16					
	PipeGT16					

$$CA_{inj}^{nfnt} = \left(\frac{(gff_1 \cdot CA_{inj,1}^{leak}) + (gff_2 \cdot CA_{inj,2}^{leak}) + (gff_3 \cdot CA_{inj,3}^{leak}) + (gff_4 \cdot CA_{inj,4}^{leak})}{gff_{total}} \right)$$

$= 4.73751 \ m^2$

PART 11 : CALCULATION OF FINAL CONSEQUENCE AREA

Step 11.1 Calculate the final component damage consequence area, Cacmd

Note that since the component damage consequence areas for toxic releases, CAcmd^{tox}, and non-flammable, non-toxic releases, CAcmd^{nfnt}, are both equal to zero. Then, the final component damage consequence area is equal to the consequence area calculated for flammable releases, CAcmd^{flam}.

$CA_{cmd} = CA_{cmd}^{flam}$ ..... equation (52)

$= 51.50 \ m^2$

Step 11.2 Calculate the final personnel injury consequence area, CA_{inj}

$CA_{inj} = \max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$ ..... equation (53)

$CA_{inj}^{flam} = 123.796 \ m^2$

$CA_{inj}^{tox} = 0.00 \ m^2$

$CA_{inj}^{nfnt} = 4.73751 \ m^2$

$CA_{inj} = \max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$

$= 123.796128 \ m^2$

Step 11.3 Calculate the final consequence area, CA, using equation below:

$CA = \max\left[CA_{cmd}, CA_{inj}\right]$

$= 123.80 \ m^2$

$= 1332.53043 \ ft^2$

ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR

LAMPIRAN 4 :

INSPECTION PLANNING AND RECOMMENDATION

PSV-2931

REV.	DATE	Explanation	Done By		Approved by	
			Name	Sign	Lecture	Sign
			Mohammad Teguh F I		Nurhadi Siswantoro,ST.,MT.	
			No. Registrasi :		Ir. Dwi Priyanta, M.SE	
			04211640000033			

	ANALISIS RISK BASED INSPECTION (RBI) PADA PRESSURE RELIEF DEVICE (PRD) SISTEM PRODUCTION GAS SEPARATOR
	Lampiran 4 = Inspection Planning and Recommendation

STEP 1 CALCULATION OF RISK ANALYSIS

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (54)

dimana :

$Risk^{prd}$ = total risiko PRD

$Risk_f^{prd}$ = risiko PRD gagal membuka

$Risk_l^{prd}$ = risiko PRD bocor

STEP 1 Menghitung resiko dari peluang kegagalan PRD untuk gagal membuka $Risk_{f.j}^{prd}$

A. RBI Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 1.14E-10 $Risk_{f.j}^{prd}$ = 1E-10 . 123.8

$C_{f,j}^{prd}$ = 123.80 m^2 = 1.4113E-08

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 2.85E-09 $Risk_{f.j}^{prd}$ = 3E-09 . 123.8

$C_{f,j}^{prd}$ = 123.80 m^2 = 3.5282E-07

B. RBI Plan Date

FIRE CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 1.78E-09 $Risk_{f.j}^{prd}$ = 2E-09 . 123.8

$C_{f,j}^{prd}$ = 123.80 m^2 = 2.2036E-07

OVERFILLING CASE

$$Risk_{f.j}^{prd} = P_{f,j}^{prd} . C_{f,j}^{prd}$$ equation (55)

dimana :

$P_{f,j}^{prd}$ = 4.45E-08 $Risk_{f.j}^{prd}$ = 4E-08 . 123.8

$C_{f,j}^{prd}$ = 123.80 m^2 = 5.5089E-06

$$Risk_f^{prd} = \sum_{j=1}^{ndc} P_{f,j}^{prd} . C_{f,j}^{prd}$$

A. RBI Date

$Risk_f^{prd}$ = 1E-08 + 4E-07

= 3.6693E-07

B. RBI Plan Date

2E-07 + 6E-06

= 5.7293E-06

STEP 1.2 Hitung risiko untuk kasus kebocoran PRD, $Risk_l^{prd}$

$$Risk_l^{prd} = P_l^{prd} . C_l^{prd}$$ equation (56)

Dimana :

P_l^{prd} = 0.0032 (RBI Date)

P_l^{prd} = 0.0497 (RBI Plan Date)

C_l^{prd} = 123.80 m^2

A. RBI Date

$Risk_l^{prd}$ = 0.0032 x 123.8

= 0.3961

B. RBI Plan Date

$Risk_l^{prd}$ = 0.0497 x 123.80

= 6.1527

STEP 1.3 Menghitung total risiko menggunakan persa57)

$$Risk^{prd} = Risk_f^{prd} + Risk_l^{prd}$$ equation (57)

A. Risk at RBI Date

$Risk^{prd}$ = 0.3961 m^2/year

= 4.2641 ft^2/year

B. Risk at RBI Plan Date

$Risk^{prd}$ = 6.1527 m^2/year

= 66.227 ft^2/year

STEP 2 Risk Matrix

Probabilty Score at RBI Date = 1E-10 + 3E-09 + 0.0032

= 3.20E-03

Probabilty Score at Plan Date = 2E-09 + 4E-08 + 0.0497

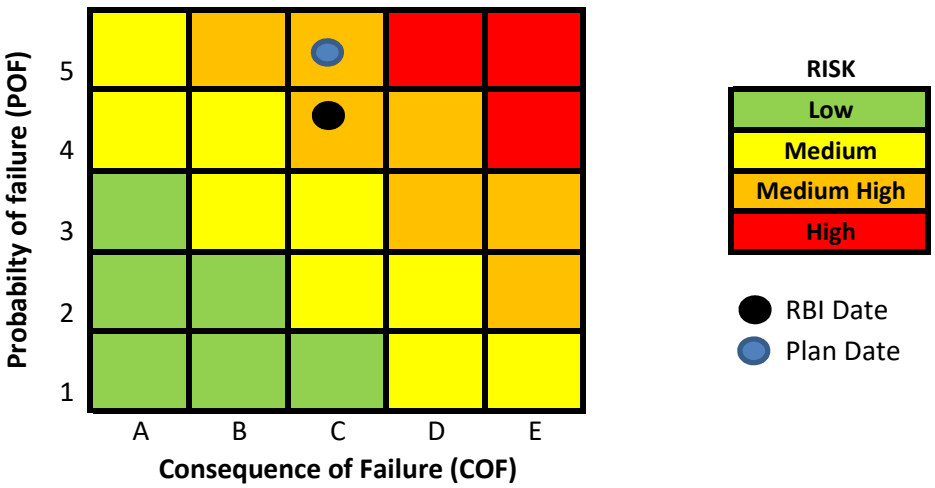
= 4.97E-02

Consequence Score = 123.80 m^2

= 1332.5 ft^2

Table 4.1 Numerical Values Associated with POF and Area-Based COF Categories

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t,I_E) \leq 3.06E-05$	$D_{ftotal} \leq 1$	A	$CA \leq 100$
2	$3.06E-05 < P_f(t,I_E) \leq 3.06E-04$	$1 < D_{ftotal} \leq 10$	B	$100 < CA \leq 1.000$
3	$3.06E-04 < P_f(t,I_E) \leq 3.06E-03$	$10 < D_{ftotal} \leq 100$	C	$1.000 < CA \leq 10.000$
4	$3.06E-03 < P_f(t,I_E) \leq 3.06E-02$	$100 < D_{ftotal} \leq 1000$	D	$10.000 < CA \leq 100.000$
5	$P_f(t,I_E) > 3.06E-02$	$D_{ftotal} > 1000$	E	$CA > 100.000$



STEP 3 Inspection Date

Target date dapat dihitung dengan cara melakukan interpolasi nilai RBI Date dan PRBI Plan Date

Dalam menentukan target date, digunakan nilai risk target sebesar 40ft^2 (3.71 m^2) untuk menentukan tahun inspection date.

Data	Date	Age	Risk (m^2/yr)
RBI Date	15/03/2020	0	0.396
Risk Target	?	?	3.710
Plan Date	15/03/2024	11	6.153

$$\frac{Y - Y_1}{Y_2 - Y_1} = \frac{X - X_1}{X_2 - X_1}$$

$$Y = Y_1 + \left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)$$

$$Y = 0 + \left(\frac{3.71 - 0.396}{6.153 - 0.396}\right)(11 - 0)$$

Y = 6.3323568 Year

Y = 2311.3102 Hari

= 13/07/2026

Berdasarkan standart API 510 memberikan rekomendasi interval inspeksi maksimal untuk *Pressure Reliev Device* yaitu 10 tahun dari inspeksi terakhir. Sehingga untuk jadwal inspeksi selanjutnya yaitu pada tanggal 17 juni 2026.

STEP 4 Recommendation

1 Inspection Category

Inspection Effectiveness	Description of Inspection	Date
C	Inspeksi visual telah dilakukan tanpa tes pop, di mana dokumentasi terperinci tentang kondisi internal PRD komponen dibuat.	17/06/2026
Fairly Effective	Tes trevitest atau in-situ telah dilakukan di tempat yang sebenarnya cairan proses tidak digunakan untuk memberi tekanan pada sistem.	

Berdasarkan standart API 581 Direkomendasikan menggunakan inspection effectiveness kategori C dengan mengaplikasikan Visual on-stream inspection

2 Inspection Strategy

Berdasarkan Standart API 576 berikut rekomendasi record visual inspeksi Pressure Relief Device

Unit	Location		Set Pressure	Test Interval
Make		:		
Style		:		
Body and bonnet material		:		
Nozzle and disk material		:		
Trim material		:		
Spring material		:		
Spring no		:		
Flange sizes				
	Inlet	:		
	Outlet	:		
Spring set pressure		:		
Relieving pressure		:		
normal operating temp		:		
Remark				

BIODATA PENULIS

Penulis bernama Mohammad Teguh Fiqih Irawan lahir di Bondowoso pada tanggal 7 Januari 1998. Penulis merupakan anak tunggal dari pasangan Bapak Abdullah dan Ibu Bima Yuliatin. Pendidikan formal yang telah ditempuh oleh penulis, yaitu TK Dharma Wanita (2002-2004), SDN Sekarputih 2 (2004-2010), SMPN 2 BONDOWOSO (2010-2013), dan SMAN 2 BONDOWOSO (2013-2016). Pada tahun 2016 penulis diterima di Departemen Teknik Sistem Perkapalan, Fakultas Teknologi Kelautan, Institut Teknologi Sepuluh Nopember melalui jalur SNMPTN dengan NRP 04211640000033. Penulis aktif di Devisi PSDM (Pengembangan Sumber Daya Mahasiswa) UKM Volly Ball ITS 2017/2018 dan 2018/2019. Penulis aktif di kepanitiaan Diesnatalis ITS cabang olahraga Volly tahun 2018 dan 2019, kepanitian Lomba PIRES (Piala Rektor ITS) tahun 2018 dan 2019. Semester 5 penulis masuk ke ruang lingkup Proyek Bapak Ir. Dwi Priyanta, M.SE. Kerja Praktek penulis yang ke 1 di PT. Dok dan Perkapalan Surabaya (DPS) dan Kerja Praktek penulis yang ke 2 di PT. Antakesuma Inti Raharja. Penulis mengambil laboratorium Digital Marine Operation and Maintenance. Penulis mengerjakan Tugas Akhir yang berjudul "**Analisis *Risk Based Inspection* (RBI) pada *Pressure Relief Device* (PRD) Sistem Production Gas Separator**". Apabila ada kritik dan saran dapat dikirim ke mohammadteguh11@gmail.com.