TUGAS AKHIR - ME184834

PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

NI LUH TRISKA ADELIA
NRP 04211640000012

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Departemen Teknik Sistem Perkapalan
Fakultas Teknologi Kelautan
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FAKULTAS TEKNOLOGI KELAUTAN
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

BACHELOR THESIS – ME 184834

INSPECTION PLANNING OF PRODUCTION SEPARATOR USING RISK BASED INSPECTION API 581 METHOD

NI LUH TRISKA ADELIA
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SUPERVISOR :
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LEMBAR PENGESAHAN

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TUGAS AKHIR

Diajukan Untuk Memenuhi Salah Satu Syarat
Memperoleh Gelar Sarjana Teknik
pada
Bidang Studi *Digital Marine Operation and Maintenance* (DMOM)
Program Studi S-1 Departemen Teknik Sistem Perkapalan
Fakultas Teknologi Kelautan
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JULI, 2020

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PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

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ABSTRAK

Eksplorasi minyak dan gas bumi terus dikembangkan. Salah satu alat penunjang dalam eksplorasi dan eksploitasi minyak dan gas bumi ialah *pressure vessel*. *Pressure vessel* didefinisikan sebagai bejana/wadah yang didesain untuk dapat menahan tekanan baik internal maupun eksternal. Salah satu jenis *pressure vessel* adalah *production separator* yang berfungsi untuk memisahkan gas, minyak dan air dari sebuah hasil eksplorasi. Dalam proses pemisahan tersebut terdapat kemungkinan risiko kegagalan yang dapat memberi dampak yang berbahaya bagi pekerja maupun lingkungan. Oleh karena itu, penyebab kegagalan pada *production separator* perlu dilakukan analisis agar dapat meminimalkan risiko yang akan terjadi. Analisis bahaya tersebut diharapkan dapat mewakili semua potensi bahaya yang berpengaruh terhadap kinerja *production separator*. Sehingga, setelah diperhitungkan analisis risiko, perlu di pertimbangkan pula jadwal inspeksi *production separator* tersebut.

Risk Based Inspection (RBI) adalah sebuah metode yang dapat digunakan untuk menentukan interval inspeksi dan jenis inspeksi/pemeriksaan. Penilaian *Risk Based Inspection* (RBI) menentukan risiko dengan menggabungkan probabilitas dan konsekuensi dari kegagalan peralatan. Oleh karena itu, secara umum metode RBI dapat diaplikasikan ke semua jenis industri dan sangat bergantung pada kondisi aktual dari peralatan industri yang dilakukan analisis.

Hasil analisis menunjukan bahwa risiko pada production separator sebesar $7{,}915 \times 10^{-3}$ m^2/yr pada saat RBI date dan $1{,}414 \times 10^{-2}$ m^2/yr pada saat plan date. Berdasarkan *probability of failure (PoF)* dan *consequence of failure (CoF)* dapat ditentukan bahwa level risiko berada pada kategori *low risk* baik pada saat *RBI date* maupun *plan date*. Hal tersebut menyebabkan jadwal inspeksi selanjutnya terlampau jauh dari standar yang ditetapkan. Sehingga jadwal inspeksi ditentukan berdasarkan pada standar API 510 yaitu 10 tahun setelah inspeksi terakhir. Metode inspeksi yang dapat diaplikasikan pada *production separator* berdasarkan pada *damage factor* yang terjadi adalah Visual Testing (VT), Ultrasonic Test (UT), Radiography Test (RT), Wet Fluorescent Magnetic Test (WFMT), Edy Current (EC), Alternating Current Field Measurement (ACFM) dan AET.

Kata kunci: (risiko, *production separator,* inspeksi*, Risk Based Inspection*)

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PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

Nama mahasiswa : Ni Luh Triska Adelia
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ABSTRACT

The development of oil and gas exploration keep on continues. One of the supporting tools in the exploration and exploitation of oil and gas is a pressure vessel. Pressure vessel is defined as vessels/containers designed to withstand internal and external pressure. One type of pressure vessel is a production separator which serve to separate gas, oil and water from an exploration product. In the process of separation there is the possibility of failure risk which can have a hazardous impact on workers or personel and the environment. Therefore, the cause of failure in the production separator needs to be analyzed in order to minimize the risk that will occur. The hazard analysis is expected to be able to represent all potential hazards that affect production separator performance. So, after calculate the risk analysis, it is also necessary to consider the production separator inspection schedule.

Risk Based Inspection (RBI) is a method that can be used to determine the inspection interval and the type of inspection. The Risk Based Inspection (RBI) assessment determines risk by combining the probability and consequences of failure. Therefore, in general the RBI method can be applied to all types of industries and is highly depends on the actual conditions of the equipment.

The analysis shows that the risk in the production separator is 7,915 x 10^{-3} m^2/yr on the RBI date and 1,414 x 10^{-2} m^2/yr on the plan date. Based on probability of failure (PoF) and consequence of failure (CoF), it can be determined that the risk level is in the low risk category both at the RBI date and plan date. That caused the next inspection schedules is too far from the schedule should be based on standard/code. So that the inspection schedule is determined based on API 510 standard which is 10 years after the last inspection. Inspection methods that can be applied to production separator based on its damage factors are Visual Testing (VT), Ultrasonic Test (UT), Radiography Test (RT), Wet Fluorescent Magnetic Test (WFMT), Edy Current (EC), Alternating Current Field Measurement (ACFM) and AET.

Keywords: (risk, production separator, inspection, Risk Based Inspection)

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Penulis menyadari bahwa dalam penulisan tugas akhir ini masih jauh dari kesempurnaan. Karena itu, penulis memohon saran dan kritik yang sifatnya membangun dari berbagai pihak. Dalam kesempatan ini penulis juga memohon maaf apabila dalam proses pengerjaan tugas akhir ini terdapat banyak kesalahan yang disengaja maupun tidak disengaja. Semoga skripsi ini dapat bermanfaat bagi para pembaca dan semua pihak

Surabaya, Juli 2020

Penulis

DAFTAR ISI

DAFTAR GAMBAR

DAFTAR TABEL

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BAB 1
PENDAHULUAN

1.1 Latar Belakang

Bahan bakar fosil berkaitan erat dengan kehidupan sehari-hari yang banyak digunakan pada sektor transportasi dan insdutri. Sehingga eksplorasi bahan bakar fosil seperti minyak bumi dan gas alam terus dilakukan untuk memenuhi kebutuhan tersebut. Bahkan pada tahun 2019, Indonesia melakukan pengeboran 28 sumur minyak dan gas bumi. Salah satu alat penunjang dalam eksplorasi dan eksploitasi minyak dan gas bumi ialah *pressure vessel*. *Pressure vessel* didefinisikan sebagai bejana/wadah yang didesain untuk dapat menahan tekanan baik internal maupun eksternal[1]. Selain itu, bejana tekan merupakan wadah tertutup yang dirancang untuk menampung cairan atau gas pada temperatur yang berbeda dari temperatur lingkungan. Bejana tekan digunakan untuk bermacam-macam aplikasi di berbagai sektor industri seperti industri kimia (*petrochemical plant*), energi pembangkit listrik (*power plant*), minyak dan gas (*oil & gas*), industri makanan dan minuman[2].

Berdasarkan prosesnya *pressure vessel* dapat dibagi dalam beberapa jenis seperti *separator, drum vessel* dan *tower vessel*. *Separator* adalah jenis dari *vessel* yang digunakan untuk memisahkan. Biasanya digunakan untuk memisahkan air, minyak dan gas yang masuk kedalam *vessel* ini. Dalam proses pemisahan tersebut terdapat risiko terjadinya kegagalan yang diakibatkan oleh kerusakan pada peralatan. Salah satu kerusakan separator dapat disebabkan oleh fluida yang ada di dalamnya. Kandungan yang terdapat dalam minyak, gas maupun air dapat menyebabkan korosi sehingga terjadi penipisan dinding separator yang dapat mengakibatkan kebocoran. Kebocoran pada *separator* dapat memberi dampak yang sangat berbahaya. Dampak yang terjadi dapat berupa kebakaran, keracunan, dan pencemaran lingkungan. Mengingat bahwa *separator* merupakan *equipment* yang tidak terlepas dari risiko kegagalan, maka perlu dilakukan inspeksi dan pemeriksaan keselamatan pada instalasi dan/atau peralatan yang digunakan dalam kegiatan usaha minyak dan gas bumi seperti yang disebutkan pada Pasal 6 Ayat 1 Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 18 Tahun 2018. Selain itu, Pasal 17 Ayat 1 pada Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 18 Tahun 2017 juga menyebutkan bahwa 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 peralata mengalami perubahan atau diragukan kemampuannya. Oleh karena itu, penyebab kerusakan pada *separator* perlu dilakukan analisis agar dapat meminimalkan risiko

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[1] API 510. 2014. Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration, Tenth Edition. Washington D.C: API Publishing Service.
[2] Prof. Mr. Amol Mali, 2015. “A Review Paper on Study of Pressure Vessel, Design and Analysis”. International Research Journal of Engineering and Technology (IRJET).

yang akan terjadi. Analisis bahaya tersebut harus dapat mewakili semua potensi bahaya yang berpengaruh terhadap kinerja *separator*. Sehingga, setelah diperhitungkan analisis risiko, perlu di pertimbangkan pula jadwal inspeksi *separator* tersebut. Hal ini dilakukan agar kinerja *separator* dapat maksimal sehingga akan didapatkan hasil produksi yang sebaik-baiknya.

Dari penjabaran diatas, perlu adanya suatu metode pencegahan terhadap kemungkinan terjadinya kerusakan dengan menjaga kualitas *separator* tersebut. *Risk Based Inspection* (RBI) adalah sebuah metode yang dapat digunakan untuk menentukan interval inspeksi dan jenis serta tingkat inspeksi/pemeriksaan. Penilaian *Risk Based Inspection* (RBI) menentukan risiko dengan menggabungkan probabilitas dan konsekuensi dari kegagalan peralatan[3]. Oleh karena itu, secara umum metode RBI dapat diaplikasikan ke semua jenis industri dan sangat bergantung pada kondisi aktual dari peralatan industri yang dilakukan analisis.

RBI diharapkan dapat menghasilkan perencanaan inspeksi yang optimal dan dapat menentukan prioritas dari risiko yang lebih rendah ke risiko yang lebih tinggi. Perencanaan inspeksi digunakan untuk mencegah kerusakan dari peralatan (*asset*) yang dapat memberi dampak besar pada sistem operasional peralatan dan dampak pada biaya yang dikeluarkan untuk menangani kerusakannya.

1.2 Rumusan Masalah

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

1. Bagaimana menentukan *probability of failure* (PoF) pada peralatan *production separator* menggunakan metode *risk based inspection*?
2. Bagaimana menentukan *consequence of failure* (CoF) pada *production separator* menggunakan metode *risk based inspection*?
3. Bagaimana menentukan level risiko pada peralatan *production separator* menggunakan metode *risk based inspection*?
4. Bagaimana menentukan *inspection planning* yang sesuai dengan kondisi tingkat *production separator* tersebut?

1.3 Tujuan

Penulisan tugas akhir ini bertujuan untuk :

1. Menentukan *probability of failure* (PoF) pada peralatan *production separator* menggunakan metode *risk based inspection.*
2. Menentukan *consequence of failure* (CoF) pada *production separator* menggunakan metode *risk based inspection.*
3. Menentukan level risiko *production separator* dengan menggunakan metode *risk based inspection*.
4. Menentukan jenis dan interval waktu inspeksi *production separator* dengan menggunakan metode *risk based inspection.*

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[3] API 510. 2014. Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration, Tenth Edition. Washington D.C: API Publishing Service.

1.4 Batasan Masalah

Batasan masalah dalam tugas akhir ini adalah:

1. *Pressure vessel* yang akan dilakukan penelitian adalah *pressure vessel* jenis *production separator* pada Central Processing Plant Perusahaan X.
2. Pemeriksaan berbasis keandalan *production separator* ini berpedoman pada *code* API RBI 581.
3. Kejadian alam tidak dipertimbangkan.

1.5 Konstribusi

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 analisis level risiko dari *production separator*.
3. Meningkatkan tingkat keselamatan bagi para pekerja maupun lingkungan.

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BAB 2
KAJIAN PUSTAKA

2.1 Ikhtisar Permasalahan

PT X merupakan sebuah perusahaan yang bergerak dalam bidang eksplorasi dan produksi minyak dan gas bumi. Salah satu penunjang untuk melakukan eksplorasi adalah *pressure vessel. Pressure vessel* didefinisikan sebagai bejana/wadah yang didesain untuk dapat menahan tekanan baik internal maupun eksternal[4]. Berdasarkan prosesnya *pressure vessel* dapat dibagi dalam beberapa jenis seperti *separator, drum vessel* dan *tower vessel*. *Separator* adalah jenis dari *vessel* yang digunakan untuk memisahkan. Sesuai namanya, *separate* yang artinya memisahkan. Biasanya digunakan untuk memisahkan air, minyak dan gas dari *crude oil* yang masuk kedalam *vessel* ini[5].

Setiap peralatan memiliki umur produksi yang sangat bergantung pada jenis dan penggunaan peralatan itu sendiri. Apabila terus dilakukan pengoperasian melebihi umur yang seharusnya, dikhawatirkan dapat mengakibatkan bahaya-bahaya yang tidak diinginkan. Selain itu peralatan dan konstruksi dalam minyak, gas, dan proses penyulingan ini mengalami kontak langsung dengan produk yang ada di dalamnya, atmosfer dan tanah. Dimana dapat diketahui bahwa kandungan dalam minyak terdapat hidrokarbon, nitrogen, oksigen dan belerang. Sedangkan gas alam adalah campuran gas homogen dari hidrokarbon, N2, CO2, H2S, H2O, dan asam organik. Kandungan-kandungan tersebut dapat menyebabkan korosi seperti H2S dapat menyebabkan korosi yang biasa disebut dengan *sour corrosion*, CO2 menyebabkan *sweet corrosion* dan O2 dapat menyebabkan *oxygen corrosion*. Korosi merupakan masalah yang sangat sering dijumpai dalam peralatan *oil and gas*. Sehingga adanya penggunaan *corrosion inhibitor* pada beberapa wilayah yang dapat dilihat pada chart di bawah ini.

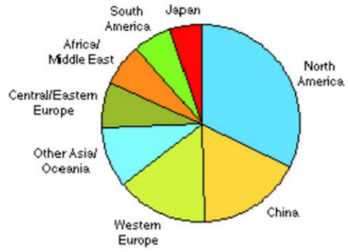

Figure 13 Pie chart showing the world consumption of corrosion inhibitors.

Gambar 2.1 Penggunaan *corrosion inhibitor* pada beberapa wilayah
Sumber: *Corrosion problems during oil and gas production and its mitigation*

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[4] API 510. 2014. Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration, Tenth Edition. Washington D.C: API Publishing Service.
[5] Indonesian Piping Knowledge, 2019. Pembagian Vessel Berdasarkan Prosesnya", <URL: http://www.idpipe.com/ >

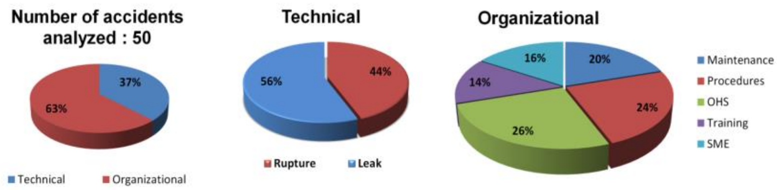
Korosi mengakibatkan adanya penipisan dinding peralatan sehingga rentan terjadinya kebocoran. Kebocoran fluida dari separator ini dapat menyebabkan bahaya yang tidak diinginkan seperti terjadinya kebakaran, ledakan, keracunan dan pencemaran lingkungan[6]. Terdapat beberapa insiden yang disebabkan oleh gagalnya sebuah peralatan seperti: [7]

- Kegagalan sistem *clamping* pada tutup bejana tekan, yang menabrak seorang pekerja di Sandycroft, Flintshire pada Oktober 2003. Pekerja bernama Giancarlo Coletti menderita cedera serius lengan kanannya.
- Sebuah ledakan di kilang terbesar Aljazair di kota pelabuhan Skikda, Aljir. Ledakan tersebut menewaskan 23 orang pada 20 Januari 2004.
- Bejana tekan seberat 22680 kg (50.000 pound) meledak di Marcus Oil di Houston Texas pada tahun 2004, pecahan material terlempar ke lingkungan sekitar sehingga merusak gereja, menghancurkan mobil jendela, terdapat bangunan di dekatnya yang mengalami kerusakan struktural dan interior. Kejadian ini mengakibatkan tiga pekerja pabrik meninggal dunia dan beberapa lainnya warga mengalami luka-luka.
- Sebuah *pressure vessel* meledak di Houston, Amerika Serikat, di musim panas 2008 yang mengakibatkan seorang supervisor meninggal dunia.

Kecelakaan pada proses kilang minyak sangat sering terjadi, sehingga dilakukan banyak penelitian untuk mengetahui penyebabnya. Sebuah penelitian menunjukan bahwa kecelakaan pada kilang minyak disebabkan oleh dua faktor yaitu faktor teknis dan organisasi. Berikut adalah diagram venn tentang fakta-fakta yang mengarah pada kecelakaan yang melibatkan bejana tekan.

Gambar 2.2 Diagram venn tentang fakta-fakta yang mengarah pada kecelakaan yang melibatkan bejana tekan
Sumber: Sylvie Nadeau, "Accident Causes Involving Pressure Vessels", 2019

[6] Groysman A, 2017. "Corrosion problems and solutions in oil, gas, refining and petrochemical industry". Koroze a ochrana materiálu 61(3) 100-117.
[7] Sylvie Nadeau, 2019. "Accident Causes Involving Pressure Vessels". GfA, Dortmund (Hrsg.): Frühjahrskongress 2019, Dresden.



Gambar 2.3 Distribusi fakta dan penyebab kecelakaan
Sumber: Sylvie Nadeau, "Accident Causes Involving Pressure Vessels", 2019

Dari gambar 2.3 dapat diketahui bahwa kecelakaan murni teknis hanya mewakili 37% dari total kecelakaan. Kategori ini dibagi menjadi dua penyebab utama, 56% disebabkan oleh kegagalan struktural dan 44% disebabkan oleh kegagalan kebocoran. Sedangkan organisasi menyebabkan 63% kecelakaan. Kategori ini dibagi menjadi lima kategori 26% karena kegagalan K3, 24% karena ketidakpatuhan terhadap prosedur, 20% karena kesalahan pemeliharaan, 16% karena subkontrak ke perusahaan kecil dan menengah dan 14% karena kurangnya pelatihan. Kejadian-kejadian seperti ini juga akan memberi kerugian berupa biaya perbaikan pada peralatan yang rusak. Sehingga perlu dilakukan penjadwalan inspeksi dan penerapan metode perawatan pada setiap peralatan.

2.2 Kajian Penelitian Terkait

Penelitian menggunakan metode *risk based inspection* pada *pressure vessel* sebelumnya telah dilakukan oleh Mohammad Reza Shishesaz & Elahe Shekari dari Petroleum University of Technology Iran, Mohammad Nazarnezhad Bajestani dari Corrosion Research Department, Research Institute of Petroleum Industry Iran dan Seyed Javad Hashemi, Abtin Engineering Company Iran. Penelitian tersebut membanding hasil perencanaan inspeksi dari API 510 dengan API 581 pada dua unit *plant* di Iran yaitu Abadan Oil Refining Company (AORC) and Esfahan Oil Refining Company (EORC). Hasil dari penelitian tersebut dapat disimpulkan bahwa interval inspeksi API 581 adalah dua kali dari interval inspeksi API 510. Selain itu didapatkan pula hasil peringkatan risiko yakni hanya 12% EORC dan 15% dari AORC yang memiliki risiko medium high risk hingga high risk.[8]

Aplikasi *Risk Based Inspection* juga pernah diterapkan pada sebuah kilang dan pabrik petrokimia di Taiwan. Inspeksi dilakukan pada sistem perpipaan dan *pressure vessel* dengan menggabungkan konsep-konsep RBI, dengan dua studi kasus, konsep *corrosion loop* dan penentuan tanggal inspeksi berikutnya yang optimal berdasarkan hasil risiko. Dengan metodologi RBI kuantitatif, dua studi kasus tersebut disimpulkan dapat mengurangi risiko dan biaya. Setelah dilakukan inspeksi, risiko Pabrik FCC, berkurang sebesar 77%, dan biaya risiko berkurang

[8] Mohammad Reza Shishesaz, 2013 "Comparison of API 510 pressure vessels inspection planning with API 581 risk-based inspection planning approaches". International Journal of Pressure Vessels and Piping.

dari USD 254.396.123 menjadi 59.207,499; sedangkan, pabrik propana sebesar 19%, dari USD 12.110,875 hingga 10.264.074, masing-masing.[9]

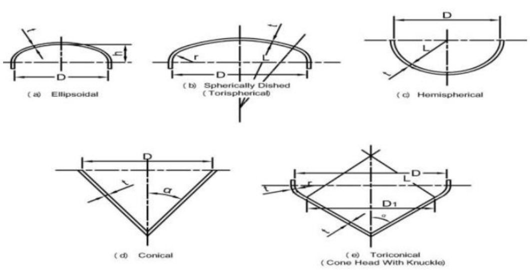
2.3 Teori Dasar

2.2.1 *Pressure Vesssel*

Pressure vessel didefinisikan sebagai bejana/wadah yang didesain untuk dapat menahan tekanan baik internal maupun eksternal. Adapun komponen-komponen utama dari *pressure vessel* meliputi[10]:

a. *Head*

Semua bejana bertekanan harus ditutup pada bagian ujungnya baik dengan *head* (kepala) atau dengan *shell* lainnya. *Head* (kepala) merupakan bagian penutup dari *vessel*. *Head* berada di bagian kanan dan kiri untuk *vessel* horisontal, atau di bagian atas dan bawah untuk *vessel* vertikal. *Head* dapat dibedakan berdasarkan bentuknya seperti *ellipsoidal, hemispherical, torispherical, conical, toriconical* dan *flat* adalah jenis kepala yang umum ditunjukkan gambar 2.4.



Gambar 2.4 Tipe-tipe head pressure vessel
Sumber : Journal of Mechanical Engineering and Technology (JMET)

b. *Shell*

Shell merupakan komponen utama yang mengandung tekanan yang berupa bagian tubuh *vessel*. *Shell* merupakan plat lembaran yang kemudian di bentuk (di roll) sampai menjadi silindris.

c. *Nozzle*

Nozzle merupakan sebuah komponen yang berbentuk silindris yang berfungsi sebagai penghubung antara *pressure vessel* dengan pipa. *Nozzle* pada

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[9] Ming-Kuen Chang, 2005. "Application of Risk Based Inspection in Refinery and Processing Piping". Journal of Loss Prevention in the Process Industries 18.
[10] V.V. Wadkar, 2015. "Design and Analysis of Pressure Vessel Using ANSYS". Journal of Mechanical Engineering and Technology (JMET).

dasarnya adalah saluran, dimana saluran tersebut menggunakan penyambung jenis *flange*. *Flange* adalah mekanisme penyambungan antara komponen satu dengan yang lain. Selain sebagai penghubung, *nozzle* juga berfungsi sebagai:

- Tempat pemasangan perlatan seperti *level gauges, thermo wells* atau *pressure gauges.*
- Menyediakan akses langsung dari peralatan lain seperti *heat exchanger* atau *mixer.*
- *Nozzle* juga kadang-kadang meluas ke bagian dalam *pressure vessel* untuk beberapa aplikasi, seperti untuk distribusi aliran inlet atau untuk masuknya *thermo wells*

Pressure vessel dibagi dalam beberapa jenis pada dasarnya, namun jika dibagi secara sederhana yaitu berdasarkan posisinya, terdapat dua jenis *pressure vessel* sebagai berikut:

a. *Pressure Vessel Horizontal*

Pressure vessel horizontal, sesuai namanya, jenis ini diletakan secara *horizontal*. *Pressure vessel horizontal* mengunakan *support* jenis *saddle* dan umumnya diaplikasikan pada fluida cair.

Gambar 2.5 *Pressure vessel* tipe horisontal
Sumber : www.phxequip.com)

b. *Pressure Vessel Vertical*

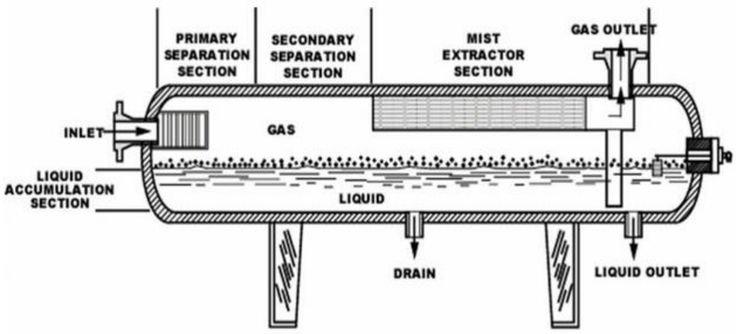
Pressure vessel vertical dilektakan secara *vertical y*ang biasanya menggunakan support jenis *leg*, *skirt* atau *lug*. *Pressure vessel* tipe vertikal umumnya digunakan untuk pemisah *(separator).*

Gambar 2.6 *Pressure vessel* tipe vertikal
(sumber : www.indiamart.com)

Selain itu, *pressure vessel* juga dibagi berdasarkan prosesnya. Adapun jenis-jenisnya adalah sebagai berikut:

a. *Separator*

Separator adalah jenis dari *vessel* yang digunakan untuk memisahkan. Sesuai namanya, *separate* yang artinya memisahkan. Biasanya digunakan untuk memisahkan air, minyak dan gas dari *crude oil* yang masuk kedalam *vessel* ini. *Separator* sendiri dibagi menjadi dua tipe, yaitu *test separator* dan *production separator*. Pengertiannya adalah *test separator* digunakan untuk mengukur berapa kadar produksi dari sebuah sumur, dari sini dapat diketahui berapa laju produksinya. Sedangkan untuk *production separator*, bertugas untuk memproduksi. Artinya minyak yang telah dipisahkan dari air maupun gas lainya, hasil tersebutlah yang nantinya akan digunakan oleh unit produksi, baik untuk dijual maupun diolah kembali untuk di murnikan.



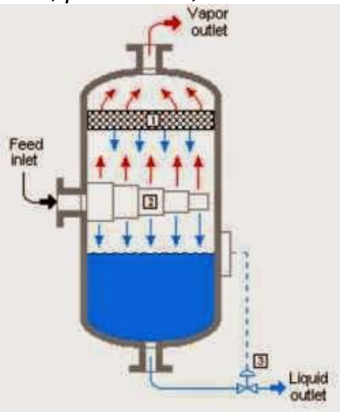
Gambar 2.7 *Separator*
(sumber : https://prezzatura.blogspot.com/)

Dalam *three phase separator*, terdapat empat bagian pemisahan, yaitu *primary section, gravity settling section, mist extraction section*, dan *liquid collecting section*. Masing-masing bagian tersebut memiliki fungsi yang berbeda sebagai berikut

- *Primary section* berfungsi untuk mengumpulkan sebagian besar fluida yang masuk. Pada bagian ini terdapat *inlet port* dan *baffle* untuk membelokkan arah aliran fluida utama dari aliran gas.
- *Secondary separation section/Gravity settling section* berfungsi untuk memisahkan butiran cairan yang sangat kecil yang tak terpisahkan di *primary section*. Prinsip utamanya adalah pengendapan gravitasi, sehingga bergantung pada perbedaan densitas gas dan cairan.
- *Mist extraction section* berfungsi untuk memisahkan butiran cairan halus berbentuk kabut yang terbawa aliran gas.
- *Liquid ccumulation section* berfungsi untuk menampung cairan yang bebas dari gas.

b. *Drum Vessel*

Drum Vessel adalah jenis *vessel* yang digunakan untuk menampung fluida baik dari *destilator* atau *condenser.* Fluida tersebut kemudian dipompakan ke proses yang lain, ke pembuangan atau ke unit produksi. Terdapat beberapa jenis *drum vessel* seperti *separator drum, reflux accumulator drum, knockout drum, flash drum, blow down dan reactor.*



Gambar 2.8 *Drum Vessel*
(sumber : http://www.idpipe.com/)

c. *Tower Vessel*

Tower atau istilahnya *column* adalah *equipment* yang paling utama dalah sebuah proses *facility*. *Column* biasanya berbentuk *vertical vessel* dan lebih tinggi dari *vessel* yang lain. *Tower vessel* digunakan untuk menyaring dan memisahkan bahan mentah *(crude oil)* yang masih terdiri dari berbagai macam fase, disebut juga dengan *fractionation column.* Pemisahan *pada tower vessel* ini memanfaatkan titik didih yang berbeda beda.

Gambar 2.9 *Tower Vessel*
(sumber: http://pipingdesigners.com/)

2.2.2 *Central Processing Plant (CPP)*

Central processing plant merupakan area dari pengolahan minyak dan gas yang didapat dari *wellhead* hingga siap untuk di jual. Dalam penulisan tugas akhir ini, penulis menggunakan data dari salah satu perusahaan minyak dan gas bumi di

Indonesia. Dalam perusahaan tersebut pada area *central processing plant* terdapat beberapa proses dalam pengolahan minyak dan gas bumi guna menghasilkan produk yang siap dijual.

2.2.3 Peraturan Pemerintah

Terdapat beberapa peraturan yang secara jelas mengatur suatu perusahaan minyak dan gas bumi untuk melakukan inspeksi pada peralatan penunjangnya guna menjamin keberhasilan dalam produksi sehingga dapat meminimalisir kegagalan.

a. Undang-undang Nomor I Tahun 1970[11]

Undang-undang Nomor I Tahun 1970 mengatur tentang keselamatan kerja. Pada bab III mengenai syarat-syarat keselamatan kerja pasal 3 ayat 1 ditetapkan syarat-syarat keselamatan kerja untuk :

- Mencegah dan mengurangi kecelakaan
- Mencegah,mengurangi dan memadamkan kebakaran
- Mencegah dan mengurangi bahaya peledakan

b. Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 38 Tahun 2017[12]

Peraturan ini tentang pemeriksaan keselamatan instalasi dan peralatan pada kegiatan usaha minyak dan gas bumi.

- Pasal 5 Ayat 1
  Untuk penjaminan terhadap pembuatan desain, pembangunan, pengoperasian, pemeliharaan, pengujian, pemeriksaan, dan pelaksanaan terhadap Instalasi dan peralatan yang digunakan dalam kegiatan usaha minyak dan gas bumi wajib dilakukan inspeksi dan pemeriksaan keselamatan.
- 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.
- Pasal 17 Ayat 1
  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.

c. Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 18 Tahun 2018[13]

Peraturan ini mengatur kembali ketentuan dalam Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 38 Tahun 2017 tentang Pemeriksaan

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[11] Undang-undang Nomor I Tahun 1970.

[12] Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 38 Tahun 2017.

[13] Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 18 Tahun 2018.

Keselamatan Instalasi dan Peralatan pada Kegiatan Usaha Minyak dan Gas Bumi

- Pasal 6 Ayat 1 dan 2
  (1) Untuk menjamin keselamatan instalasi dan peralatan sebagaimana dimaksud dalam Pasal 3, setiap instalasi dan/atau peralatan yang digunakan dalam kegiatan usaha minyak dan gas bumi wajib dilakukan;
    - Inspeksi; dan/atau
    - Pemeriksaan Keselamatan.
  (2) Jenis peralatan yang wajib dilakukan inspeksi dan pemeriksaan keselamatan pada kegiatan usaha minyak dan gas bumi terdiri dari:
    - Alat pengaman yang digunakan untuk melindungi peralatan;
    - Bejana dengan tekanan desain di atas atau di bawah tekanan atmosferik dan berukuran sama dengan atau lebih dari nominal pipe size 6;
    - Tangki penimbun dengan tekanan atmosferik yang digunakan untuk menyimpan minyak dan/atau gas bumi;
    - Pesawat angkat yang digunakan untuk mengangkat barang atau orang;
    - Peralatan putar yaitu pompa atau kompresor yang digunakan untuk mengalirkan minyak bumi dan gas bumi; dan
    - Peralatan yang membangkitkan, mendistribusikan, dan mengendalikan sistem tenaga listrik meliputi power generator, power transformer dan panel distribusi.

d. Pedoman Tata Kerja (PTK) 041 SKK Migas[14]

Jenis kegiatan yang tercakup dalam PTK ini adalah kegiatan pemeliharaan fasilitas produksi minyak dan gas bumi dalam sektor kegiatan usaha hulu, pada peralatan fasilitas produksi. Setiap data dan dokumen yang terkait dengan program pemeliharaan diperiksa secara berkala oleh KKKS dan disimpan dalam suatu sistem manajemen data yang dapat diperbaharui dan diakses setiap saat. Data-data tersebut meliputi data teknis utama *(engineering master data),* gambar-gambar teknis dan data integritas dan keandalan, termasuk *Risk Based Inspection* (RBI).

2.2.4 Risiko

Risiko merupakan kemungkinan terjadinya peristiwa yang dapat merugikan perusahaan, atau bahaya yang dapat terjadi akibat sebuah proses yang sedang berlangsung atau kejadian yang akan datang. Dampak yang paling dihindari diantaranya hal-hal yang kemungkinan akan membahayakan kesehatan dan keselamatan manusia serta lingkungan sebagai akibat dari teknologi yang berkembang saat ini.

[14] Pedoman Tata Kerja (PTK) 041 SKK Migas.

Risiko didefinisikan sebagai kombinasi antara *probability of failure (PoF)* dan *consequence of failure (CoF).* Risiko dapat dihitung dengan persamaan[15]:

Risk = Probability x Consequence

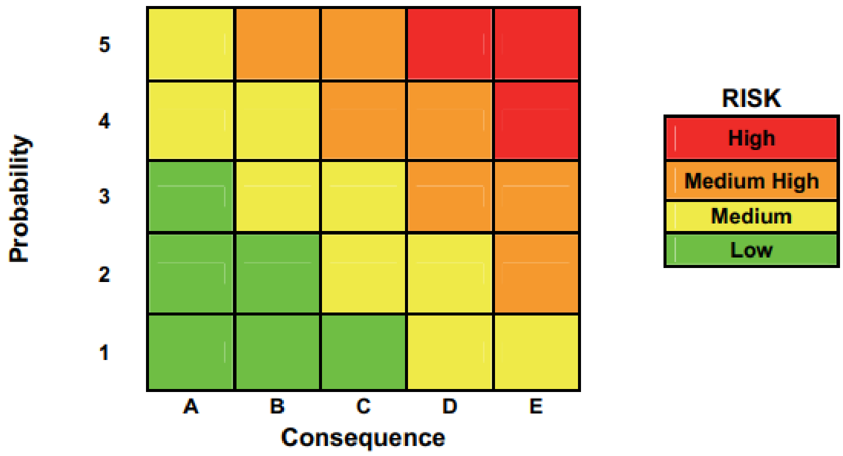
Dimana:

- *Probability :* Kemungkinan terjadinya peristiwa persatuan waktu.
- *Consequence :* Seberapa besar tingkat kerusakan yang diakibatkan karena adanya bahaya.

Terdapat beberapa cara untuk menentukan level risiko seperti:

a. Risk Matrix

Merencanakan nilai POF dan COF pada matriks risiko adalah metode yang efektif untuk menggambarkan risiko secara grafis. POF adalah diplot sepanjang satu sumbu, sedangkan COF diplot sepanjang sumbu lainnya. Ini tanggung jawab pemilik-pengguna untuk menentukan dan mendokumentasikan dasar untuk rentang kategori POF dan COF dan target risiko yang digunakan. Komponen risiko tertinggi mengarah kesudut kanan atas.



Gambar 2.10. Balance Risk Matrix
(Sumber : API Recommenced Practice 581)

b. Iso-risk Plot

Metode lain yang efektif untuk menyajikan hasil risiko adalah *iso-risk plot*. *Iso-risk plot* menunjukkan grafik POF dan nilai-nilai COF dalam log-log, grafik dua dimensi di mana risiko meningkat menuju sudut kanan atas.

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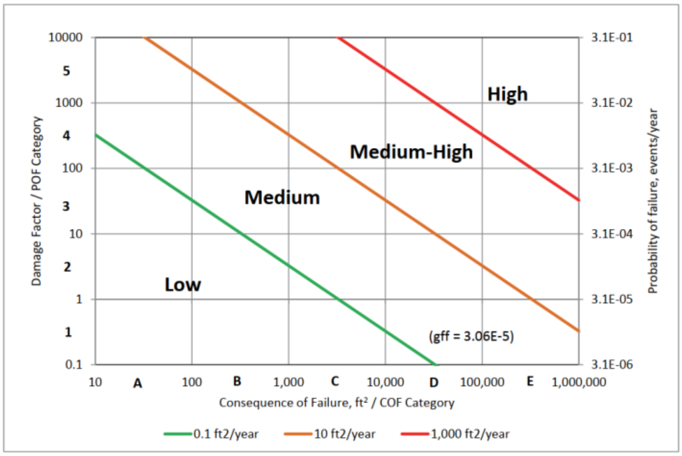
[15] API RP 580. 2016. Risk Based Inspection Technology, 3rd Edition. Washington, D.C: API Publishing Services.

Komponen di dekat garis iso-risiko mewakili tingkat risiko yang setara. Komponen diberi peringkat berdasarkan risiko untuk inspeksi, dan rencana inspeksi dikembangkan untuk komponen berdasarkan kriteria penerimaan risiko yang ditentukan yang telah diatur.



Gambar 2.11. Contoh Iso-risk Plot untuk Konsekuensi Area
(Sumber : API Recommenced Practice 581)

2.2.5 Risk Based Inspection (RBI)

Sejak awal tahun 90, *Risk Based Inspection* (RBI) digunakan untuk mengelola risiko dan menentukan prioritas risiko pada industri kimia dan industri minyak & gas. RBI adalah sebuah pendekatan dalam manajemen inspeksi dan penilaian risiko untuk merencanakan, menguji dan menafsirkan hasil isnpeksi. Menggunakan RBI dapat menentukan jadwal inspeksi berdasarkan tingginya risiko pada sebuah peralatan.

Prosedur RBI dapat diterapkan secara kualitatif, kuantitatif, atau dengan menggunakan aspek keduanya (yaitu semi-kuantitatif). Setiap pendekatan menyediakan cara sistematis untuk menyaring risiko, mengidentifikasi bidang-bidang yang berpotensi menjadi perhatian, dan mengembangkan daftar yang diprioritaskan untuk pemeriksaan atau analisis yang lebih mendalam. Masing-masing mengembangkan ukuran peringkat risiko untuk digunakan mengevaluasi secara terpisah PoF dan potensi CoF. Kedua nilai ini kemudian digabungkan untuk memperkirakan risiko kegagalan.

2.2.5.1 Program Risk Based Inspection

Adapun program *Risk Based Inspection* meliputi:

- Memprioritaskan sistem atau proses dalam suatu operasi berdasarkan risiko.
- Menentukan nilai risiko atau kategori yang terkait dengan item peralatan dalam suatu sistem atau proses berdasarkan metodologi yang konsisten.
- Menentukan peringkat peralatan yang diprioritaskan berdasarkan risiko.
- Pengembangan program inspeksi yang sesuai untuk mengatasi risiko utama. Suatu metode yang secara sistematis dapat mengelola risiko yang terkait dengan pengoperasian peralatan.

2.2.5.2 Kelebihan dan Kekurangan Risk Based Inspection

Berikut merupakan tabel dari kelebihan dan kekurangan dari pengaplikasian risk based inspection.

Tabel 2.1 Kelebihan dan Kekurangan Metode RBI

Metode	Kelebihan	Kekurangan
Risk Based	Perencanaan inspeksi yang optimal dan dapat menentukan prioritas dari risiko yang lebih rendah ke risiko yang lebih tinggi.	Penerapan metode RBI tidak akan efektif apabila terdapat kekurangan data yang dibutuhkan
	Penurunan risiko dari fasilitas atau equipment yang diteliti atas kepatuhan terhadap standar/kode	
	Biaya Pemeriksaan dan Perawatan yang Dioptimalkan	

Berdasarkan tabel 2.1 dapat disimpulkan bahwa alasan diterapkannya metode RBI karena metode ini berbasis pada kuantifikasi resiko tidak hanya untuk komponen basis, tapi juga merangkup resiko dari semua komponen pada instalasi keseluruhan. Selebihnya, pendekatan dengan metode RBI memberikan petunjuk untuk tindakan pencegahan resiko yang harus dilakukan, dengan berdasarkan hasil inspeksi. Alasan lain dari RBI adalah pendekatan RBI adalah sebuah metode yang dilakukan berdasarkan kondisi dan dapat memberikan basis rasional untuk beradaptasi pada inspeksi yang dilakukan pada kondisi komponen dan untuk memprioritaskan inspeksi dengan memprioritaskan usaha sesuai dengan kepentingan komponen tersebut.

2.2.6 Probability of Failure (PoF)

Analisis probabilitas dalam program RBI dilakukan untuk memperkirakan probabilitas dari konsekuensi tertentu yang dihasilkan dari kehilangan penahanan yang terjadi karena mekanisme kerusakan. Berdasarkan API 581, perhitungan probability of failure adalah sebagai berikut[16]:

$$P_f\ (t) = gff.D_f\ (t).F_{MS} \quad (2.1)$$

dimana:

$P_f\ (t)$ = Probability of Failure

gff = Total Generic Failure Frequency

$D_f\ (t)$ = Damage Factor

F_{MS} = Management System Factor

[16] API RP 581. 2016. Risk Based Inspection Methodology, 3rd Edition. Washington D.C: API Publishing Service.

2.2.6.1 Generic Failure Frequency (gff)

Generic Failure Frequency (gff) adalah frekuensi kegagalan secara umum yang dimiliki oleh masing-masing peralatan untuk mekanisme kerusakan tertentu yang disebabkan oleh lingkungan operasi dari peralatan tersebut. Generic failure frequency dari tipe komponen diperkirakan menggunakan catatan dari semua plant pada perusahaan atau dari berbagai plant dalam suatu industri, dari sumber literatur, dan dari basis data keandalan komersial. Sehingga nilai gff tersebut dapat mewakili industry secara umum daripada nilai frekuensi kegagalan yang sebenarnya dari peralatan tertentu. GFF diasumsikan mengikuti log-normal distribusi, dengan tingkat kesalahan mulai dari 3% hingga 10%. Nilai ini juga terdapat dalam beberapa bentuk lubang keluaran.

2.2.6.2 Damage Factor (D_f)

Damage Factor (D_f) adalah faktor yang digunakan untuk mengevaluasi jumlah kerusakan yang mungkin ada sebagai fungsi waktu dalam layanan dan efektivitas kegiatan inspeksi. DF dihitung tidak dimaksudkan untuk mencerminkan POF aktual untuk keperluan analisis reliabilitas. DF mencerminkan tingkat relative kekhawatiran tentang komponen berdasarkan pada asumsi yang dinyatakan di masing-masing bagian yang berlaku dari dokumen. Terdapat 21 jenis *damage factor* yaitu:

- *Thinning Damage Factor*
- *Component Lining Damage Factor*
- *SCC Damage Factor – Caustic Cracking*
- *SCC Damage Factor – Amine Cracking*
- *SCC Damage Factor – Sulfide Stress Cracking*
- *SCC Damage Factor – HIC / SOHIC – H2S*
- *SCC Damage Factor – Alkaline Carbonate Cracking*
- *SCC Damage Factor – PTA Cracking*
- *SCC Damage Factor – CLSCC*
- *SCC Damage Factor – HSC-HF*
- *SCC Damage Factor – HIC / SOHIC – HF*
- *External Corrosion Damage Factor – Ferritic Component*
- *External CLSCC Damage Factor Austenitic Component*
- *CUI Damage Factor – Ferritic Component*
- *External CUI CLSCC Damage Factor – Austenitic Component*
- *HTHA Damage Factor*
- *Brittle Damage Factor*
- *Temper Embrittlement Damage Factor*
- *Embrittlement Damage Factor*
- *Sigma Phase Embrittlement Damage Factor*
- *Piping Mechanical Fatigue Damage Factor.*

Kedua puluh satu *damage factor* tersebut memiliki kriterianya masing-masing. Untuk mengawali perhitungan *probability of failure* pada komponen tertentu, dilakukan penyaringan damage factor agar dapat mengetahui kerusakan jenis apa saja yang terjadi di komponen tersebut. Penyaringan tersebut dapat dilakukan melalui data komponen serta pengamatan di lokasi. *Damage factor* ditentukan dengan melakukan *screening* dari API RP 581, sesuai dengan kondisi peralatan terkait termasuk komposisi kimia dalam fluida yang melewati peralatan tersebut.

2.2.6.3 Management System Factor

Management System Factor adalah faktor yang berasal dari hasil evaluasi fasilitas atau unit operasi sistem manajemen yang memengaruhi risiko pada peralatan. Evaluasi sistem manajemen mencakup semua area sistem *process system management* (PSM) fasilitas yang berdampak langsung atau tidak langsung pada integritas mekanik peralatan proses. Daftar subjek yang dicakup dalam manajemen evaluasi sistem dan bobot yang diberikan untuk setiap subjek disajikan pada tabel 3.3 Part 2 API RP 581. Evaluasi sistem manajemen mencakup berbagai topik dan, sebagai akibatnya, membutuhkan masukan dari beberapa disiplin ilmu yang berbeda dalam fasilitas untuk menjawab semua pertanyaan. Idealnya, perwakilan dari pabrik berikut fungsi harus diwawancarai:

- Manajemen Pabrik
- Operasi
- Pemeliharaan
- Keamanan
- Inspeksi
- Pelatihan
- Teknik

Tidak ada skor spesifik yang menunjukkan kepatuhan atau ketidakpatuhan terhadap API maupun OSHA. Skor 1.000 sama dengan pencapaian keunggulan dalam masalah PSM yang memengaruhi integritas mekanik.

2.2.7 Consequence of Failure (CoF)

Consequence of Failure (CoF) dilakukan untuk memperkirakan konsekuensi yang mungkin terjadi pada peralatan. Menghitung CoF juga digunakan untuk menetapkan prioritas untuk inspeksi program. Terdapat dua metodologi perhitungan CoF. Metodologi CoF tingkat 1 digunakan untuk daftar cairan berbahaya yang ditentukan. Metodologi CoF tingkat 2 digunakan untuk daftar cairan berbahaya dengan kisaran yang lebih luas dengan perhitungan yang lebih teliti. Konsekuensi kegagalan dapat disajikan dalam bentuk kegagalan area atau kegagalan financial.

2.2.7.1 Kategori Consequences

Terdapat beberapa kategori konsekuen yang dianalisa, sebagaimana dijelaskan sebagai berikut.

- Flammable and Explosive Consequences

  Flammable and explosive consequence dihitung dengan menggunakan *event tree* untuk menentukan probabilitas dari berbagai hasil (contoh. Kebakaran kolam, kebakaran kilat, ledakan awan uap), dikombinasikan dengan pemodelan komputer untuk menentukan besarnya konsekuensi. Area konsekuensi dapat ditentukan berdasarkan cedera personil yang serius dan kerusakan komponen akibat radiasi dan ledakan termal. Kerugian finansial ditentukan berdasarkan area yang terkena dampak rilis.

- Toxic Consequences

  Toxic consequence dihitung dengan menggunakan pemodelan komputer untuk menentukan besarnya area konsekuensi sebagai akibat dari paparan berlebih kepada personel terhadap konsentrasi racun dalam uap. Jika cairan mudah terbakar dan beracun, probabilitas kejadian toksik mengasumsikan bahwa pelepasannya dinyalakan, konsekuensi toksik dapat diabaikan (misal. Racun terbakar oleh api). Kerugian finansial ditentukan berdasarkan area yang terkena dampak.
- Non-flammable, Non-toxic Consequences

  Non-flammable, non-toxic consequences dipertimbangkan karena masih dapat menimbulkan dampak serius. Konsekuensi dari percikan kimiawi dan luka bakar uap suhu tinggi ditentukan berdasarkan cedera serius pada personel. Ledakan fisik dan ledakan mendidih cairan uap juga dapat menyebabkan cedera serius pada personil dan kerusakan komponen.
- Financial Consequences

  Financial consequences termasuk kerugian diakibatkan gangguan bisnis dan biaya yang terkait dengan pelepasan ke lingkungan. Konsekuensi gangguan bisnis diperkirakan sebagai fungsi dari hasil area konsekuensi yang mudah terbakar dan tidak mudah terbakar. Konsekuensi lingkungan ditentukan secara langsung dari massa yang tersedia untuk rilis atau dari laju rilis.

2.2.7.2 Perhitungan *Consequences of Failure*

API RP 581 mencantumkan langkah-langkah perhitungan dari *consequence of failures* yang mana dikutip pada tabel berikut.

Tabel 2.2 *Consequence of failures analysis steps*

Step	Description
1	Determine the released fluid and its properties, including the release phase.
2	Select a set of release hole sizes to determine the possible range of consequence in the risk calculation
3	Calculate the theoritical release rate
4	Estimate the total amount of fluid available for release
5	Determine the type of release, continuous or instantaneous, to determine the method used for modelling the dispersion and consequence
6	Estimate the impact of detection and isolation systems on release magnitude.
7	Determine the release rate and mass for the consequence analysis
8	Calculate flammable/explosive consequence
9	Calculate toxic consequence

Step	Description
10	Calculate non-flammable, non-toxic consequence
11	Determine the final probability weighted component damage and personnel injury consequence areas
12	Calculate financial consequence

2.2.8 Program Inspeksi

Inspeksi adalah kegiatan yang dilakukan untuk memverifikasi bahwa bahan, fabrikasi, pemeriksaan, pengujian, perbaikan, dan data lainnya relevan dengan peralatan, sesuai dengan kode yang berlaku, teknik, dan prosedur tertulis pemilik-pengguna. Untuk kegiatan inspeksi sendiri, ada 3 yaitu inspeksi internal, on-stream dan eksternal. Inspeksi internal adalah inspeksi harus dilakukan pada saat alat tidak beroperasi. Sedangkan inspeksi on-stream dilakukan pada saat peralatan sedang beroperasi. Inspeksi eksternal dilakukan hanya menggunakan visual untuk mengecek apakah kondisi struktural atau eksternal dari alat dalam kondisi yang baik (API 510, 2014).

2.2.8.1 Kategori Inspeksi

Inspeksi dilaksanakan dengan tujuan mengurangi risiko dari equipment dan mendapatkan informasi terkini mengenai kondisi equipment tersebut. Kategori akurasi dari metode inspeksi itulah yang disebut dengan *inspection effectiveness*. Setiap *damage factor* memiliki *inspection effectiveness* masing-masing yang dijelaskan pada Annex 2.C API RP 581. Berikut adalah salah satu contoh *inspection effectiveness* untuk *sulfide stress cracking*.

Table 2.3 Inspection effectiveness untuk sulfide stress cracking

Kategori Inspeksi	Kategori	Inspeksi Intrusive	Inspeksi Non-Intrusif
A	Highly effective	Untuk las / area las yang dipilih: 100% WFMT / ACFM dengan follow up terhadap seluruh indikasi relevan.	Untuk las / area las yang dipilih: 100% ultrasonic scanning secara otomatis atau manual.
B	Usually effective	Untuk las / area las yang dipilih: >75% WFMT / ACFM dengan follow up terhadap seluruh indikasi relevan.	Untuk las / area las yang dipilih: >75% ultrasonic scanning secara otomatis atau manual. **ATAU** >75% AE testing dengan follow up di seluruh indikasi relevan.
C	Fairly effective	Untuk las / area las yang dipilih: >35% WFMT / ACFM dengan follow up terhadap seluruh indikasi relevan.	Untuk las / area las yang dipilih: >35% ultrasonic scanning secara otomatis atau manual. **ATAU**

Kategori Inspeski	Kategori	Inspeksi Intrusive	Inspeksi Non-Intrusif
			>35% tes radiographic.
D	Poorly effective	Untuk las / area las yang dipilih: >10% WFMT / ACFM dengan follow up terhadap seluruh indikasi relevan.	Untuk las / area las yang dipilih: >35% ultrasonic scanning secara otomatis atau manual. **ATAU** >10% tes radiographic.
E	Ineffecti -ve	Teknik inspeksi yang tidak efektif	Teknik inspeksi yang tidak efektif

2.2.8.2 Metode Inspeksi

Menurut Sulardi (2019), untuk jenis inspeksi *on-stream* berupa inspeksi visual dan untuk jenis *off-stream* biasanya dideskripsikan sebagai teknik *nondestructive evaluation (NDE), nondestructive testing (NDT), atau nondestructive Inspection (NDI)*[17]. Berikut ini merupakan penjelasan jenis-jenis metode inspeksi:

1. Visual Inspection[18]

   Visual Testing (VT) adalah metode yang digunakan secara ekstensif untuk mengevaluasi kondisi atau kualitas suatu barang. Hal ini mudah dilakukan, murah dan biasanya tidak memerlukan peralatan khusus. Pengujian visual dapat dilakukan dengan mata sendiri atau dapat ditingkatkan dengan penggunaan sistem optik seperti *magnifiers* dan mikroskop.

   Inspeksi visual harus dilakukan di lingkungan yang bersih dan nyaman dengan penerangan yang memadai. Harus ada akses ke bagian-bagian yang akan diperiksa dan harus memperhatiakan keselamatan, posisi kerja, dan kondisi atmosfir. Potongan uji harus bersih dan bebas dari pelapis pelindung. Berikut adalah jenis-jenis inspeksi visual:

   - Direct Visual Examination

     Direct visual examination biasanya dapat dilakukan ketika akses cukup untuk menempatkan mata dalam jarak 24 inch (600 mm) dari permukaan yang akan diperiksa dan pada sudut tidak kurang dari 30 derajat ke permukaan benda yang akan diperiksa. Mirror dapat digunakan untuk meningkatkan sudut penglihatan, dan alat bantu seperti lensa pembesar dapat digunakan untuk membantu pemeriksaan. Penerangan (cahaya putih alami atau tambahan) untuk bagian tertentu. Intensitas

[17] Sulardi. 2019. "Inspeksi Industri Pengolahan Migas". Jurnal Jieom.
[18] ASME Section V. 2011. Nondestructive Examination: ASME Boiler and Pressure Vessel Committee on Nondestructive Examination. Three Park Avenue, New York: The American Society of Mechanical Engineers.

cahaya minimum pada permukaan pemeriksaan harus 100 footcandles (1000 lux).

- Remote Visual Examination

  Pemeriksaan dapat menggunakan alat bantu visual seperti cermin, teleskop, *borescopes*, serat optik, kamera, atau instrumen lainnya yang sesuai. Sistem tersebut harus memiliki kemampuan resolusi setidaknya setara dengan yang dapat diperoleh dengan pengamatan visual secara langsung.

- Translucent Visual Examination

  Metode pemeriksaan visual transparan menggunakan bantuan pencahayaan buatan, yang bisa terkandung dalam iluminator yang menghasilkan arah cahaya. Iluminator harus memberikan intensitas cahaya yang akan menerangi dan meredupkan cahaya secara merata pada area yang diperiksa. Pencahayaan sekitar harus diatur sedemikian rupa sehingga tidak ada silau atau refleksi dari permukaan yang sedang diperiksa. Sumber cahaya buatan harus memiliki intensitas yang cukup untuk memungkinkan "menyalakan" setiap tembus variasi ketebalan laminasi.

2. Liquid Penetrant Inspection

   Metode ini merupakan metode pemeriksaan nondestructive *evaluation* (NDE) yang menggunakan pewarna *fluorescent* untuk menampakan kerusakan permukaan pada bagian-bagian dan peralatan yang mungkin tidak terlihat. Teknik ini bekerja melalui prinsip "aksi kapiler", suatu proses di mana cairan mengalir ke ruang sempit tanpa bantuan dari gravitasi. Karena ini adalah salah satu teknik NDE termudah dan paling murah untuk dilakukan, LPE adalah salah satu teknik inspeksi yang paling umum digunakan di banyak industri, termasuk minyak dan gas.

3. Magnetic Particle Inspection (MPI)

   Metode *magnetic particle inspection* (MPI) merupakan suatu metode inspeksi yang memanfaatkan prinsip gaya magnet. Metode ini sama dengan metode *liquid penetrant inspection* yang hanya mampu mendeteksi cacat permukaan. Pada inspeksi ini digunakan sebuah magnet (*yoke*) yang digunakan untuk mendeteksi cacat material. Terdapat dua jenis MPI sebagai berikut:

- Wet Magnetic Particle Testing (WMPT)

  Inspeksi partikel magnetik basah, melibatkan pengaplikasian partikel saat tersuspensi dalam pembawa cairan. Inspeksi partikel magnetik basah paling umum dilakukan menggunakan unit inspeksi stasioner, basah, horizontal tetapi suspensi juga tersedia dalam kaleng semprot untuk digunakan dengan *yoke* elektromagnetik.

- Dry Magnetic Particle Testing (DMPT).

  Dalam teknik pengujian partikel magnetik ini, partikel kering ditaburkan ke permukaan benda uji saat benda tersebut dimagnetisasi. Inspeksi partikel kering sangat cocok untuk inspeksi yang dilakukan pada permukaan kasar. Ketika *yoke* elektromagnetik digunakan, arus AC atau setengah gelombang DC menciptakan medan magnet yang memberikan mobilitas pada serbuk.

4. Ultrasonic Testing (UT) Inspection

    Ultrasonic Testing (UT) adalah *nondestructive examination (NDE)* yang menggunakan gelombang ultrasonik pendek dan frekuensi tinggi untuk mengidentifikasi cacat pada suatu bahan. Umumnya bekerja dengan memancarkan gelombang ke material. Dengan mengukur gelombang ini, sifat-sifat material dan kerusakan internal dapat diidentifikasi. Jenis-jenis inspeksi ini meliputi:

    - Advanced Ultrasonic Backscatter Technique (AUBT)

        Advanced Ultrasonic Backscatter Technique (AUBT) adalah teknik UT yang dikembangkan untuk mendeteksi kerusakan dari *High-Temperature Hydrogen Attack (HTHA).* Teknik ini untuk digunakan dalam bejana tekan dan perpipaan. Teknik ini memanfaatkan frekuensi tinggi, *probe UT broadband* dan osiloskop digital.

    - Phased Array Ultrasonic Testing (PAUT)

        Phased Array Ultrasonic Testing (PAUT) adalah teknik UT yang menggunakan *probe* UT yang terdiri dari berbagai elemen kecil. Setiap elemen dalam sistem PAUT dapat bergetar secara individual. Metode ini dilakukan dengan perhitungan waktu komputer, melalui proses yang dikenal sebagai penahapan. Hal tersebut memungkinkan sistem untuk mengarahkan sinar terfokus melalui berbagai sudut dan jarak fokus.

    - Long Range Ultrasonic Testing (LRUT)

        Long Range Ultrasonic Testing (LRUT) adalah metode UT yang dikembangkan untuk memungkinkan pengujian materi dalam volume besar dari satu titik uji. Metode ini bekerja dengan cara memperbaiki cincin transduser secara seragam di sekitar pipa. Cincin ini kemudian menghasilkan serangkaian gelombang frekuensi rendah. Gelombang kemudian dapat merambat secara simetris di sepanjang sumbu pipa. Metode ini dapat memberikan cakupan lengkap dari dinding pipa.

    - Internal Rotating Inspection System (IRIS)

        Internal Rotating Inspection System (IRIS) adalah teknik ultrasonik yang digunakan untuk mendeteksi korosi pada pipa dan tabung. Dengan menggunakan *probe* yang dimasukkan ke bagian dalam pipa atau tabung yang dapat menghasilkan gelombang suara. *Probe* akan bergerak melalui pipa, memindai sambil berjalan.

    - Dry-Coupled Ultrasonic Testing (DCUT)

        Dry-Coupled Ultrasonic Testing (DCUT) adalah alternatif, metode berbiaya rendah yang tidak memerlukan cairan kopel untuk memeriksa bahan logam dan non logam. Selain itu, transduser DCUT mampu menahan tegangan tinggi. DCUT adalah metode serbaguna yang dapat dilakukan menggunakan transduser fleksibel, kontak, roda, atau jarak jauh.

- Rapid Ultrasonic Gridding (RUG)

  Rapid Ultrasonic Gridding (RUG) adalah metode NDE untuk melakukan ketebalan ultrasonik di mana beberapa *probe* ketebalan ultrasonik digunakan secara bersamaan, untuk secara cepat mengumpulkan hasil pengukuran ketebalan di ruangan yang telah ditentukan atau ad hoc. Seperti metode UT lainnya, RUG merekam data A-Scan mentah, yang dapat disajikan dalam mode B-Scan atau C-Scan atau digunakan untuk membuat representasi visual sebagai model 3-D. Namun, RUG mampu menangkap beberapa titik data A-Scan dengan kecepatan yang jauh lebih cepat daripada teknik pengukuran ketebalan tradisional.

5. Radiographic Inspection

   Radiographic Testing (RT) adalah *nondestructive examination (NDE)* yang melibatkan penggunaan sinar-x atau sinar gamma untuk melihat struktur internal suatu komponen. Dalam industri petrokimia, RT sering digunakan untuk memeriksa mesin, seperti bejana tekan dan katup, untuk mendeteksi adanya kekurangan. RT juga digunakan untuk memeriksa perbaikan lasan. Jenis-jenis inspeksi ini meliputi:

   - Conventional or Film Radiography

     Radiografi konvensional menggunakan film sensitif yang bereaksi terhadap radiasi yang dipancarkan untuk menangkap gambar dari bagian yang sedang diuji. Gambar ini kemudian dapat diperiksa untuk bukti kerusakan atau kecacatan. Keterbatasan terbesar untuk teknik ini adalah bahwa film hanya dapat digunakan sekali dan mereka membutuhkan waktu lama untuk diproses dan ditafsirkan.

   - Digital Radiography

     Tidak seperti radiografi konvensional, radiografi digital tidak memerlukan film. Sebaliknya, ia menggunakan detektor digital untuk menampilkan gambar radiografi pada layar komputer yang hampir secara instan. Hal tersebut memungkinkan waktu yang lebih singkat sehingga gambar dapat ditafsirkan lebih cepat. Selain itu, gambar digital memiliki kualitas yang jauh lebih tinggi jika dibandingkan dengan gambar radiografi konvensional. Dengan kemampuan untuk menangkap gambar yang sangat berkualitas, teknologi ini dapat digunakan untuk mengidentifikasi cacat pada suatu bahan, benda asing dalam suatu sistem, memeriksa perbaikan las, dan memeriksa korosi pada isolasi. Empat teknik radiografi digital yang paling umum digunakan dalam industri pengolahan minyak & gas dan kimia adalah sebagai berikut:

     - Computed Tomography (CT)

       Computed tomography (CT) adalah teknik yang membutuhkan ratusan hingga ribuan (tergantung pada ukuran komponen) dari pemindaian radiografi 2D dan menumpangkannya untuk membuat gambar radiografi 3D. Dalam lingkungan industri, CT dapat dicapai dengan dua cara. Dalam satu metode, komponen yang akan diperiksa tetap diam sementara sumber radiasi dan detektor x-ray berputar di sekitar komponen. Teknik ini lebih mungkin digunakan untuk komponen besar. Metode kedua terdiri dari sumber radiasi dan detektor x-ray yang diam sementara komponen diputar 360 derajat. Teknik kedua ini lebih berguna ketika komponennya kecil atau memiliki geometri yang kompleks. Meskipun teknologi ini tepat waktu, mahal, dan membutuhkan sejumlah besar penyimpanan data, CT memberikan gambar yang sangat akurat, dapat diulang dan direproduksi, dan meminimalkan kesalahan manusia.

- Radiografi Real-time (RTR)

  Radiografi Real-time (RTR), seperti namanya, adalah bentuk radiografi digital yang terjadi secara *real time*. RTR bekerja dengan memancarkan radiasi melalui suatu objek. Sinar-sinar ini kemudian berinteraksi dengan layar fosfor khusus atau detektor panel datar yang mengandung sensor mikro-elektronik. Interaksi antara panel dan radiasi menciptakan gambar digital yang dapat dilihat dan dianalisis secara *real time*.

- Computed Radiography (CR)

  Computed radiography (CR) menggunakan pelat fosfor yang menggantikan film dalam teknik radiografi konvensional. Teknik ini jauh lebih cepat daripada radiografi film tetapi lebih lambat dari *direct radiography*. CR memerlukan beberapa langkah ekstra dibandingkan dengan *direct radiography*. Pertama, secara tidak langsung menangkap gambar komponen pada pelat fosfor, kemudian mengubah gambar menjadi sinyal digital yang dapat divisualisasikan pada monitor komputer. Kualitas gambar lumayan bagus tetapi dapat ditingkatkan menggunakan alat dan teknik yang sesuai (yaitu, menyesuaikan kontras, kecerahan, dan lain-lain tanpa mengurangi integritas). Penting untuk mengetahui bagaimana alat, seperti menyesuaikan kontras yang mempengaruhi gambar. Ketelitian juga harus diperhatikan untuk memastikan cacat kecil tetap terlihat setelah peningkatan dilakukan.

- Direct Radiography (DR)

  Direct Radiography (DR) juga merupakan bentuk radiografi digital dan sangat mirip dengan computed radiography. Perbedaan utama terletak pada bagaimana gambar yang ditangkap. Di DR, detektor panel datar digunakan untuk menangkap gambar secara langsung dan menampilkan gambar itu di layar komputer. Meskipun metode ini cepat dan menghasilkan gambar berkualitas tinggi, metode ini lebih mahal daripada radiografi komputer.

6. Electromagnetic Inspection

   Jenis-jenis inspeksi dengan menggunakan metode ini meliputi:

- Magnetic Flux Leakage (MFL)

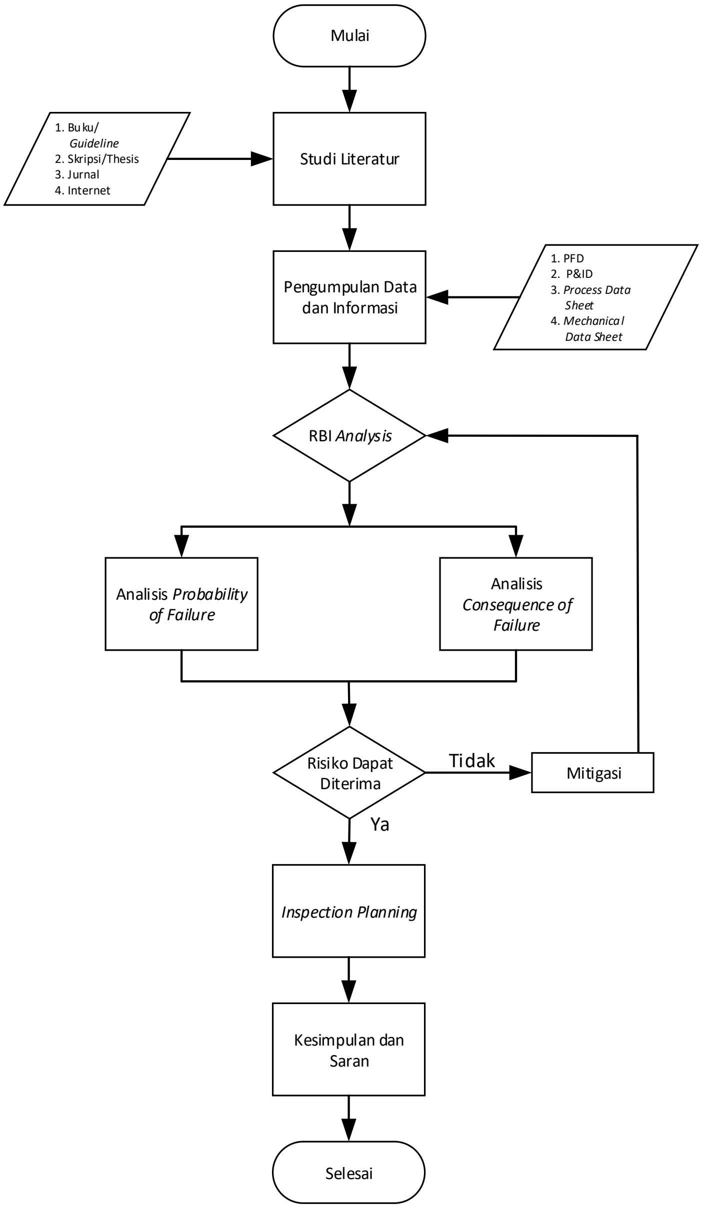
  Magnetic flux leakage (MFL) metode pengujian *nondestructive examination (NDE)* yang digunakan untuk mendeteksi dan menilai korosi, pitting dan kehilangan dinding di tangki penyimpanan logam dan pipa dan jaringan pipa berlapis. Magnet yang kuat digunakan untuk memagnetisasi baja. Di daerah di mana ada korosi atau logam yang hilang, medan magnet "bocor" dari baja. Alat MFL menggunakan sensor yang ditempatkan di antara kutub magnet untuk menentukan bidang kebocoran.

- *Eddy current*

  Secara umum, inspeksi *eddy current* adalah metode pengujian non-destruktif yang menggunakan prinsip induksi elektromagnetik. Ketika arus bolak-balik diterapkan ke konduktor, dalam kasus *probe eddy current*, medan magnet berkembang di sekitarnya yang berubah dalam intensitas sebagai arus alternatif. Jika konduktor lain, dalam hal ini bahan yang diuji, didekatkan dengan bidang pertama, arus akan diinduksi di dalamnya juga. Jika ada kekurangan pada bahan ini maka *eddy current* yang berasal darinya akan terdistorsi.

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 risiko dan perencanaan inspeksi seperti pada gambar 3.1.



Gambar 3.1 Skema pengerjaan penelitian

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 literatur dilakukan dengan cara membaca dan merangkum isi buku/*guideline*, skripsi/thesis yang berhubungan dengan tugas akhir dan mencari jurnal pada *science direct* ataupun mencari definisi-definisi istilah dalam tugas akhir. Tabel 3.1 menunjukkan hasil studi literatur yang telah dilakukan.

Tabel 3.1 Hasil studi literatur

Referensi	Hasil yang didapatkan
Technical Inspection Engineering and Risk Based Inspection in order to optimize inspection plans	Referensi tambahan dalam menyusun latar belakang, kajian pustaka dan metodologi penelitian
Guideline : a. API 510 b. API 580 c. API 581	Pedoman dalam menyusun langkah-langkah dalam perhitungan *Risk Based Inspection*
Peraturan Pemerintah khususnya Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 38 Tahun 2017	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.
Pustaka Internet	Definisi istilah *pressure vessel*, jenis-jenis *pressure vessel*, jenis-jenis inspeksi dan lain-lain.

3.2 Pengumpulan Data

Metode pengumpulan data dilakukan dengan mengumpulkan data konstruksi dan operasional *equipment* dari perusahaan. Data yang dibutuhkan meliputi:

- PFD, P&ID *production separator.*
- *Process data sheet.*
- *Mechanical data sheet.*
- *Heat Material Balance.*
- *Material selection proposal* dari peralatan tersebut.
- *Mechanical calculation report* dari *production separator.*
- Komposisi kimia dari fluida yang melewati *production separator.*

Berikut adalah data komposisi kimia pada peralatan yang akan dianalisa. Data ini akan digunakan untuk *screening criteria damage factor*.

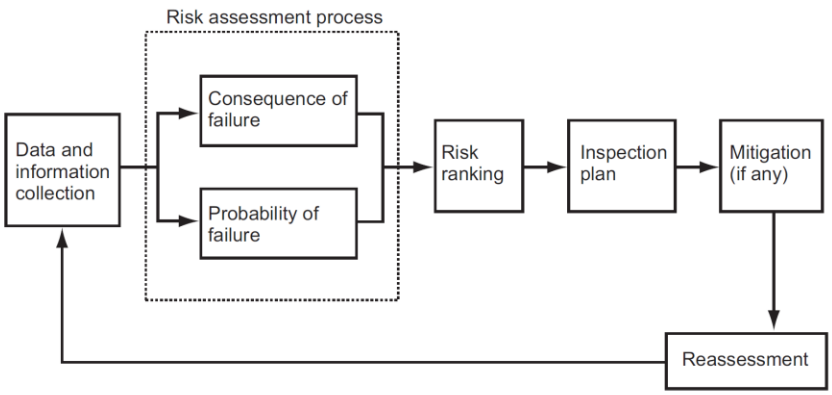
Tabel 3.2 Komposisi Kimia

Composition	% Mol	Composition	% Mol
n-Heptane	0,1434	*H2S*	0,1
n-Octane	0.5205	*CO2*	5
n-Nonane	0,3375	*Methane*	81,3444
n-Decane	0,2183	*Nitrogen*	0,7929
C11+	0,4	*Ethane*	3,9499
TEGlycol	0	*Propane*	2,0128
CS2	0,0002	*H2O*	2,3129
t-B-Mercaptan	0,0002	*i - Butane*	0,5095
Benzene	0,0336	*n- Butane*	0,7434
Toluene	0,3663	*i - Pentane*	0,4269
p-Xylene	0	*n - Pentane*	0,3534
aMDEA	0	*n - Hexane*	0,4341

Data-data yang telah didapatkan nantinya akan digunakan dalam melakukan *screening damage mechanism*, perhitungan *probability of failure*, *consequence of failure*, risiko, dan penjadwalan program inspeksi.

3.3 RBI Analysis

Setelah melakukan pengumpulan data, analisis RBI dapat dimulai dengan menghitung *probability of failure* dan *consequence of failure*. Gambar 3.2 berikut akan mengambarkan proses analisis RBI. Dimana proses selanjutnya akan dijelaskan pada sub bab berikutnya.



Gambar 3.2 Risk based inspection planning method
Sumber: API Recommenced Practice 580

3.4 Analisis *Probability*

Perhitungan *probability of failure* dipengaruhi oleh *generic failure frequency*, *damage factor*, dan *management systems factor*. Persamaan (3.1) berikut adalah persamaan untuk menghitung *probability of failure.*

$$Pf\ (t) = gff \times Fms \times Df\ (t) \qquad (3.1)$$

3.4.1 Penentuan Generic Failure Frequency

Generic failure frequency dimaksudkan untuk menjadi perwakilan frekuensi kegagalan dari kegagalan untuk mekanisme kerusakan tertentu yang disebabkan oleh lingkungan operasi dari peralatan tersebut dan disediakan untuk beberapa ukuran lubang untuk berbagai jenis peralatan. Tabel 01.B.1 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE adalah tabel nilai *generic failure frequency* untuk beberapa peralatan.

3.4.2 Menghitung Damage Factor.

Untuk menghitung nilai *damage factor* dapat dimulai dengan melakukan *screening criteria* berdasarkan Part 2 API RP 581. Terdapat 21 jenis *damage factor* yang dapat terjadi. Jenis *damage mechanism* pada peralatan tergantung pada kondisi peralatan tersebut, baik komposisi kimia yang terkandung dalam fluida yang melewatinya maupun bahan pembuat peralatan tersebut. Tabel 3.3 berikut adalah *screening criteria* dari beberapa *damage factor.*

Tabel 3.3 Damage factor screening criteria

No	Damage Factor	Screening Criteria	Yes/No
1	Thinning Damage Factor	All components should be checked for thinning.	Yes
2	Component Lining Damage Factor	If the component has an inorganic or organic lining, then the component should be evaluated for lining damage.	Yes
3	Scc Damage Factor – Sulfide Stress Cracking	If the component's material of construction is carbon or low alloy steel and the process environment contains water and H2S in any concentration, then the component should be evaluated for susceptibility to SSC.	Yes
4	Scc Damage Factor – Hic/Sohic-H2s	If the component's material of construction is carbon or low alloy steel and the process environment contains water and H2S in any concentration, then the component should be evaluated for susceptibility to HIC/SOHICH2S cracking.	Yes

Berikut adalah penjelasan mekanisme perhitungan untuk beberapa *damage factor:*

3.4.2.1 Thinning Damage Factor

Thinning merupakan degradasi logam karena lingkungannya yang mengakibatkan penipisan ketebalan logam tersebut, dengan kata lain korosi. Terdapat beberapa mekanisme thinning yang dapat terjadi untuk mengetahui apakah thinning terjadi secara local atau general. Tipe thinning tersebut berpengaruh pada penentuan inspeksi untuk peralatan. Berikut adalah langkah-langkah perhitungan thinning:

- Menentukan *furnished thickness*, t, dan usia komponen terhitung dari waktu instalasi, age.
- Menentukan *corrosion rate* untuk *base material*, Cr_{bm}, berdasarkan material konstruksi dan lingkungannya, serta *cladding/overlay corrosion rate*, Cr_{cm}. Terdapat beberapa skenario untuk menentukan laju korosi berdasarkan data yang tersedia dan kondisi dari peralatan itu sendiri, seperti:

- Perhitungan laju korosi dari perusahaan.
- Perkiraan laju korosi berdasarkan saran para ahli.
- Perhitungan laju korosi berdasarkan Annex 2B API RP 581. Tabel 01.B.2 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE akan menjelaskan mekanisme-mekanisme thinning yang dapat terjadi sesuai dengan Annex 2.B Part 2 API RP 581. Apabila terdapat beberapa mekanisme pada sebuah peralatan, maka nilai laju korosi maksimum yang harus digunakan.

- Menentukan waktu operasi, age_{tk}, sejak ketebalan komponen pada inspeksi terakhir, t_{rdi}. Jika tidak ada perhitungan ketebalan komponen, maka t_{rdi} = t, dan age_{tk} = age.
- Untuk *cladding/weld overlay pressure vessel components*, hitung usia untuk habisnya ketebalan *cladding/weld overlay* pada inspeksi terakhir, age_{rc}:

$$age_{rc} = \max\left[\left(\frac{t_{rdi} - tbm}{C_{r\,cm}}\right), 0.0\right] \quad (3.2)$$

- Menentukan ketebalan minimum dari komponen, t_{min}.
  Untuk menentukan ketebalan minimum dapat menggunakan kode standar dari komponen maupun hasil perhitungan perusahaan.
- Menentukan parameter A_{rt} (age relating thickness).
  Untuk komponen dengan cladding/weld overlay dengan $age_{tk} \geq age_{rc}$ menggunakan persamaan:

$$A_{rt} = \frac{Cr_{c,m}.\ age_{tk} + Cr_{b,m}.\ (age_{tk} - age_{rc})}{t_{rdi}} \quad (3.3)$$

- Menghitung nilai flowstress, FS^{thin}.

$$FS^{Thin} = \frac{(YS+TS)}{2}.\ E.1{,}1 \quad (3.4)$$

- Menghitung parameter strength ratio, SR^{thin}.

$$SR_P^{Thin} = \frac{S.E}{FS^{Thin}}.\ \frac{Max\,(t_{min}, t_c)}{FS^{Thin}} \quad (3.5)$$

- Mentukan jumlah dari inspeksi untuk setiap efektifitas dari inspeksi. N_A^{Thin}, ,N_B^{Thin}, N_C^{Thin} , N_D^{Thin} berdasarkan data dari perusahaan. Untuk menentukan lingkup dari inspection effectiveness dapat dilihat pada tabel 01.B.3 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE
- Menghitung *factor inspection effectivenes*, $I_1^{Thin}, I_2^{Thin}, I_3^{Thin}$, menggunakan persamaan (3.5), (3.6), (3,7) dengan *prior probabilities*, $Pr_{p1}^{Thin}, Pr_{p2}^{Thin}, Pr_{p3}^{Thin}$, dari tabel 01.B.4 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE, serta jumlah inspeksi, $N_A^{Thin}, N_B^{Thin}, N_C^{Thin}, N_D^{Thin}$ dari langkah sebelumnya. Untuk nilai Conditional probability didapatkan dari tabel 01.B.5 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE.

$$I_1^{Thin} = Pr_{P1}^{Thin}(Co_{P1}^{ThinA})^{N_A^{Thin}}(Co_{P1}^{ThinB})^{N_B^{Thin}}(Co_{P1}^{ThinC})^{N_C^{Thin}}(Co_{P1}^{ThinD})^{N_D^{Thin}} \quad (3.6)$$

$$I_2^{Thin} = Pr_{P2}^{Thin}(Co_{P2}^{ThinA})^{N_A^{Thin}}(Co_{P2}^{ThinB})^{N_B^{Thin}}(Co_{P2}^{ThinC})^{N_C^{Thin}}(Co_{P2}^{ThinD})^{N_A^{Thin}} \quad (3.7)$$

$$I_3^{Thin} = Pr_{P3}^{Thin}(Co_{P3}^{ThinA})^{N_A^{Thin}}(Co_{P3}^{ThinB})^{N_B^{Thin}}(Co_{P3}^{ThinC})^{N_C^{Thin}}(Co_{P3}^{ThinD})^{N_A^{Thin}} \quad (3.8)$$

- Menghitung *Posterior Probability*, $Po_{p1}^{Thin}, Po_{p2}^{Thin}, Po_{p3}^{Thin}$.

$$Po_{p1}^{Thin} = \frac{I_1^{Thin}}{I_1^{Thin} + I_2^{Thin} + I_3^{Thin}} \quad (3.9)$$

$$Po_{p2}^{Thin} = \frac{I_2^{Thin}}{I_1^{Thin} + I_2^{Thin} + I_3^{Thin}} \quad (3.10)$$

$$Po_{p3}^{Thin} = \frac{I_3^{Thin}}{I_1^{Thin} + I_2^{Thin} + I_3^{Thin}} \quad (3.11)$$

- Menghitung parameter, $ß_1^{Thin}, ß_2^{Thin}, ß_3^{Thin}$, dengan persamaan (3.11), (3.12), dan (3.13) dengan nilai $COV_{\Delta t} = 0.2$, $COV_{sf} = 0.2$, dan $COV_P = 0.05$.

$$ß_1^{Thin} = \frac{1-D_{S1} \cdot A_{rt}-SR_P^{Thin}}{\sqrt{D_{S1}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2+(1-D_{S1} \cdot A_{rt})^2 \cdot COV_{sf}{}^2+(SR_P^{Thin})^2 \cdot (COV_P)^2}} \quad (3.12)$$

$$ß_2^{Thin} = \frac{1-D_{S2} \cdot A_{rt}-SR_P^{Thin}}{\sqrt{D_{S2}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2+(1-D_{S2} \cdot A_{rt})^2 \cdot COV_{sf}{}^2+(SR_P^{Thin})^2 \cdot (COV_P)^2}} \quad (3.13)$$

$$ß_3^{Thin} = \frac{1-D_{S3} \cdot A_{rt}-SR_P^{Thin}}{\sqrt{D_{S3}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2+(1-D_{S3} \cdot A_{rt})^2 \cdot COV_{sf}{}^2+(SR_P^{Thin})^2 \cdot (COV_P)^2}} \quad (3.14)$$

- Untuk komponen tank bottom, tentukan base damage factor untuk thinning menggunakan Tabel 4.8 dari API RP 581 Part 2 dan perhitungan A_{rt} parameter dari langkah 6.
- Menghitung base damage factor, D_{fB}^{Thin},

$$D_{fb}^{Thin} = [\frac{\left(Po_{P1}^{Thin}\Phi(-\beta_1^{Thin})\right)+\left(Po_{P2}^{Thin}\Phi(-\beta_2^{Thin})\right)+\left(Po_{P3}^{Thin}\Phi(-\beta_3^{Thin})\right)}{1.56E-0.4} \quad (3.15)$$

- Menentukan DF untuk thinning, D_f^{Thin}. (3.16)

$$D_f^{Thin} = \text{Max}[(\frac{(D_{fb}^{Thin} \cdot F_{IP} \cdot F_{DL} \cdot F_{WD} \cdot F_{AM} \cdot F_{SM})}{F_{OM}}),0.1]$$

- Tentukan DF Total untuk thinning, D_{f-gov}^{Thin}.
  Apabila terdapat internal liner damage factor,
  $$D_{f-gov}^{Thin} = \min[D_f^{Thin}, D_f^{elin}] \quad (3.17)$$
  Apabila tidak terdapat internal liner damage factor
  $$D_{f-gov}^{Thin} = D_f^{Thin} \quad (3.18)$$

3.4.2.2 Component Lining Damage Factor

Jika komponen memiliki lapisan anorganik atau organik, maka komponen tersebut harus dievaluasi untuk *lining damage factor*. Lapisan ini berfungsi sebagai pelindung pada peralatan dan akan menipis seiring waktu, sehingga memiliki umur yang terbatas. Berikut adalah langkah-langkah untuk menghitung *lining damage factor:*

- Menentukan jenis lining dan waktu dalam layanan, age, umur lapisan berdasarkan instalasi lapisan tanggal atau tanggal inspeksi terakhir uuntuk efektivitas A atau B. Untuk jenis lining dapat dilihat pada tabel 01.B.6 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE.
- Menentukan nilai dasar *lining damage factor*, menggunakan tabel 01.B.7 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE sebagaimana berlaku, berdasarkan usia dan jenis lapisan dari langkah 1.
- Menentukan *damage factor* untuk kerusakan *lining*, menggunakan persamaan (3.18).
  $$DF_f^{elin} = DF_{fB}^{elin} \ x \ F_{LC} \ x \ F_{OM} \quad (3.19)$$

  Adjustmen factor ditentukan seperti yang dijelaskan di bawah ini:
- *Adjustment for lining condition dapat ditentukan berdasarkan tabel 3.4 berikut.*

Tabel 3.4 Lining Condition Adjustment

Qualitative Condition	Description	Adjustment Multiplier - FLC
Poor	The lining has either had previous failures or exhibits conditions that may lead to failure in the near future. Repairs to previous failures are not successful or are of poor quality	10
Average	The lining is not showing signs of excessive attack by any damage mechanisms. Local repairs may have been performed, but they are of good quality and have successfully corrected the lining condition.	2
Good	The lining is in "like new" condition with no signs of attack by any damage mechanisms. There has been no need for any repairs to the lining.	1

- *Adjustment for On-Line Monitoring*
  Jika komponen mendapatkan perlakuan *online monitoring* maka FOM = 0,1; jika tidak FOM = 1,0.

3.4.2.3 Sulfide Stress Cracking Damage Factor

Sulfide stress cracking (SSC) didefinisikan sebagai keretakan diakibatkan kombinasi tensile stress dan lingkungan yang mengandung air dan H2S. SSC adalah bentuk hydrogen stress cracking yang dihasilkan dari penyerapan hidrogen atom yang dihasilkan oleh proses korosi sulfida pada permukaan logam. SSC biasanya lebih mudah terjadi pada baja berkekuatan tinggi (high strength/hardness) dalam endapan las keras atau heat affected zone (HAZ) dari baja berkekuatan rendah. Tingkat kerentanan terhadap SCC utamanya dipengaruhi fluks permeasi hidrogen pada baja. Kerentanan terhadap SCC juga dipengaruhi oleh pH dan konsentrasi H2S di air. Semakin jauh dari pH netral dan/atau semakin tinggi konsentrasi H2S, maka akan semakin rentan terhadap SSC. Berikut adalah langkah-langkah perhitungan sulfide stress cracking damage factor:

- Menentukan environmental severity (potential level dari hydrogen flux) untuk cracking berdasarkan konten H2S di air dan pH-nya. Penentuan dilakukan dengan data dari perusahaan dan tabel 3.5 berikut.

Tabel 3.5 Environmental severity – SCC

pH of water	Environmental severity as a function of H_2S content of water			
	< 50 ppm	50 to 1000 ppm	1000 to 10000 ppm	>10000 ppm
< 5,5	Low	Moderate	High	High
5,5 to 7,5	Low	Low	Low	Moderate
7,6 to 8,3	Low	Moderate	Moderate	Moderate
8,4 to 8,9	Low	Moderate	Moderate*	High*
> 9,0	Low	Moderate	High*	High*
Note: *If cyanides are present, increase the susceptibility to SSC one category for pH > 8,3 and H2S Concentrations greater than 1000ppm				

- Menentukan susceptibility untuk cracking dengan memperhatikan environmental severity di langkah 1, maksimum brinell hardness of weldments, dan kondisi PWHT komponen berdasarkan table 01.B.8 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE
- Menentukan severity index, SVI berdasarkan susceptibility.

Tabel 3.6 Severity Index

Susceptibility	Severity Index - S_{VI}
High	100
Medium	10
Low	1
None	0

- Menentukan waktu beroperasi, age, sejak inspeksi level A, B, atau C dilakukan dengan tidak adanya cracking atau cracking yang diperbaiki. Sedangkan untuk cracking terdeteksi tapi tidak diperbaiki harus dievaluasi dan rekomendasi inspeksi mendatang berdasarkan evaluasi FFS.
- Menentukan jumlah inspeksi dan efektivitasnya mengacu pada section 8.6.2 di API RP 581 Part 2 untuk inspeksi terakhir pada waktu beroperasi. Gabungkan nilai tersebut untuk efektivitas yang lebih tinggi berdasarkan section 3.4.3 di API RP 581 Part 2
- Menentukan base damage factor untuk sulfide stress cracking, D_{fb}^{scc}, berdasarkan severity indeks, efektivitas inspeksi, dan jumlah inspeksi, mengacu pada tabel 01.B.9 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE.
- Menentukan damage factor berdasarkan waktu operasi sejak inspeksi terakhir.

$$D_{f}^{scc} = D_{fB}^{scc}.(Max[age, 1.0])^{1.1} \quad (3.20)$$

3.4.2.4 Stress Corrosion Cracking – HIC/SOHIC-H2S

HIC/SOHIC – H2S merupakan singkatan dari *hydrogen-induced cracking dan stress oriented hydrogen-induced cracking* karena pengaruh H2S. HIC didefinisikan sebagai retakan internal bertahap yang menghubungkan hidrogen blister yang berdekatan pada bidang yang berbeda dalam logam, atau ke permukaan logam. HIC terjadi bukan karena stress eksternal, namun karena penumpukan tekanan internal dari hidrogen blister. Interaksi bidang dengan stress tinggi cenderung mengakibatkan keretakan yang menghubungkan hidrogen blister di bidang berbeda pada logam. Kerentanan terhadap HIC utamanya dipengaruhi oleh kadar sulfur pada logam tersebut. Semakin tinggi kadarnya, maka semakin rentan. Pun kerentanan terhadap HIC juga dipengaruhi (bukan yang utama) oleh pH dan konsentrasi H2S di air. Semakin jauh dari pH netral dan/atau semakin tinggi konsentrasi H2S, maka akan semakin rentan terhadap HIC.

SOHIC didefinisikan sebagai susunan blister yang tergabung karena hydrogen-induced cracking yang sejajar dengan arah ketebalan baja sebagai hasil dari tensile stress yang terjadi secara lokal. SOHIC merupakan gabungan HIC yang umumnya terjadi di base material yang berdekatan dengan HAZ, area tertinggi dari stress karena penumpukan internal pressure dan residual stress dari pengelasan. Sama halnya dengan HIC, kualitas dari logam (konten sulfur), serta konten H2S mempengaruhi kerentanan terhadap SOHIC. Sebagai tambahan, pengurangan residual stress karena post weld heat treatment (PWHT) dapat mengurangi kerentanan terhadap SOHIC. Berikut adalah langkah-langkah perhitungan HIC/SOHIC-H2S damage factor.

- Menentukan environmental severity (potential level dari hydrogen flux) untuk cracking berdasarkan konten H2S di air dan pH-nya. Gunakan tabel 3.5 untuk menyelesaikan langkah ini.
- Menentukan susceptibility untuk cracking dengan memperhatikan environmental severity di langkah 1, maksimum brinell hardness of

weldments, dan kondisi PWHT komponen berdasarkan table 01.B.10 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE.

- Menentukan severity index, SVI berdasarkan susceptibility. Gunakan tabel 3.6 untuk langkah ini.
- Menentukan waktu beroperasi, agetk, sejak inspeksi level A, B, atau C dilakukan dengan tidak adanya cracking atau cracking diperbaiki. Cracking terdeteksi tapi tidak diperbaiki harus dievaluasi dan rekomendasi inspeksi mendatang berdasarkan evaluasi FFS.
- Menentukan jumlah inspeksi dan efektivitasnya mengacu pada section 8.6.2 di API RP 581 Part 2 untuk inspeksi terakhir pada waktu beroperasi. Gabungkan nilai tersebut untuk efektivitas yang lebih tinggi berdasarkan section 3.4.3 di API RP 581 Part 2.
- Menentukan base damage factor untuk sulfide stress cracking, $D_{fb}^{HIC/SOHIC-H_2S}$, berdasarkan severity indeks, efektivitas inspeksi, dan jumlah inspeksi, mengacu pada tabel 01.B.9 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE.
- Menentukan on-line adjustment factor FOM dengan table 3.7.

Tabel 3.7 Faktor on-line adjustment

On-Line Monitoring Method	Adjustment Factors as a Function of On-line Monitoring - F_{om}
Key Process Variables	2
Hyrogen Probes	2
Key Process Variables & Hydrogen probes	4

- Menentukan damage factor berdasarkan waktu operasi sejak inspeksi terakhir (usia yang sama pada langkah 4).

$$D_f^{HIC/SOHIC-H_2S} = \frac{D_{fB}^{HIC/SOHIC-H_2S}.\,(Max[age, 1.0])^{1.1}}{F_{OM}} \quad (3.21)$$

- Total damage factor untuk stress corrosion cracking

- Apabila terdapat lebih dari 1 damage factor untuk stress corrosion cracking, maka nilai tersebut digabungkan dengan persamaan 3.22.

$$D_{f-gov}^{scc} = max\begin{bmatrix} D_f^{caustic}, D_f^{amine}, D_f^{scc}, D_f^{HIC/SOHIC-H_2S}, D_f^{ACSCC}, \\ D_f^{PASCC}, D_f^{CLSCC}, D_f^{HSC\_HF}, D_f^{HIC/SOHIC-HF} \end{bmatrix} \quad (3.22)$$

3.4.2.5 External Corrosion Damage Factor

Berikut adalah langkah-langkah perhitungan external corrosion damage factor:

- Menentukan furnished thickness, t, dan usia komponen dari waktu instalasi.

- Menentukan corrosion rate, Cr_B, berdasarkan operating temperature pada table 01.B.11 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE.
- Menentukan corrosion rate final, C_r.

$$C_r = C_{rB} \cdot max[(F_{EQ}, F_{IF})] \tag{3.23}$$

- Menentukan usia komponen, age_{tk}, dan thickness dari inspeksi terakhir t_{rde}.
- Menentukan usia coating dari waktu instalasi, age_{coat}.

$$Age_{coat} = Calculation\ date - Coating\ Installation\ date \tag{3.24}$$

- Menentukan coating adjustment $Coat_{adj}$.

  - Jika $age_{tk} \geq age_{coat}$, maka:

  $Coat_{adj} = 0$ no or poor coating

  $Coat_{adj} = \min[5, Age_{coat}]$ medium coating

  $Coat_{adj} = \min[15, Age_{coat}]$ high coating

  - Jika $age_{tk} \leq age_{coat}$, maka:

  $Coat_{adj} = 0$ no or poor coating

  $Coat_{adj} = \min[5, Age_{coat}] - \min[5, age_{coat} - age_{tk}]$ medium coating

  $Coat_{adj} = \min[15, Age_{coat}] - \min[15, age_{coat} - age_{tk}]$ high coating

- Menentukan usia komponen, age, dimana korosi eksternal bisa terjadi.

$$Age = Age_{tk} - Coat_{adj} \tag{3.25}$$

- Menentukan allowable stress, S, efisiensi sambungan las, E, dan ketebalan minimum yang diperlukan, $t_{min.}$, per kode konstruksi atau API 579-1 / ASME FFS-1.
- Menentukan parameter A_{rt} berdasarkan age_{tk}, dan t_{rde} pada Langkah 4 dan C_r pada Langkah 3.

$$A_{rt} = \frac{Cr \cdot age}{t_{rde}} \tag{3.26}$$

- Menghitung nilai Flow stress, $FS^{extcorr}$.

$$FS^{extcorr} = \frac{(YS+TS)}{2}. \text{E.1,1}$$

- Menghitung parameter strength ratio, $SR^{extcorr}$.

$$SR_P^{extcorr} = \frac{S.E}{FS^{extcorr}} \cdot \frac{Max\,(t_{min}, t_c)}{FS^{extcorr}} \tag{3.27}$$

- Menentukan jumlah dari inspeksi serta efektifitas dari inspeksi tersebut. , $N_A^{extcorr}$, $N_B^{extcorr}$, $N_C^{extcorr}$, $N_D^{extcorr}$ berdasarkan data dari perusahaan dapat didefinisikan dari tabel 01.B.12 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE.

- Menghitung factor inspection effectiveness, $I_1^{extcorr}, I_2^{extcorr}, I_3^{extcorr}$, menggunakan persamaan berikut, prior probabilities, $Pr_{p1}^{extcorr}, Pr_{p2}^{extcorr}, Pr_{p3}^{extcorr}$, dari table 01.B.4 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE, conditional probabilities, $Co_{p1}^{extcorr}, Co_{p2}^{extcorr}, Co_{p3}^{extcorr}$, dari table 01.B.5 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF

FAILURE dan jumlah inspeksi, $N_A^{extcorr}, N_B^{extcorr}, N_C^{extcorr}, N_D^{extcorr}$, dari langkah sebelumnya.

$$I_1^{extcorr} = Pr_{P1}^{extcorr}(Co_{P1}^{extcorrA})^{N_A^{ex}}(Co_{P1}^{extcorrB})^{N_B^{ex}}(Co_{P1}^{extcorrC})^{N_C^{ex}}(Co_{P1}^{extcorrD})^{N_D^{ex}} \quad (3.28)$$

$$I_2^{extcorr} = Pr_{P2}^{extcorr}(Co_{P2}^{extcorrA})^{N_A^{ex}}(Co_{P2}^{extcorrB})^{N_B^{ex}}(Co_{P2}^{extcorrC})^{N_C^{ex}}(Co_{P2}^{extcorrD})^{N_D^{ex}} \quad (3.29)$$

$$I_3^{extcorr} = Pr_{P3}^{extcorr}(Co_{P3}^{extcorrA})^{N_A^{ex}}(Co_{P3}^{extcorrB})^{N_B^{ex}}(Co_{P3}^{extcorrC})^{N_C^{ex}}(Co_{P3}^{extcorrD})^{N_D^{ex}} \quad (3.30)$$

- Hitung Posterior Probability, $Po_{p1}^{extcorr}, Po_{p2}^{extcorr}, Po_{p3}^{extcorr}$.

$$Po_{p1}^{extcorr} = \frac{I_1^{extcorr}}{I_1^{extcorr} + I_2^{extcorr} + I_3^{extcorr}} \quad (3.31)$$

$$Po_{p2}^{extcorr} = \frac{I_2^{extcorr}}{I_1^{extcorr} + I_2^{extcorr} + I_3^{extcorr}} \quad (3.32)$$

$$Po_{p3}^{extcorr} = \frac{I_3^{extcorr}}{I_1^{extcorr} + I_2^{extcorr} + I_3^{extcorr}} \quad (3.33)$$

- Menghitung parameter, $ß_1^{extcorr}, ß_2^{extcorr}, ß_3^{extcorr}$, dengan persamaan (3.34), (3.35), dan (3.36) dengan nilai $COV_{\Delta t} = 0.2$, $COV_{sf} = 0.2$, dan $COV_P = 0.05$.

$$ß_1^{extcorr} = \frac{1-D_{S1}\,.\,A_{rt}-SR_P^{extcorr}}{\sqrt{D_{S1}{}^2.\,A_{rt}{}^2.\,COV_{\Delta t}{}^2+(1-D_{S1}.A_{rt})^2.COV_{sf}{}^2+(SR_P^{extcorr})^2.(COV_P)^2}} \quad (3.34)$$

$$ß_2^{extcorr} = \frac{1-D_{S2}\,.\,A_{rt}-SR_P^{extcorr}}{\sqrt{D_{S2}{}^2.\,A_{rt}{}^2.\,COV_{\Delta t}{}^2+(1-D_{S2}.A_{rt})^2.COV_{sf}{}^2+(SR_P^{extcorr})^2.(COV_P)^2}} \quad (3.35)$$

$$ß_3^{extcorr} = \frac{1-D_{S3}\,.\,A_{rt}-SR_P^{extcorr}}{\sqrt{D_{S3}{}^2.\,A_{rt}{}^2.\,COV_{\Delta t}{}^2+(1-D_{S3}.A_{rt})^2.COV_{sf}{}^2+(SR_P^{extcorr})^2.(COV_P)^2}} \quad (3.36)$$

- Menghitung DF untuk external corrosion, $D_{fB}^{extcorr}$,

$$D_{fb}^{extcorr} = [\frac{\left(Po_{P1}^{extcorr}\Phi(-\beta_1^{extcorr})\right)+\left(Po_{P2}^{extcorr}\Phi(-\beta_2^{extcorr})\right)+\left(Po_{P3}^{extcorr}\Phi(-\beta_3^{extcorr})\right)}{1.56E-0.4} \quad (3.37)$$

3.4.2.6 Total Damage Factor

Apabila terdapat lebih dari satu *damage mechanisms*, aturan berikut digunakan untuk menggabungkan *damage factor*. Total *damage factor* diberikan oleh persamaan (3.38) ketika damage eksternal dan/atau thinning diklasifikasikan sebagai lokal dan karenanya, tidak mungkin terjadi di lokasi yang sama.

$$D_{f-total} = max\left[D_{f-gov}^{thin}, D_{f-gov}^{extd}\right] + D_{f-gov}^{scc} + D_f^{htha} + D_{f-gov}^{brit} + D_f^{mfat} \quad (3.38)$$

Jika damage eksternal dan thinning terjadi secara general, maka damage kemungkinan terjadi di lokasi yang sama dan total DF diberikan oleh Persamaan (3.39).

$$D_{f-total} = D_{f-gov}^{thin} + D_{f-gov}^{extd} + D_{f-gov}^{scc} + D_f^{htha} + D_{f-gov}^{brit} + D_f^{mfat} \quad (3.39)$$

3.4.3 Penentuan Management System Factor

Penentuan *management systems factor* dilakukan dengan cara melihat hasil evaluasi fasilitas atau unit operasi sistem manajemen yang memengaruhi risiko pada peralatan. Evaluasi ini terdiri dari beberapa wawancara dengan bidang plant management, operasi, inspeksi, keselamatan, pelatihan, perawatan dan engineering. Skala yang direkomendasikan untuk mengubah skor evaluasi sistem manajemen menjadi sistem manajemen faktor didasarkan pada asumsi bahwa plant "rata-rata" akan menghasilkan skor 50% (500 dari kemungkinan skor 1.000) pada evaluasi sistem manajemen, dan bahwa skor 100% akan sama dengan penurunan satu tingkat total risiko unit. Berdasarkan skor ini, Persamaan (3.40) dan (3.41) digunakan untuk menghitung faktor sistem manajemen, F_{MS}, untuk setiap skor evaluasi sistem manajemen. Perhatikan bahwa skor manajemen pertama-tama harus dikonversi ke persentase (antara 0 dan 100) sebagai berikut:

$$pscor = \frac{Score}{1000} \cdot 100 \text{ [unit is 100\%]} \quad (3.40)$$

$$Fms = 10^{(-0.02 \cdot pscore+1)} \quad (3.41)$$

3.5 Analisis Consequences

Konsekuensi dalam penilaian API RBI digunakan untuk membantu dalam membuat *ranking equipment* berdasarkan risiko dan juga untuk menetapkan prioritas untuk program inspeksi. Berikut adalah langkah-langkah untuk analisis konsekuensi tanpa memperhatikan segi ekonomis:

3.5.1 Menentukan fluida yang dikeluarkan serta karakteristiknya.

3.5.1.1 Menentukan fluida representatif mengacu ke API RP 581 Part 3.

Fluida representatif ditentukan berdasarkan komposisi kimia dari fluida. Fluida representative merupakan fluida yang paling dominan. Namun, apabila berupa campuran pemilihan fluida representatif disarankan fluida yang memiliki karakter *flammable* dan/atau *toxic* dimana diasumsikan memiliki nilai CoF lebih tinggi. Table 01.C.1 pada LAMPIRAN 01.C: TABLES TO CALCULATE CONSEQUENCE OF FAILURE akan menjelaskan beberapa pilihan fluida representative.

3.5.1.2 Menentukan fase fluida yang tersimpan

Penentuan jenis fluida yang tersimpan pada peralatan apakah gas atau cairan.

3.5.1.3 Menentukan karakter dari fluida yang tersimpan

Parameter yang ditentukan adalah sebagai berikut:

MW : Molecular Weight (kg/kg-mol)
k : Ideal gas specific heat ratio
AIT : Auto-ignition Temperature (K)

Nilai dari parameter tersebut tercantum pada tabel 01.C.2 pada LAMPIRAN 01.C: TABLES TO CALCULATE CONSEQUENCE OF FAILURE

3.5.1.4 Menentukan fase tetap fluida setelah terlepas ke atmosfer dan fase saat masih tersimpan berdasarkan table 3.8.

Tabel 3.8 Langkah 1 - fase fluida

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (after release) Conditions	Determination of Final Phase of Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	Model as gas unless the fluid boiling point at ambient conditions is greater than 80ºF, then model as a liquid
Liquid	Liquid	Model as liquid

3.5.2 Pilih ukuran lubang (release hole size) untuk menentukan rentang nilai konsekuensi di perhitungan.

3.5.2.1 Menghitung lubang pelepasan dengan menentukan ukuran untuk masing-masing diameternya.

Berdasarkan Annex 3.A API RP 581 untuk peralatan bejana tekan, ukuran empat lubang pelepasan standar diasumsikan untuk semua ukuran dan semua jenis bejana tekan. Sehingga, mulai dari ukuran lubang pelepasan kecil, menengah, besar, dan pecah harus dihitung. Tabel 01.C.3 pada LAMPIRAN 01.C: TABLES TO CALCULATE CONSEQUENCE OF FAILURE menunjukan ukuran diameter untuk masing-masing lubang pelepasan.

3.5.2.2 Mentukan nilai gff_n, untuk tiap ukuran release hole.

Nilai dari *generic failure frequencies* untuk tiap ukuran release hole ada pada table 01.B.1 pada LAMPIRAN 01B: TABLES TO CALCULATE PROBABILITY OF FAILURE

3.5.3 Menghitung theoretical release rate

3.5.3.1 Memilih persamaan release rate berdasarkan fase fluida pada langkah 3.5.1.2

Persamaan (3.42) merupakan persamaan *release rate* apabila tekanan saat tersimpan (P_s) lebih besar dari tekanan transisi (P_{trans}).

$$W_n = \frac{Cd}{C2} \, x \, An \, \text{x Ps} \sqrt{\left(\frac{k \, x \, MW \, x \, gc}{R \, x \, Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad (3.42)$$

3.5.3.2 Mengitung luasan release hole size, An, di tiap release hole dengan persamaan (3.43),

$$An = \frac{\pi dn^2}{4} \quad (3.43)$$

3.5.3.3 Untuk liquid releases, hitung viscosity correction factor untuk setiap lubang keluaran (Kv,n).

3.5.3.4 Menghitung release rate untuk setiap lubang keluaran, Wn , untuk setiap luasan An.

Hitung *theoretical release rate* (W_n) untuk setiap lubang keluaran berdasarkan luasan (A_n) yang sudah ditentukan di langkah 3.5.3.2.

3.5.4 Estimasi total fluida yang dapat dikeluarkan

3.5.4.1 Menentukan grup komponen and equipment menjadi inventaris.

Berdasarkan API RP 581 untuk konsekuensi kegagalan (COF) peralatan yang dinilai harus digabungkan dengan komponen lain yang dapat berkontribusi untuk menambah jumlah rilis inventaris.

3.5.4.2 Menghitung massa fluida,$massa_{comp}$,

Estimasi volume untuk tipe komponen tersedia di Annex 3.A API RP 581, atau dapat dilihat pada table 01.C.4 pada LAMPIRAN 01.C: TABLES TO CALCULATE CONSEQUENCE OF FAILURE.

$$Mass_{comp} = \rho \text{ x } V_{comp} \quad (3.44)$$

3.5.4.3 Menghitung massa fluida di masing-masing komponen lain yang termasuk dalam kelompok inventaris, $massa_{comp,\,i}$.

3.5.4.4 Menghitung massa fluida dalam grup inventaris, $massa_{inv}$, menggunakan persamaan ini di bawah ini.

$$\sum mass_{inv} = \sum_{i=1}^{n} mass_{comp,i} \quad (3.45)$$

3.5.4.5 Menghitung laju aliran dari lubang diameter 203 mm (8 inci), $W_{max.}$

Hitung laju aliran dari lubang 203 mm (8 inci) diameter, W_{max8}, menggunakan persamaan (3.46) seperti yang berlaku dengan $A_n = A_8$ = 32,450 mm^2 (50,3 $inch^2$). Ini adalah laju aliran maksimum yang dapat ditambahkan ke massa cairan peralatan dari peralatan di sekitarnya dalam grup inventory.

$$W_{max8} = \frac{Cd}{C2} \, x \, An \text{ x Ps} \sqrt{\left(\frac{k \, x \, MW \, x \, gc}{R \, x \, Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad (3.46)$$

3.5.4.6 Menghitung laju massa fluida $mass_{add,n}$ di tiap lubang keluaran

Menentukan massa fluida tambahan untuk setiap ukuran lubang pelepasan yang dihasilkan dari tiga menit aliran dari kelompok persediaan menggunakan persamaan di bawah ini di bawah ini.

$$Mass_{add,n} = 180 \; . \; min[Wn \; , Wmax8] \quad (3.47)$$

3.5.4.7 Menghitung available mass untuk setiap lubang keluaran

Untuk setiap ukurang lubang keluaran, hitung available mass for release menggunakan persamaan (3.48).

$$Mass_{avail,n} = min\; [\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv} \quad (3.48)$$

3.5.5 Menentukan tipe keluaran (continuous, atau instantaneous).

Instantaeous release atau pelepasan sesaat adalah pelepasan yang terjadi begitu cepat sehingga fluida menyebar sebagai kumpulan besar. Sedangkan *continous release* atau pelepasan menerus adalah pelepasan yang terjadi dalam periode waktu yang lebih lama, memungkinkan cairan untuk menyebar dalam bentuk elips memanjang.

3.5.5.1 Menghitung waktu yang dibutuhkan untuk melepaskan 4536 kg (10.000 lbs) cairan untuk setiap ukuran lubang

Untuk menentukan waktu yang dibutuhkan untuk melepaskan 4536 kg (10.000 lbs) cairan untuk setiap ukuran lubang dapat diadopsi dari persamaan (3.49)

$$t_n = \frac{C3}{W_n} \tag{3.49}$$

3.5.5.2 Menentukan tipe keluaran (continuous atau instantaneous)

- Jika ukuran lubang pelepasan adalah 6,35 mm (0,25 inci) atau kurang, maka jenis pelepasan secara *continuous*.
- Jika $t_n \leq 180$ detik dan massa pelepasan lebih dari 4536 kgs (10000 lbs.), maka jenis pelepasan adalah *instantaneous*; jika tidak maka jenis pelepasan *continuous*.

3.5.6 Estimasi dampak dari system deteksi dan isolasi pada setiap keluaran

Setiap *petrochemical processing plants* umumnya memiliki sistem deteksi, sistem isolasi, dan juga sistem mitigasi yang dirancang untuk mengurangi kemungkinan dampak dari komposisi atau cairan berbahaya. Berdasarkan Tabel 4.5 Part 3 API RP 581 tercantum tentang skenario sistem deteksi dan isolasi yang mungkin milik perusahaan minyak dan gas tertentu sebagai sistem keselamatannya setiap kali magnitude terjadi.

3.5.6.1 Menentukan sistem deteksi dan isolasi yang ada di unit

Detection and Isolation Systems – These systems are designed to detect and isolate a leak, and tend to reduce the magnitude and duration of the release. Mitigation Systems – These systems are designed to mitigate or reduce the consequence of a release. Untuk menentukan sistem deteksi dan isolasi dapat menggunakan tabel 3.9 dan tabel 3.10.

3.5.6.2 Memilih klasifikasi yang sesuai (A, B, atau C) untuk sistem deteksi menggunakan tabel 3.9.

Tabel 3.9 Klasifikasi tipe system deteksi

Type of Detection System	Classification
Instrumentation designed specifically to detect material losses by changes in operating conditions (i.e. loss of pressure or flow) in the system	A
Suitably located detectors to determine when the material is present outside the pressure-containing envelop	B
Visual detection, cameras, or detectors with marginal coverage	C

3.5.6.3 Memilih klasifikasi yang sesuai (A, B, atau C) untuk sistem isolasi menggunakan tabel 3.10.

Tabel 3.10 Klasifikasi tipe sistem isolasi

Type of Isolation System	Classification
Isolation or shutdown systems activated directly from process instrumentation or detectors, with no operator intervention	A
Isolation or shutdown systems activated by operators in the control room or other suitabel location remote from the leak	B
Isolation dependent on manually operated valves	C

3.5.6.4 Menentukan faktor reduksi pelepasan, $fact_{di}$, tipe dari sistem isolasi dan deteksi sebagaimana dipilih dalam langkah 3.5.6.2 dan 3.5.6.3

3.5.6.5 Menentukan total durasi kebocoran untuk setiap ukuran lubang rilis yang dipilih, $ld_{max,\,n}$, menggunakan klasifikasi dari langkah 3.5.6.2 dan 3.5.6.3 dan tabel 01.C.5 pada LAMPIRAN 01.C: TABLES TO CALCULATE CONSEQUENCE OF FAILURE.

3.5.7 Menentukan release rate dan mass untuk analisa consequence

Untuk pelepasan yang berkelanjutan *(continuos release rate)*, pelepasan dimodelkan sebagai kondisi keadaan stabil: oleh karena itu, release rate digunakan sebagai input untuk analisis konsekuensi. Laju pelepasan yang digunakan dalam analisis adalah pelepasan teoritis yang disesuaikan dengan keberadaan unit deteksi dan isolasi sebagaimana dirumuskan dalam persamaan (3.50):

$$Rate_n = W_n\,(1 - fact_{di}) \qquad (3.50)$$

Untuk pelepasan instan *(instataneous release rate)*, laju pelapasan massa diperlukan untuk analisa lebih lanjut. Laju pelepasan massa, $mass_{avail,n}$, digunakan sebagai batas atas laju pelepasan massa, $mass_n$, seperti pada persamaan (3.51):

$$mass_n = min\left[\{rate_n . Id_n\}, mass_{avail,n}\right] \qquad (3.51)$$

3.5.7.1 Hitung adjusted release rate, $rate_n$, menggunakan persamaan (3.50)

3.5.7.2 Hitung waktu kebocoran, ld_n, untuk setiap release hole dengan persamaan (3.52)

$$ldn = min\,.\ [\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\ .\ ld_{max,n}\,] \qquad (3.52)$$

3.5.7.3 Hitung release mass, $mass_n$, untuk setiap ukuran release hole.

Untuk setiap ukuran release hole, hitung release mass, $mass_n$, menggunakan persamaan (3.50) berdasarkan release rate, $rate_n$, durasi kebocoran, Id_n, dan, $mass_{avail,n}$.

3.5.8 Hitung flammable/explosive consequence

Consequence of area diestimasi dengan *release rate* ($Rate_n$) untuk *continuous release type* dan *mass rate* ($Mass_n$) untuk tipe *instantaneous release.*

3.5.8.1 Memilih faktor reduksi mitigasi konsekuensi area, $fact_{mit}$, dari tabel 3.11 berikut.

Tabel 3.11 Faktor reduksi mitigasi konsekuensi area

Mitigation System	Consequence Area Adjustment	$Fact_{mit}$
Inventory blowdown , couple with isolation system classification B or higher	Reduce consequence area by 25 %	0.25
Fire water deluge system and monitor	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

3.5.8.2 Hitung efisiensi energi, $eneff_n$, untuk setiap ukuran lubang menggunakan persamaan yang disebutkan (3.53).

$$eneff_4 = 4.\, log_{10}\left[C_4\, .\, mass_n\right] - 15 \tag{3.53}$$

3.5.8.3 Menentukan tipe fluida, baik tipe 0 maupun tipe 1 dari tabel 01.C.1 pada LAMPIRAN 01.C: TABLES TO CALCULATE CONSEQUENCE OF FAILURE.

3.5.8.4 Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari kerusakan komponen untuk Auto-Ignition Not Likely, Continuous Release (AINT-CONT), $CA^{AINL\text{-}CONT}$.

Konsekuensi area dari kerusakan komponen Auto-Ignition Not Likely untuk continuous release dapat dihitung dengan:

$$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b\, .\, (1 - fact_{mit}) \tag{3.54}$$

3.5.8.5 Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari kerusakan komponen untuk Auto-Ignition Likely, Continuous Release (AIT-CONT), $CA^{AIL\text{-}CONT}$.

Konsekuensi area dari kerusakan komponen Auto-Ignition Likely untuk continuous release dapat dihitung dengan:

$$CA_{cmd,n}^{AIL-CONT} = \alpha(rate_n)^b\, .\, (1 - fact_{mit}) \tag{3.55}$$

3.5.8.6 Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari kerusakan komponen untuk Auto-Ignition Not Likely, Instantaneous Release (AINT-INST), $CA^{AINL\text{-}INST}$.

Konsekuensi area dari kerusakan komponen Auto-Ignition Not Likely untuk instantaneous release dapat dihitung dengan:

$$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b\, .\, \left(\frac{1 - fact_{mit}}{eneff_n}\right) \tag{3.56}$$

3.5.8.7 Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari kerusakan komponen untuk Auto-Ignition Likely, Instantaneous Release (AIT-INST), $CA^{AIL\text{-}INST}$.

Konsekuensi area dari kerusakan komponen Auto-Ignition Not Likely untuk instantaneous release dapat dihitung dengan:

$$CA_{cmd,n}^{AIL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (3.57)$$

3.5.8.8 Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari personnel injury untuk Auto-Ignition Not Likely, Continuous Release (AINL-CONT), $CA^{AINL\text{-}CONT}$.

Konsekuensi area dari personnel Auto-Ignition Not Likely untuk continuous release dapat dihitung dengan:

$$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1-fact_{mit}) \quad (3.58)$$

3.5.8.9 Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari personnel injury untuk Auto-Ignition Likely, Continuous Release (AIT-CONT), $CA^{AIL\text{-}CONT}$.

Konsekuensi area dari personnel Auto-Ignition Not Likely untuk continuous release dapat dihitung dengan:

$$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1-fact_{mit}) \quad (3.59)$$

3.5.8.10Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari personnel injury untuk r Auto-Ignition Not Likely, Instantaneous Release (AINL-INST), $CA^{AINL\text{-}INST}$.

Konsekuensi area dari personnel Auto-Ignition Not Likely untuk instantaneous release dapat dihitung dengan:

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (3.60)$$

3.5.8.11Untuk setiap ukurang lubang keluaran, hitung konsekuensi area dari personnel injury untuk Auto-Ignition Likely, Instantaneous Release (AIL-INST), $CA^{AIL\text{-}INST}$.

Konsekuensi area dari personnel injury Auto-Ignition Likely untuk instantaneous release dapat dihitung dengan::

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (3.61)$$

3.5.8.12Hitung instantaneous/continuous blending factor, $fact_n$, untuk setiap lubang keluaran yang sesuai dengan tipe keluaran pada tiap lubang.

- Untuk jenis pelepasan *continuous*

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad (3.62)$$

- Untuk jenis pelepasan *instantaneous*
  Pada jenis pelepasan *instantaneous, blending factor* tidak dihitung. Karena definisi instantaneous release adalah satu keluaran besar, $rate_n$, lebih besar (4356 kgs (10000 lbs.) dalam 3 menit), maka *blending factor* sama dengan 1.0.

$$fact_n^{IC} = 1.0 \tag{3.63}$$

3.5.8.13 Hitung AIT blending factor, $fact^{AIT}$, menggunakan persamaan (3.64), (3.65), or (3.66).

$$fact^{AIT} = 0 \quad \text{if } T_s + C_6 \leq AIT \tag{3.64}$$

$$fact^{AIT} = \frac{(T_s - AIT + C_6)}{2\ x\ C_6} \quad \text{if } T_s + C_6 > AIT > T_s - C_6 \tag{3.65}$$

$$fact^{AIT} = 1 \quad \text{if } T_s - C_6 \geq AIT \tag{3.66}$$

3.5.8.14 Hitung continuous/instantaneous blended consequence area untuk komponen dan personil menggunakan persamaan (3.67) sampai (3.70) berdasarkan nilai konsekuensi area yang telah dihitung pada langkah-langkah sebelumnya.

$$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} x\ fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} x\ (1 - fact_n^{IC}) \tag{3.67}$$

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AINL-INST} x\ fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} x\ (1 - fact_n^{IC}) \tag{3.68}$$

$$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} x\ fact_n^{IC} + CA_{inj,n}^{AIL-CONT} x\ (1 - fact_n^{IC}) \tag{3.69}$$

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} x\ fact_n^{IC} + CA_{inj,n}^{AINL-CONT} x\ (1 - fact_n^{IC}) \tag{3.70}$$

3.5.8.15 Hitung AIT blended consequence areas untuk komponen menggunakan persamaan (3.71) dan (3.72).

$$CA_{cmd,n}^{flam} = CA_{cmd,n}^{AIL}\ x\ fact^{AIT} + CA_{cmd,n}^{AINL} x\ (1 - fact^{AIT}) \tag{3.71}$$

$$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL}\ x\ fact^{AIT} + CA_{inj,n}^{AINL} x\ (1 - fact^{AIT}) \tag{3.72}$$

3.5.8.16 Hitung consequence areas final untuk kerusakan komponen dan personil menggunakan persamaan (3.73) and (3.74).

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \tag{3.73}$$

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \tag{3.74}$$

3.5.9 Hitung toxic consequence

3.5.9.1 Untuk setiap lubang keluaran, hitung durasi efektif penyebaran toxic menggunakan persamaan:

$$ld_n^{tox} = \min\left(3000\ ,\ \left\{\frac{mass_n}{W_n}\right\},\ \left\{60.\ ld_{max,n}\right\}\right) \tag{3.75}$$

3.5.9.2 Menentukan persentase toxic dari komponen toxic, dalam fluida yang dilepaskan. Fluida lepas adalah fluida murni, $mfrac^{tox}$ = 1.0. Apabila terdapat lebih dari satu komponen toxic dalam campuran cairan pelepasan, prosedur ini dapat diulang untuk setiap komponen toxic.

3.5.9.3 Untuk setiap ukuran lubang pelepasan, hitung laju pelepasan, dan massa yang dilepaskan yang akan digunakan dalam analisis toxic menggunakan persamaan (3.76) and (3.77).

- For continuous release type

$$rate_n^{tox} = mfrac^{tox}.W_n \quad (3.76)$$

- For instantaneous release type

$$mass_n^{tox} = mfrac^{tox}.mass_n \quad (3.77)$$

3.5.9.4 Untuk setiap ukuran lubang pelepasan, hitung area konsekuensi toksik untuk setiap ukuran lubang pelepasan.

Langkah ini diperlukan apabila komposisi kimia dalam aliran fluida mengandung H_2S dan/atau HF. Menggunakan persamaan (3.78) untuk continuous release dan (3.79) untuk instantaneous release type.

- Untuk jenis pelepasan *continuous*

$$CA_{inj,n}^{toxCONT} = e(Rate_n^{tox})^{\wedge}f \quad (3.78)$$

- Untuk jenis pelepasan *instantaneous*

$$CA_{inj,n}^{tox-INST} = e(Mass_n^{tox})^{\wedge}f \quad (3.79)$$

3.5.9.5 Apabila terdapat komponen toxic tambahan di campuran fluida keluaran, langkah 3.5.9.2 hingga 3.5.9.4 harus diulang. Jika tidak ada, langkah 3.5.9.5 dapat dilewati.

3.5.9.6 Tentukan konsekuensi area toxic untuk injuri personil sesuai persamaan (3.80)

$$CA_{inj}^{tox} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{tox}}{gff_{total}}\right) \quad (3.80)$$

3.5.10 Hitung non-flammable, non-toxic consequence

Non-flammable dan *non-toxic* difokuskan terhadap uap, serta konten acid dan caustic. Uap terbentuk pada suhu 100^{o}C, namun pada jarak beberapa meter uap akan bercampur dengan udara dan menjadi lebih dingin. Untuk pendekatan ini, kecelakaan dapat terjadi diatas suhu 60^{o}C.

3.5.10.1 Untuk setiap ukurang lubang keluaran, hitung non-flammable dan non-toxic consequence area

- Untuk proses steam menggunakan:
  - Untuk jenis pelepasan continuous

$$CA_{inj,n}^{CONT} = (C_9.\text{Rate}_n) \quad (3.81)$$

  - Untuk jenis pelepasan instantaneous

$$CA_{inj,n}^{INST} = (C_{10}.\text{ Mass}_n)^{0.6384} \quad (3.82)$$

- Untuk proses yang mengandung acid dan caustic menggunakan:
  - Untuk jenis pelepasan continuous

$$CA_{inj,n}^{CONT} = 0.2 \cdot C_8 \cdot g\left(C_4 \cdot rate_n\right)^h \qquad (3.83)$$

  - Untuk jenis pelepasan instantaneous

$$CA_{inj,n}^{INST} = 0 \qquad (3.84)$$

3.5.10.2 Untuk setiap ukuran lubang pelepasan, hitung faktor blending continuous atau instantaneous , $fact_{id}$, untuk steam menggunakan persamaan (3.84) berikut. Sedangkan untuk acid atau caustic, $fact_n^{IC} = 0$.

$$fact_n^{IC} = min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \qquad (3.85)$$

3.5.10.3 Untuk setiap ukuran lubang keluaran, hitung consequence area untuk non-flammable dan non-toxic personel injury dari langkah 3.5.10.1 dan 3.5.10.2.

$$CA_{cmd,n}^{leak} = 0 \qquad (3.86)$$

$$CA_{inj,n}^{leak} = CA_{inj,n}^{INST} . fact_n^{IC} + CA_{inj,n}^{CONT} . \left(1 - fact_n^{IC}\right) \qquad (3.87)$$

3.5.10.4 Tentukan non-flammable, non-toxic consequence areas final untuk personnel injury menggunakan (3.87)

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}}\right) \qquad (3.88)$$

3.5.11 Hitung consequence untuk kerusakan komponen dan personil, untuk menghitung total consequence

3.5.11.1 Hitung component damage consequence area final, CA_{cmd}, menggunakan persamaan (3.89)

$$CA_{cmd} = CA_{cmd}^{flam} \qquad (3.89)$$

3.5.11.2 Hitung personnel injury consequence area final, CA_{inj}, menggunakan persamaan (3.90)

$$CA_{inj} = \max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right] \qquad (3.90)$$

3.5.11.3 Calculate the final consequence rea, CA, menggunakan persamaan (3.91)

$$CA = \max\left[CA_{cmd}, CA_{inj}\right] \qquad (3.91)$$

3.6 Penentuan Level Risiko

Setelah diketahui *probability of failure* dan *consequence of failure* dari *production separator* maka akan dapat ditentukan level risikonya dengan menentukan kategori untuk *probability of failure* dan *consequence of failure* menggunakan nilai pada tabel 01.D.1 pada LAMPIRAN 01.D: TABLES TO CALCULATE RISK. Kategori tersebut kemudian dikonversi ke dalam risk matrix seperti pada gambar 2.10. Level risiko yang didapatkan dapat berada pada tingkat risiko berikut ini:

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

3.7 Mitigasi

Setelah menghitung *Probability of Failure (POF)* dan *Consequence of Failure (COF)*, risiko dapat ditentukan. Jika risiko diterima, selanjutnya dapat melakukan perencanaan inspeksi menggunakan metodologi perawatan yang tepat. Apabila risiko tidak dapat diterima, maka harus melakukan beberapa langkah mitigasi yang mengharuskan untuk menghitung kembali POF dan COF hingga hasilnya diterima sepenuhnya.

3.8 Inspection Planning

Pada bagian ini ditentukan jadwal dan jenis dari *inspection planning* berdasarkan pada fluida yang melewati peralatan, kondisi desain peralatan, tipe komponen dan material pembentuk serta *damage mechanism* dari peralatan. Untuk jenis dari *inspection planning* dapat dilihat pada Part 1 API RP 581 dan API 572 untuk tipe komponen *pressure vessel*. Pemeriksaan atau inspeksi harus dijadwalkan pada interval dengan mempertimbangkan interval maksimum seperti yang ditetapkan pada *code* dan *standart*. Dalam API 510 menyebutkan bahwa interval inspeksi maksimum untuk *internal inspection* adalah 10 tahun atau tidak lebih dari setengah umur peralatan. Sedangkan untuk *external inspection* maksimal setiap 5 tahun sekali.

3.9 Kesimpulan dan Saran

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
ANALISA DATA

4.1 Deskripsi Proses dan Data Pressure Vessel

Production separator befungsi untuk memisahkan air, minyak dan gas dari fluida yang masuk kedalam *vessel* ini. Sesuai dengan namanya, production separator, bertugas untuk memproduksi. Artinya minyak yang telah dipisahkan dari air maupun gas lainya, hasil tersebutlah yang nantinya akan digunakan oleh unit produksi, baik untuk dijual maupun diolah kembali untuk di murnikan. Pada production separator milik PT. XX ini, separator mendapatkan menerima fluida dari sumur yang sebelumnya melalui production cooler dan dari hydrocarbon recovery pump. Setelah melewati production separator, fluida ini akan diterima oleh HP Fuel Gas Scrubber, Production Filter Coalescer dan Condensate Surge Vessel. Data PFD dari production separator dapat dilihat di LAMPIRAN 01.A: GENERAL SPECIFICATION OF PRODUCTION SEPARATOR.

Tabel 4.1 Pressure vessel general specification

PRESSURE VESSEL GENERAL SPECIFICATION	
Tag Number	ABC-V-0007
Quantity	1
Service	3 Phase Separator
Type of Pressure Vessel	Horisontal
	Drum
Geometry Data	2:1 Ellipsodial
Code	ASME Section VIII Division 2 2010 Edition
Design Pressure	1300 psi
Design Temperature	140°F
Operating Pressure	905 psi
Operating Temperature	120°F
Operating Steam Flow rate	375,524 Kg/s
Dimension	2591 ID x 6706 T-T
Empty Weight	64,24 kg
Operating Weight	81,03 kg
Full of Water	100,67 kg
Vessel Volume	35340,12 liter
Support	Saddle
Joint Efficiency (Head/Shell)	1
Corrosion Allowance	6,23 mm
	0,2453 inch
Year built	2014
Material	SA 516 Gr. 70
Last inspection	1 Juni 2014

4.2 Screening Damage Factor

Damage factor menyediakan *screening tools* untuk menentukan prioritas inspeksi dan mengoptimalkan upaya inspeksi. Fungsi dasar *damage factor* adalah untuk secara statistik mengevaluasi jumlah kerusakan yang mungkin ada sebagai fungsi waktu dalam layanan dan efektivitas kegiatan inspeksi. Dari hasil screening criteria pada LAMPIRAN 02: DAMAGE FACTOR SCREENING QUESTION, *damage factor* yang dapat terjadi pada production separator adalah sebagai berikut:

- Thinning Damage Factor
- Component Lining Damage Factor
- SCC Damage Factor - Sulfide Stress Cracking
- SCC Damage Factor - HIC/SOHIC – H2S
- External Corrosion Damage Factor

4.3 Analisis Probability

Untuk mendapatkan nilai *probability of failure* diperlukan nilai *damage factor, generic failure frequency* dan *factor management system*. Dalam menentukan *damage factor* dilakukan *screening criteria* yang terlampir pada LAMPIRAN 02: DAMAGE FACTOR SCREENING QUESTION. *Damage factor* yang sesuai dengan kondisi *production separator* adalah *thinning, component lining damage factor, sulfide stress cracking, HIC/SOHIC – H2S damage factor* dan *external corrosion damage factor*. Berikut adalah langkah-langkah perhitungannya:

4.3.1 Thinning Damage Factor

Thinning merupakan degradasi logam karena lingkungannya yang mengakibatkan penipisan ketebalan logam tersebut. Untuk mengetahui nilai damage factor thinning, memerlukan data laju korosi material. Data tersebut didapatkan perhitungan lajur korosi berdasarkan mekanisme thinning pada Annex 2.B API RP 581 maupun hasil dari inspeksi terakhir terhadap equipment. Namun karena equipment yang dianalisa belum pernah dilakukan inspeksi, maka digunakan perhitungan lajur korosi berdasarkan pada Annex 2.B API RP 581. Thinning dapat terjadi karena beberapa mekanisme. Untuk kasus ini, mekanisme thinning yang sesuai dengan *screening criteria corrosion rate* API RP 581 adalah *sour water corrosion* dan *acid sour water corrosion*. *Sour water dan acid sour water corrosion* terjadi karena adanya H2S pada larutan yang pH nya di bawah 7,0. Untuk detail perhitungan dapat dilihat di LAMPIRAN 3: CALCULATION OF PROBABILITY OF FAILURE. Hasil perhitungan *thinning* menghasilkan nilai damage factor sebesar 0,1 untuk *shell section* dan *head section* dari Production Separator ABC-V-0007 baik pada saat RBI *date* maupun *plan date*.

4.3.2 Component Lining Damage Factor

Semua lapisan memiliki tingkat perlindungan tertentu dari lingkungan operasi. Banyak lapisan akan bertahan untuk jangka waktu yang tidak terbatas, pada dasarnya kebal terhadap mekanisme kerusakan yang dapat terjadi. Lapisan lain perlahan akan menurun seiring waktu, dan memiliki kehidupan yang terbatas. Dalam kasus seperti itu, usia lapisan (atau tahun sejak inspeksi terakhir) menjadi penting dalam menetapkan suatu faktor. Jenis lining pada peralatan yang dilakukan analisa adalah striped lined alloy di mana materialnya terbuat dari SS 316L. Dengan usia 6 tahun dari tahun inspeksi terakhir. Untuk detail perhitungan dapat dilihat pada LAMPIRAN 3: CALCULATION OF PROBABILITY OF FAILURE. Setelah *component lining damage factor* dihitung, kemudian dibandingkan dengan *thinning damage factor* yang ditentukan untuk bahan dasar. Nilai minimum dari kedua nilai inilah yang digunakan. Dari hasil perhitungan, nilai damage factor lining adalah sebesar 4 untuk RBI *date* dan 18 untuk *Plan date*. Sehingga nilai yang digunakan untuk perhitungan total DF adalah nilai dari *thinning damage facto*r. Dasar untuk ini adalah bahwa jika kerusakan penipisan kecil dibandingkan dengan lining DF, maka itu tidak masalah jika lining telah gagal atau tidak.

4.3.3 Sulfide Stress Cracking

Sulfide stress cracking (SSC) didefinisikan sebagai keretakan diakibatkan kombinasi tensile stress dan lingkungan yang mengandung air dan H2S. SSC adalah tipe *hydrogen stress cracking* yang dihasilkan dari penyerapan atom hidrogen yang dihasilkan oleh proses korosi sulfida pada permukaan logam. *Sulfide stress cracking (SSC)* dapat terjadi walaupun hanya mengandung 1 ppm H2S dalam air. Kerentanan material terhadap sulfide stress cracking dapat diturunkan dengan perlakuan PWHT *(post weld heat treatment)* pada komponen. Pada production separator yang dianalisa mendapat perlukan PWHT. Dengan kandungan H2S sebanyak 1000 ppm dan mendapat perlakuan PWHT didapatkan hasil *damage factor* sebesar 0 untuk RBI *date* maupun *Plan date*.

4.3.4 HIC/SOHIC – H2S

HIC/SOHIC – H2S merupakan singkatan dari *hydrogen-induced cracking* dan *stress oriented hydrogen-induced cracking* karena pengaruh H2S. HIC didefinisikan sebagai retakan internal bertahap yang menghubungkan hidrogen blister yang berdekatan pada bidang yang berbeda dalam logam, atau ke permukaan logam. HIC terjadi bukan karena stress eksternal, namun karena penumpukan tekanan internal dari hidrogen blister. Sedangkan SOHIC didefinisikan sebagai susunan blister yang tergabung karena *hydrogen-induced cracking* yang sejajar dengan arah ketebalan baja sebagai hasil dari tensile stress yang terjadi secara local.

Kerentanan material terhadap HIC/SOHIC akan menurun seiring dengan lebih rendahnya konsentrasi sulfur pada baja, serta perlakuan PWHT pada komponen. Material konstruksi yang digunakan adalah SS 316L dengan konten sulfur 0,03%. Komponen yang mengalami perlakuan PWHT, sehingga menghasilkan *damage factor* 3,317 untuk *shell section* dan *head section* pada saat RBI *date*. Sedangkan pada saat *plan date* nilai *damage factor* sebesar 6,008. Untuk detail perhitungan dapat dilihat di LAMPIRAN 3: CALCULATION OF PROBABILITY OF FAILURE.

4.3.5 External Corrosion Damage Factor

Sebagian besar *plant* atau fasilitas yang berada pada lokasi dengan curah hujan tahunan tinggi dan lokasi dekat dengan laut lebih rentan terhadap korosi eksternal daripada fasilitas yang berada pada lokasi yang lebih dingin, lebih kering, dan di benua tengah. Selain terpengaruh oleh iklim, unit yang terletak di dekat *cooling tower* dan *steam vent* sangat rentan terhadap korosi eksternal, dan juga untuk unit yang siklus suhu operasinya melalui titik embun secara teratur. Untuk detail perhitungan dapat dilihat di LAMPIRAN 3: CALCULATION OF PROBABILITY OF FAILURE. Hasil perhitungan *external corrosion damage factor* menghasilkan nilai *damage factor* sebesar 0,0017575 untuk *shell section* dan 0,0017594 *head section* pada saat RBI *date.*

Probability of failure didefinisikan sebagai kemungkinan terjadinya kegagalan pada sebuah komponen/peralatan. Dalam menentukan nilai probability of failure diperlukan tiga nilai yaitu nilai damage factor, generic failure frequency dan factor management system. Nilai damage factor seperti telah yang dihitung pada LAMPIRAN 3: CALCULATION OF PROBABILITY OF FAILURE dengan nilai total damage factor sebesar 3,4185167 untuk *shell section* dan 3,4185186 untuk *head section* pada saat RBI *date*. Sedangkan pada saat plan date nilai damage factor sebesar 6,1095803 untuk *shell section* dan 6,1095875 untuk *head section.* Nilai *generic failure frequency* dapat dilihat pada tabel 3.1 API 581 yaitu sebesar $3.06x10^{-5}$ untuk peralatan jenis *vessel*. Untuk nilai *factor management system* digunakan nilai rata-rata berdasarkan rekomendasi API 581 dengan nilai 50% (500 dari 1000 nilai). Sehingga nilai POF yang dihasilkan sebesar $1{,}046x10^{-4}$ pada saat RBI *date* dan $1{,}869x10^{-4}$ pada saat *plan date.*

4.4 Analisis Consequences

Terdapat 11 langkah dalam perhitungan consequence of failure dari production separator yang dianalisa.

4.4.1 Menentukan representatif fluida berdasarkan table 4.1 API RP 581 beserta karakteristiknya.

Fluida representatif ditentukan berdasarkan komposisi kimia dari fluida, sehingga fluida dengan jumlah mol terbanyak yang dipilih menjadi representatif. Namun, apabila berupa campuran ada pertimbangan yang perlu diperhatikan. Tercantum pada API RP 581 Annex 3.A apabila terdapat senyawa inert seperti CO2 dan air, maka fluida representatif ditentukan berdasarkan dengan mengutamakan senyawa dengan dampak flammable/toxic, selain kedua senyawa tersebut. Berdasarkan heat material balance (HMB) komponen yang dianalisa, fluida dengan jumlah mol terbanyak adalah methane dengan persentase sebanyak 81,344%. Methane termasuk dalam kelompok C1-C2 pada tabel 4.1 API RP 581. Fluida yang disimpan dalam production separator diasumsikan sebagai gas.

4.4.2 Pilih ukuran lubang (release hole size) untuk menentukan rentang nilai konsekuensi di perhitungan.

Terdapat 4 ukuran lubang keluaran yaitu, small, medium, large, dan rupture. Berdasarkan annex 3.A Part 3 API RP 581, untuk komponen jenis *pressure vessel*, tiap ukuran dihitung sebagai jenjang nilai konsekuensi yang dihasilkan. Sehingga berdasarkan table 01.C.3 pada LAMPIRAN 01.C: TABLES TO CALCULATE CONSEQUENCE OF FAILURE, diambil ukuran lubang keluaran untuk *small* sebesar 0,25 inch, *medium* 1 inch, *large* 4 inch, dan *rupture* 16 inch.

4.4.3 Menghitung theoretical release rate.

Release rate tergantung pada sifat fisik material, fase awal, kondisi saat beroperasi dan ukuran lubang keluaran yang ditetapkan. Untuk menghitung *theoretical release rate* (Wn) dibutuhkan beberapa data yang salah satunya adalah area keluaran (An) untuk masing-masing lubang keluaran yang telah ditentukan pada langkah 4.4.2. Nilai Wn yang didapatkan dari perhitungan sebagai berikut:

W1 = 0,0106516 kg/s,
W2 = 0,1704261 kg/s,
W3 = 2,7268187 kg/s,
W4 = 43,629100 kg/s.

4.4.4 Estimasi jumlah fluida yang dikeluarkan.

Komponen yang dievaluasi adalah bagian dari kelompok komponen yang lebih besar yang bias dianggap menyediakan inventaris yang lancar untuk dikeluarkan. Estimas nilai massa komponen berdasarkan Annex 3.A Part 3 API RP 581, dimana persentase volume liquid dan gas pada production separator masing-masing sebesar 50%. Sehingga hasil perhitungan mass inventory adalah sebesar 17534 kg. Selanjutnya dilakukan perhitungan massa tambahan. Untuk massa tambahan sendiri, API 581 mengestimasi bahwa terdapat batasan massa untuk lubang keluaran sebesar 8 inch, karena dalam 3 menit akan ada intervensi dari operator terhadap kebocoran. Hasil perhitungan dari massa komponen, massa inventory dan massa tambahan digunakan untuk menentukan massa fluida yang dapat dikeluarkan. Berikut adalah massa fluida yang dapat dikeluarkan untuk setiap ukuran lubang keluaran ($mass_{avail,n}$):

$mass_{avail,1}$ = 17534 kg/s
$mass_{avail,2}$ = 17534 kg/s
$mass_{avail,3}$ = 17534 kg/s
$mass_{avail,4}$ = 17534 kg/s

4.4.5 Menentukan tipe keluaran (continuous atau instantaneous).

Terdapat dua tipe keluaran yaitu continuous dan instantaneous. Proses untuk menentukan jenis keluaran yang sesuai untuk model membutuhkan penentuan waktu yang diperlukan lepaskan 4.536 kg (10.000 lbs) cairan, melalui masing-masing ukuran lubang pelepasan. Ini telah ditentukan untuk menjadi titik transisi antara kedua jenis keluaran. Tipe continuous adalah keluaran yang terjadi dalam periode waktu yang lebih lama, memungkinkan cairan untuk menyebar dalam bentuk elips memanjang (tergantung pada kondisi cuaca). Sedangkan untuk tipe instantaneous terjadi dalam periode waktu lebih cepat yaitu kurang dari 180 detik. Perhitungan dilakukan untuk melihat durasi mengeluarkan massa 4536 kg fluida di tiap hole size.

t_1 = 425850,08 s (*continuous*),
t_2 = 26615,63 s (*continuous*),
t_3 = 1663,47 s (*continuous*),
t_4 = 103,96 s (*instantaneous*).

Hasil perhitungan menunjukkan bahwa ukuran lubang *small*, *medium* dan *large* mengeluarkan massa senilai 4536 kg dengan waktu lebih dari 180 detik. Sedangkan untuk ukuran lubang *rupture* dengan waktu kurang dari 180 detik sehingga memiliki tipe keluaran *instantaneous.*

4.4.6 Mengestimasi dampak dari sistem deteksi dan isolasi.

Petrochemical processing plants biasanya memiliki beragam sistem deteksi, isolasi, dan mitigasi dirancang untuk mengurangi efek dari pelepasan bahan berbahaya. Pada PT. XX diasumsikan bahwa sistem deteksi dan isolasinya bernilai A. Beberapa sistem mengurangi besarnya dan durasi keluaran dengan mendeteksi dan mengisolasi kebocoran. Sistem lain mengurangi area konsekuensi dengan meminimalkan peluang batasan penyebaran material. Apabila kedua system tersebut bernilai A, maka waktu maksimum kebocoran untuk tiap lubang keluaran adalah sebagai berikut:

$Id_{max,1}$ = 20 minutes,
$Id_{max,2}$ = 10 minutes,
$Id_{max,3}$ = 5 minutes,
$Id_{max,4}$ = 5 minutes.

4.4.7 Menentukan release rate dan mass untuk perhitungan consequence.

Terdapat dua tipe keluaran *(release)* seperti yang telah ditentukan pada langkah 5. Untuk tipe continuous keluaran dimodelkan stabil, sehingga *release rate* digunakan sebagai input analisa konsekuensi. *Release rate* yang digunakan berhubungan dengan *theoretical rate* yang telah dihitung pada langkah 4.4.3. Berikut adalah hasil perhitungan release rate untuk masing-masing lubang keluaran:

$Rate_1$ = 0,0079887 kg/s
$Rate_2$ = 0,1278196 kg/s
$Rate_3$ = 2,0451140 kg/s
$Rate_4$ = 32,721825 kg/s.

Untuk keluaran tipe instantaneous diperlukan nilai *release mass*. Nilai massa fluida ($mass_{avail,n}$) yang telah dihitung pada langkah 4.4.4 digunakan sebagai batasan menentukan *release mass*. Berikut adalah hasil perhitungan *release mass*:

$Mass_1$ = 9,5864722 kg
$Mass_2$ = 76,691778 kg
$Mass_3$ = 613,53422 kg
$Mass_4$ = 9816,5476 kg

4.4.8 Menghitung flammable/explosive consequence.

Release rate dan *mass rate* yang telah ditentukan pada langkah 4.4.7 digunakan sebagai input untuk menghitung konsekuensi area. Probabilitas penyalaan untuk pelepasan *continuous* adalah konstan dan adalah sebuah fungsi material yang dilepaskan dan apakah cairan berada pada atau di atas suhu penyalaan otomatisnya. Sehingga probabilitas tidak meningkat sebagai fungsi dari tingkat rilis. Untuk tipe *instantaneous*, probabilitas pengapian naik secara signifikan. Pelepasan *instantaneous* didefinisikan sebagai keluaran yang lebih besar dari 4,536 kg dalam 3 menit yang setara dengan tingkat pelepasan 25,2 kg/s. Pelepasan *continuous* 25,5 kg/s akan memiliki konsekuensi yang jauh lebih rendah daripada pelepasan *instantaneous* pada 25,2 kg/s dari bahan yang sama. Dalam perhitungan konsekuensi flammability pada komponen, dibutuhkan konstanta komponen *damage flammable*. Perhitungan dilakukan pada setiap lubang keluaran dengan kedua tipe pelepasan *(continuous/instantaneous)* dan dengan kondisi temperature operasi pada *auto ignition not likely maupun auto ignition likely*. Hasil yang didapatkan dalam perhitungan konsekuensi *flammability* pada komponen adalah sebagai berikut:

CA_{cmd}^{flam} = 1,3653 m^2

Sedangkan untuk perhitungan konsekuensi *flammability* pada personil, dibutuhkan konstanta *personnel injury flammable*. Perhitungan dilakukan dengan langkah yang sama seperti perhitungan untuk konsekuensi *flammability* komponen. Berikut adalah hasil perhitungan konsekuensi *flammability* pada personil:

CA_{inj}^{flam} = 9,5131 m^2

4.4.9 Menghitung toxic consequence.

Fluida beracun mirip dengan fluida mudah terbakar. Namun tidak semua pelepasan beracun hanya menghasilkan satu jenis dampak saja. Seperti halnya fluida beracun yang mengandung hidrokarbon akan memberikan dampak *flammable*. Berdasarkan komposisi kimia dari peralatan yang dievaluasi terdapat kandungan 0,1% H2S dan 0,0015% Chloride. Dalam hal ini Chlorine hanya memberi dampak *toxic* sedangkan H2S juga memberikan dampak *flammable.*

Untuk melakukan perhitungan *toxic consequence* dibutuhkan nilai *release duration* dan *release rate*. Selain itu, nilai dari *toxic consequence* juga tergantung pada konsentrasi senyawa tersebut. Hasil perhitungan toxic consequence adalah seluas 22,278 m^2 .

4.4.10 Menghitung non flammable dan non toxic consequence.

Pada langkah ini konsekuensi dihitung untuk kondisi *steam* dan kondisi *acid and caustic*. Kebocoran uap dan asam tidak terjadi dalam konsekuensi kerusakan komponen, sehingga hanya memberi dampak cedera pada personil. Kebocoran uap diasumsikan dapat mengakibatkan cedera apabila memiliki temperatur diatas 60°C. Peralatan yang dievaluasi hanya beroperasi pada temperatur 48,8°C sehingga tidak dilakukan perhitungan untuk kebocoran uap. Perhitungan dilakukan untuk kebocoran asam dengan hasil seluas 75,664 m^2 .

4.4.11 Menghitung final consequence area.

Nilai akhir dari *consequence area* merupakan nilai maksimum dari konsekuensi kerusakan komponen dan konsekuensi dampak pada personil. Nilai konsekuensi kerusakan komponen hanya dihitung pada *flammable consequence* dengan hasil seluas 1,3653 m^2. Sedangkan konsekuensi dampak pada personil dihitung pada f*lammable consequence, toxic consequence* serta *non flammable and non toxic consequence*. Berikut adalah hasil perhitungan konsekuensi dampak pada personil untuk setiap jenis konsekuensi:

CA_{inj}^{flam} = 9,5131 m^2

CA_{inj}^{tox} = 22,278 m^2

CA_{inj}^{nfnt} = 75,664 m^2

Nilai maksimum konsekuensi dampak pada personil adalah seluas 75,664 m^2. Sehingga nilai akhir dari consequence area adalah seluas 75,664 m^2.

4.5 Penentuan Level Risiko

Risiko didefinisikan sebagai kombinasi antara *probability of failure (PoF)* dan *consequence of failure (CoF).* Perhitungan risiko dilakukan pada saat RBI date dan plan date. Untuk level risiko pada production separator ditentukan berdasarkan *probability of failure (PoF)* dan *consequence of failure (CoF).*

4.5.1 Penentuan Level Risiko RBI Date

Berikut adalah hasil pehitungan risiko pada saat RBI date:

Risk = 7,915 x 10^{-3} m^2/yr (shell)

Risk = 7,915 x 10^{-3} m^2/yr (head)

Berdasarkan *probability of failure (PoF)* dan *consequence of failure (CoF)* pada saat RBI *date*, dapat ditentukan bahwa level risiko pada *shell section* dan *head section* berada pada kategori *low risk.*

4.5.2 Penentuan Level Risiko Plan Date

Berikut adalah hasil pehitungan risiko pada saat plan date:

Risk = 1,414 x 10^{-2} m^2/yr (shell)

Risk = 1,414 x 10^{-2} m^2/yr (head)

Berdasarkan *probability of failure (PoF)* dan *consequence of failure (CoF)* pada saat *plan date*, dapat ditentukan bahwa level risiko pada *shell section* dan *head section* berada pada kategori *low risk.*

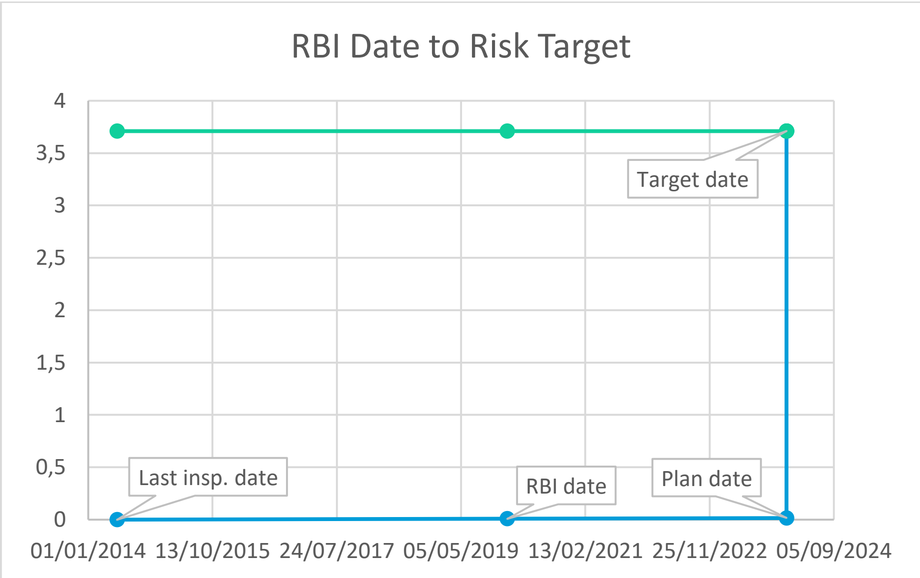
Penentuan tingkat risiko dilakukan dengan membandingkan nilai risiko yang didapatkan dengan *risk target*. Apabila hasil perbandingan menunjukkan bahwa risiko lebih besar dari *risk target*, maka akan dilakukan langkah mitigasi. Pada kasus ini risiko bernilai lebih kecil dari risk target sehingga tidak dilakukan mitigasi untuk memperkecil risiko. Selanjutnya akan ditentukan *inspection planning*.

4.6 Penentuan Inspection Planning

Inspection planning adalah serangkaian strategi terdokumentasi yang merinci ruang lingkup, metode, dan waktu inspeksi khusus untuk menentukan kondisi peralatan tertentu. Program inspeksi adalah kombinasi metode NDE (misal, visual, ultrasonic, radiografi, dll.). Sebelum target risiko yang ditentukan pengguna tercapai, inspeksi peralatan direkomendasikan berdasarkan mekanisme kerusakan komponen dengan DF tertinggi. API 510 menyatakan *bahwa pressure vessel* harus diinspeksi *internal* atau *on-stream* maksimal setiap 10 tahun atau pada saat umur *pressure vessel* telah mencapai setengah dari *remaining life*-nya, tergantung nilai mana yang lebih rendah. Langkah-langkah untuk menentukan *inspection planning* adalah sebagai berikut:

4.6.1 Penentuan target date

Dikarenakan hasil risiko tidak melebih target risiko pada saat plan date, maka pada saat penentuan target date diperoleh interval yang sangat jauh dari estimasi dan rekomendasi API 510 standard. Dalam hal ini, API RP 581 merekomendasikan tanggal jatuh tempo inspeksi untuk tujuan penjadwalan inspeksi dapat diatur ke tanggal rencana sehingga analisis ulang risiko akan dilakukan pada akhir periode rencana *(plan date)*. Sehingga *target date* untuk *production separator* jatuh pada tanggal 1 Januari 2024, bertepatan dengan plan date yang telah sesuai dengan rekomendasi API 510 yaitu 10 tahun setelah inspeksi terakhir. Berikut adalah kurva yang menunjukan target date:



Gambar 4.1 Grafik RBI Date to Risk Target

4.6.2 Penentuan Rekomendasi Inspeksi

Pada API RP 581 terdapat 5 (lima) kategori *inspection effectiveness*. Untuk menentukan efektivitas inspeksi yang akan dilakukan pada *equipment* terdapat 3 kasus yang dapat digunakan sebagai pertimbangan. Apabila risiko peralatan melebihi target/batas risiko pada saat *RBI date* maupun selama *plan date* maka *inspection effectiveness* ditujukan untuk menurunkan risiko. Sedangkan apabila risiko tidak melebihi target/batas risiko maka tidak dilakukan pemeriksaan selama periode *plan date* namun harus diadakan pemeriksaan pada akhir periode *plan date*. Hasil analisa *production separator* menunjukan bahwa risiko pada saat *plan date* tidak melebihi target/batas risiko, sehingga API 581 menyarankan tidak ada inspeksi selama periode *plan date*. Namun karena *plant/site* ini merupakan instalasi baru yang dibangun pada tahun 2014, sehingga belum pernah diadakan inspeksi, dan dalam analisa ini hanya menggunakan data pembangunan instalasi, maka inspeksi dengan efektivitas tinggi perlu dilakukan untuk mengetahui kondisi terbaru dari peralatan setelah 10 tahun beroperasi. Strategi inspeksi diterapkan untuk memperoleh informasi yang diperlukan untuk mengurangi ketidakpastian tentang status kerusakan peralatan yang sebenarnya dengan mengkonfirmasi adanya kerusakan, mendapatkan perkiraan tingkat kerusakan yang lebih akurat dan mengevaluasi tingkat kerusakan. Tingkat pengurangan POF tergantung pada efektivitas pemeriksaan untuk mendeteksi dan mengukur jenis kerusakan tertentu dari mekanisme kerusakan. Karena itu, tingkat efektivitas pemeriksaan yang lebih tinggi akan mengurangi ketidakpastian status kerusakan komponen dan mengurangi POF. Sehingga direkomendasikan *inspection effectiveness* C yang dapat mencakup kurang lebih 50% *suspect area* pada peralatan. Berikut adalah rekomendasi inspeksi untuk setiap *damage factor* yang ditentukan berdasarkan standar API 571 dan ASME Section V:

4.6.2.1 Local Thinning Damage Factor

1. Kategori Inspeksi

Tabel 4.2 Kategori Inspeksi Local Thinning Damage Factor

Damage Factor	Inspection Effectiveness	Description		Due Date	
				Shell	Head
Local Thinning Damage Factor	C	For the total suspect area:		01/01/2024	01/01/2024
		1	**>50%** coverage of the CML's using ultrasonic scanning or profile radiography.		

2. Metode Inspeksi
   - Visual Testing (VT) Inspection
     - Direct Visual Examination
     - Remote Visual Examination
     - Translucent Visual Examination
   - Ultrasonic Test (UT) Inspection
     - Automated Ultrasonic Backscatter Technique (AUBT)
     - Phased Array Ultrasonic Testing (PAUT)

- Long Range Ultrasonic Testing (LRUT)
- Internal Rotating Inspection Systems (IRIS)
- Time of Flight Diffraction (TOFD)
- Dry-Coupled Ultrasonic Testing (DCUT)

• Radiography Test (RT) Inspection
- Conventional or Film Radiography
- Real Time Radiography (RTR)
- Computed Tomography (CT)
- Direct Radiography (DR)
- Computed Radiography (CR)

4.6.2.2 Lining Damage Factor

1. Kategori Inspeksi

Tabel 4.3 Kategori Inspeksi Component Lining Damage Factor

<table>
<tr><th rowspan="2">Damage Factor</th><th rowspan="2">Inspection Effectiveness</th><th rowspan="2" colspan="2">Description</th><th colspan="2">Due Date</th></tr>
<tr><th>Shell</th><th>Head</th></tr>
<tr><td rowspan="2">Linning Damage Factor</td><td rowspan="2">C</td><td colspan="2">For the total surface area: scanning.</td><td rowspan="2">01/01/2024</td><td rowspan="2">01/01/2024</td></tr>
<tr><td>1</td><td>>65% automated or manual ultrasonic scanning.</td></tr>
</table>

2. Metode Inspeksi

• Visual Testing (VT) Inspection
- Direct Visual Examination
- Remote Visual Examination
- Translucent Visual Examination

• Ultrasonic Test (UT) Inspection
- Automated Ultrasonic Backscatter Technique (AUBT)
- Phased Array Ultrasonic Testing (PAUT)
- Long Range Ultrasonic Testing (LRUT)
- Internal Rotating Inspection Systems (IRIS)
- Time of Flight Diffraction (TOFD)
- Dry-Coupled Ultrasonic Testing (DCUT)

• Radiography Test (RT) Inspection
- Conventional or Film Radiography
- Real Time Radiography (RTR)
- Computed Tomography (CT)
- Direct Radiography (DR)
- Computed Radiography (CR)

4.6.2.3 Sulfide Stress Cracking

1. Kategori Inspeksi

Tabel 4.4 Kategori Inspeksi Sulfide Stress Cracking

Damage Factor	Inspection Effectiveness	Description		Due Date	
				Shell	Head
Sulfide Stress Cracking	C	For selected welds / weld area:		01/01/2024	01/01/2024
		1	**>35%** automated or manual ultrasonic scanning		
		OR			
		2	**>35%** radiographic testing.		

2. Metode Inspeksi
   - Wet Fluorescent Magnetic Test (WFMT)
   - Edy Current (EC)
   - Alternating Current Field Measurement (ACFM)
   - Acoustic Emission Testing (AET)
   - UT with External SWUT
   - Radiography Test (RT) Inspection
     - Conventional or Film Radiography
     - Real Time Radiography (RTR)
     - Computed Tomography (CT)
     - Direct Radiography (DR)
     - Computed Radiography (CR)

4.6.2.4 HIC/SOHIC-H2S Stress Cracking

1. Kategori Inspeksi

Tabel 4.5 Kategori Inspeksi HIC/SOHIC-H2S Stress Cracking

Damage Factor	Inspection Effectiveness	Description		Due Date	
				Shell	Head
HIC/SOHIC – H2S Stress Cracking	C	For the total surface area:		01/01/2024	01/01/2024
		1	**>5%** C scan of the base metal using advanced UT		
		AND			
		2	**HIC:** One 0.5-ft2 area, C scan of the base metal using advanced UT on each plate and the heads.		

2. Metode Inspeksi
   - Wet Fluorescent Magnetic Test (WFMT)
   - Edy Current (EC)
   - Alternating Current Field Measurement (ACFM)
   - Acoustic Emission Testing (AET)
   - UT with External SWUT
   - Radiography Test (RT) Inspection
     - Conventional or Film Radiography
     - Real Time Radiography (RTR)
     - Computed Tomography (CT)
     - Direct Radiography (DR)
     - Computed Radiography (CR)

4.6.2.5 External Corrosion Damage Factor

1. Kategori Inspeksi

Tabel 4.6 Kategori Inspeksi External Corrosion Damage Factor

Damage Factor	Inspection Effectiveness	Description	Due Date	
			Shell	Head
External Corrosion Damage Factor	C	Visual inspection of **>30%** of the exposed surface area with follow-up by UT, RT or pit gauge as required.	01/01/2024	01/01/2024

2. Metode Inspeksi
   - Visual Testing (VT) Inspection
     - Direct Visual Examination
     - Remote Visual Examination
     - Translucent Visual Examination
   - Ultrasonic Test (UT) Inspection
     - Automated Ultrasonic Backscatter Technique (AUBT)
     - Phased Array Ultrasonic Testing (PAUT)
     - Long Range Ultrasonic Testing (LRUT)
     - Internal Rotating Inspection Systems (IRIS)
     - Time of Flight Diffraction (TOFD)
     - Dry-Coupled Ultrasonic Testing (DCUT
   - Radiography Test (RT) Inspection
     - Conventional or Film Radiography
     - Real Time Radiography (RTR)
     - Computed Tomography (CT)
     - Direct Radiography (DR)
     - Computed Radiography (CR)

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BAB 5
KESIMPULAN DAN SARAN

5.1 Kesimpulan

5.1.1 Berikut adalah nilai dan kategori dari *probability of failure* pada saat RBI *date* dan *Plan date.*

- Pada saat RBI Date

		PoF	
		Nilai	Kategori
Production Separator	Shell	$1,046x10^{-4}$	2
	Head	$1,046x10^{-4}$	2

- Pada saat Plan Date

		PoF	
		Nilai	Kategori
Production Separator	Shell	$1,869x10^{-4}$	2
	Head	$1,869x10^{-4}$	2

5.1.2 Berikut adalah nilai dan kategori dari *consequence of failure* pada saat RBI *date* dan *Plan date.*

- Pada saat RBI Date

		CoF	
		Nilai	Kategori
Production Separator	Shell	75,66	B
	Head	75,66	B

- Pada saat Plan Date

		CoF	
		Nilai	Kategori
Production Separator	Shell	75,66	B
	Head	75,66	B

5.1.3 Berikut adalah nilai dan kategori dari risiko pada saat RBI *date* dan *Plan date.*

- Pada saat RBI Date

		Risiko	
		Nilai	Kategori
Production Separator	Shell	$1,41x10^{-2}$	Low
	Head	$1,41x10^{-2}$	Low

- Pada saat Plan Date

		Risiko	
		Nilai	Kategori
Production Separator	Shell	$1{,}41x10^{-2}$	Low
	Head	$1{,}41x10^{-2}$	Low

5.1.4 *Inspection planning* untuk production separator mencakup jadwal, kategori dan metode inspeksi.

- Jadwal inspeksi dilaksanakan 10 tahun setelah inspeksi terakhir yaitu pada 01/01/2024.
- Kategori minimum efektivitas dari inspeksi ditentukan untuk masing-masing damage factor adalah sebagai berikut:
  - Thinning Damage Factor : inspection effectiveness level C
  - Component Lining Damage Factor : inspection effectiveness level C
  - SCC - Sulfide Stress Cracking : inspection effectiveness level C
  - SCC - HIC/SOHIC – H2S : inspection effectiveness level C
  - External Corrosion Damage Factor : inspection effectiveness level C
- Metode inspeksi yang dapat diaplikasikan secara umum pada production separator adalah *Visual Testing (VT) Inspection, Ultrasonic Test (UT) Inspection* dan Radiography Test (RT) Inspection. Sedangkan untuk *damage mechanism stress corrosion cracking* terdapat tambahan metode seperti *Wet Fluorescent Magnetic Test (WFMT), Edy Current (EC), Alternating Current Field Measurement (ACFM) dan Acoustic Emission Testing (AET).*

5.2 Saran

5.2.1 Data yang digunakan dalam analisis RBI seharusnya lebih lengkap sesuai dengan kebutuhan analisa, sehingga hasil analisis diharapkan lebih akurat.

5.2.2 Hasil perhitungan *target date inspection planning* lebih lama dibandingkan ketentuan dari API 510, sehingga untuk jadwal inspeksi disarankan mengikuti ketentuan API 510.

5.2.3 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 analisa POF.

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BIODATA PENULIS

Ni Luh Triska Adelia lahir di kota Tabanan Provinsi Bali bertepatan dengan peringatan Hari Kartini yaitu pada 21 April 1998. Penulis merupakan anak pertama dari tiga bersaudara. Penulis mengenyam pendidikan formal pada SD Negeri 1 Perean Tengah (2004-2010), SMP Negeri 2 Baturiti (2010-2013) dan SMA Negeri 1 Tabanan (2013-2016). Setelah lulus dari bangku SMA, penulis melanjutkan pendidikan di Departemen Teknik Sistem Perkapalan, Fakultas Teknologi Kelautan, Institut Teknologi Sepuluh Nopember melalui jalur Seleksi Nasional Masuk Perguruan Tinggi Negeri (SNMPTN).

Selama menempuh masa studi penulis aktif dalam berbagai organisasi dan kepanitiaan. Diantaranya sebagai sekretaris Departemen Seni dan Minat Bakat TPKH-ITS Periode 2017/2018, sebagai koordinator Steering Committee TPKH-ITS 2018, sebagai Sekretaris Biro METIC Himasiskal FTK-ITS Periode 2018, sebagai Sekretaris Kabinet I Himasiskal FTK-ITS Periode 2019. Dalam kepanitiaan penulis pernah memegang amanah sebagai Bendahara I big event Gempita Pesona Dewata TPKH-ITS 2018 dan staf ahli Symphony Marine Icon 2019. Selama masa perkuliahan, penulis melaksanakan kerja praktik di PT. Adiluhung Saranasegara Indonesia, PT. Pelni Cabang Surabaya dan PT. BKI Cabang Utama Klas Surabaya.

LAMPIRAN

	PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

DOC. NO. 01

GENERAL DATA

Rev	Date	Remark	Prepared by		Approved by	
			Name	Sign	Name	Sign
			Ni Luh Triska Adelia		Ir. Dwi Priyanta, M.SE	
					Nurhadi Siswantoro, S.T., M.T	

PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

DOC. NO. 01A

GENERAL SPECIFICATION OF PRODUCTION SEPARATOR

1 GENERAL SPECIFICATION OF PRODUCTION SEPARATOR

Tag Number	:	ABC-V-0007	
Quantity	:	1	
Service	:	3 Phase Separator	
Manufactured by	:	-	
Type of Pressure Vessel	:	Horisontal	
	:	Drum	
Geometri Data	:	2:1 Ellipsoidal	
Code	:	ASME Section VIII Division 2 2010 Edition	
Design Pressure	:	1300	psi
Design Temperature	:	140	°F
Operating Pressure	:	905	psi
Operating Temperature	:	120	°F
Operating Steam Flow rate	:	375,52	Kg/s
Dimension	:	2591 ID x 6706 T-T	
Empty Weight	:	64,24	Kg
Operating Weight	:	81,03	Kg
Full of Water	:	100,67	Kg
Vessel Volume	:	4E+10	mm3
		35340	liter
Support	:	Saddle	
Joint Efficiency (Head/Shell)	:	1	
Insulation (Hot/Cold)	:	No	
Corrosion Allowance	:	6,23	mm
	:	0,2453	inch
Year Built	:	2014	
Material	:	SA 516 Gr. 70	
Last Inspection	:	-	

1.A SHELL DATA

Tag Number		:	ABC-V-0007	
Quantity		:	1	
Service		:	3 Phase Separator	
Code		:	ASME Section VIII Division 2 2010 Edition	
Design Pressure	(P)	:	1300	psig
Design Temperature	(T)	:	140	°F
Outer Diameter	(OD)	:	2747	mm
		:	108,150	inch

Material		:	SA 516 Gr. 70	
Allowable Stress	(S)	:	24100	psi
		:	1661,6	bar
		:	166164	kPa
Efficiency	(Ef)	:	1	
Corrosion Allowance	(CA)	:	5,94	mm
		:	0,2339	inch
Thickness	(t)	:	78	mm (include 3mm cladding)
		:	3,0709	inch
Required thickness	(treq)	:	72,0587	mm
			2,8370	inch

1.B HEAD DATA

Tag Number		:	ABC-V-0007	
Quantity		:	1	
Service		:	3 Phase Separator	
Code		:	ASME Section VIII Division 2 2010 Edition	
Design Pressure	(P)	:	1300	psig
Design Temperature	(T)	:	140	°F
Outer Diameter	(OD)	:	2731	mm
		:	107,520	inch
Material		:	SA 516 Gr. 70	
Allowable Stress	(S)	:	24100	psig
		:	1661,6	bar
		:	166163,72	kPa
Efficiency	(Ef)	:	1	
Corrosion Allowance	(CA)	:	6,02	mm
		:	0,2370	inch
Thickness	(t)	:	70	mm (include 3mm cladding)
		:	2,7559	inch
Required thickness	(treq)	:	63,9813	mm
			2,5189	inch

2 HEAT MATERIAL BALANCE

2.A CHEMICAL COMPOSITION

Composition	% Mol
H2S	0,1
CO2	5
Methane	81,344
Nitrogen	0,7929
Ethane	3,9499
Propane	2,0128
H2O	2,3129
i - Butane	0,5095
n- Butane	0,7434
i - Pentane	0,4269
n - Pentane	0,3534
n - Hexane	0,4341

Composition	% Mol
n-Heptane	0,1434
n-Octane	0.5205
n-Nonane	0,3375
n-Decane	0,2183
C11+	0,4
TEGlycol	0
CS2	0,0002
-B-Mercaptar	0,0002
Benzene	0,0336
Toluene	0,3663
p-Xylene	0
aMDEA	0

ADDITIONAL COMPOSITION

Chloride = 15,531 ppm

= 0,00155 %

2.B PROPERTIES

Properties	Unit	Overall	Vapour	HC Liquid	Aqueous
Vapour Fraction	<none>	0.944	-	-	-
Pressure	psig	905	-	-	-
Temperature	F	120	-	-	-
Mass Flow	lb/hr	442150	375524	59133	7493
Molecular Weight	<none>	22,2	19,96	85,33	18,04
Mass Density	lb/ft3	3,94	3,39	41,58	61,89
Mass Heat Capacity	Btu/lb-F	0,59	0,586	0,55	0,99
Heat flow	MMBtu/hr	-863,9	-	-	-
Std Gas Flow	MMSCFD	-	170,99	-	-
Actual Gas Flow	ACFM	-	1864	-	-
Thermal Conductivity	Btu/hr-ft-F	-	0,023	0,057	0,371
Viscosity	cP	-	0,014	0,311	0,555
Compressibility	<none>	-	0,87	-	-
Cp/Cv (Gamma)	<none>	-	1,473	1,31	1,16
Std Liquid Vol Flow	barrel/day	-	-	5777	505
Actual Volume Flow	barrel/day	-	-	6079	517
Surface Tension	dyne/cm	-	-	13,31	67,88

2.C CALCULATION OF FLOW VELOCITY

Q = V x A

$$V = \frac{Q}{A}$$

Where :

Q : Debit (m3/s)

V : Velocity (m/s)

A : Area (m2)

$$\text{Debit} = \frac{Mass\ Flow}{Mass\ Density}$$

Q = 112220,812 ft3/hr

= 0,8826167 m3/s

$$A = \pi r^2$$

$A = 3{,}14 \times (1295{,}5)^2$

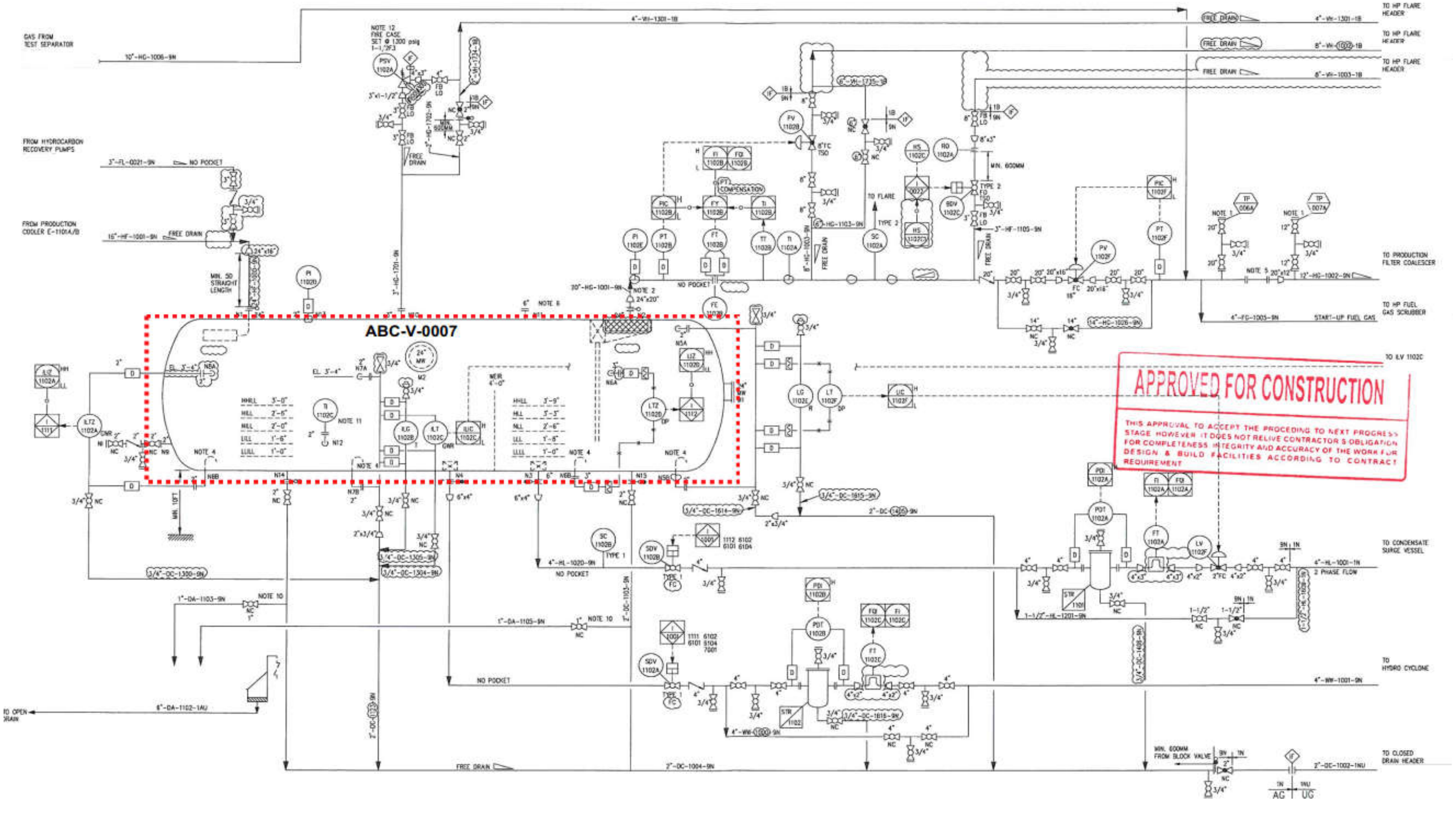
A = 5269925,59 mm2

= 5,26992559 m2

$$V = \frac{Q}{A}$$

= 0,16748181 m/s

	GENERAL SPECIFICATION OF PRODUCTION SEPARATOR	Doc. No:	01A
	PROCESS FLOW DIAGRAM	Page:	5



DOC. NO. 01.B

TABLES TO CALCULATE PROBABILITY OF FAILURE

	TABLES TO CALCULATE PROBABILITY OF FAILURE	Doc. No:	01.B
		Page:	1

1. **Table 01.B.1 Suggested Component Generic Failure Frequencies**

Equipment Type	Component Type	gff as a Function of Hole Size (failures/yr)				gff_{total} (failures/yr)
		Small	Medium	Large	Rupture	
Compressor	COMPC	8.0E-06	2.0E-05	2.0E-06	0	3.00E-05
Compressor	COMPR	8.0E-06	2.0E-05	2.0E-06	6.00E-07	3.60E-05
Heat Exchanger	HEXSS	8.0E-06	2.0E-05	2.0E-06	6.0E-07	3.06E-05
	HEXTS					
Pipe	PIPE-1	2.8E-05	0	0	2.6E-06	3.06E-05
	PIPE-2					
Pipe	PIPE-4	8.0E-06	2.0E-05	0	2.6E-06	3.06E-05
	PIPE-6					
Pipe	PIPE-8	8.0E-06	2.0E-05	2.0E-06	6.0E-07	3.06E-05
	PIPE-10					
	PIPE-12					
	PIPE-16					
	PIPEGT16					
Pump	PUMP2S	8.0E-06	2.0E-05	2.0E-06	6.0E-07	3.06E-05
	PUMPR					
	PUMP1S					
Tank650	TANKBOTTOM	7.2E-04	0	0	2.0E-06	7.20E-04
Tank650	COURSE-1-10	7.0E-05	2.0E-05	5.0E-06	1.0E-07	1.00E-04
Vessel/FinFan	KODRUM	8.0E-06	2.0E-05	2.0E-06	6.0E-07	3.06E-05
	COLBTM					
	FINFAN					
	FILTER					
	DRUM					
	REACTOR					
	COLTOP					
	COLMID					

2. Table 01.B.2 Screening Questions for Corrosion Rate Calculations

No.	Type of Corrosion	Screening Question		Action
1.	Hydrochloric Acid (HCl) Corrosion	1.	Does the process contain HCl?	If Yes to all, proceed to 2.B.2
		2.	Is free water present in the process stream (including initial condensing condition)?	
		3.	Is the pH < 7.0?	
2.	High Temperature Sulfidic/Naphtenic Acid Corrosion	1.	Does the process contain oil with sulfur compounds?	If Yes to both, proceed to 2.B.3
		2.	Is the operating temperature > 204^oC (400^oF)?	
3.	Sulfuric Acid Corrosion	1.	Does the process contain H_2SO_4?	If Yes to both, proceed to 2.B.4
4.	High Temperature H_2S/H_2 Corrosion	1.	Does the process contain H_2 and Hydrogen?	If Yes, proceed to 2.B.5
		2.	Is the operating temperature > 204^oC (400^oF)?	
5.	Hydrifluoric Corrosion	1.	Does the process contain HF?	If Yes, proceed to 2.B.6
6.	Sour Water Corrsion	1.	Is free water with H_2S present?	If Yes, proceed to 2.B.7
7.	Amine Corrosion	1.	Is equipment exposed to acid gas treaating amines (MEA, DEA, DIPA, or MDEA)?	If Yes, proceed to 2.B.8
8.	High Temperature Oxidation Corrosion	1.	Is the temperature ≥ 482^oC (900^oF)?	If Yes to both, proceed to 2.B.9
		2.	Is the oxygen present?	
9.	Acid Sour Water Corrosion	1.	Is free water with H_2S present and pH < 7.0?	If Yes, proceed to 2.B.10
		2.	Does the proocess contain < 50 ppm chlorides?	
10.	Cooling Water	1.	Is equipment in cooling water service?	If Yes, proceed to 2.B.11
11.	Soil Side Corrosion	1.	Is equipment in contact with soil (buried or partially	If Yes, proceed to 2.B.12
		2.	Is the material of construction carbon steel?	

Table 01.B.2 Continue-Screening Questions for Corrosion Rate Calculations

No.	Type of Corrosion	Screening Question		Action
12.	CO_2 Corrosion	1.	Is the free water with CO_2 present (including consideration for dew point	If Yes, proceed to 2.B.13
		2.	Is the material of construction carbon steel or < 13% Cr?	
13.	AST Bottom	1.	Is the equipment item an AST tank bottom?	If Yes, proceed to 2.B.14

3. Table 01.B.3 LoIE Example for Local Thinning

Inspection Category	Inspection Effectiveness Category	Intrusive Inspection Example	Non-intrusive Inspection Example
A	Highly Effective	For the total surface area: 1 100% visual examination (with removal of internal packing, trays, etc.) **AND** 2 100% follow-up at locally thinned areas	For the total suspect area: 100% coverage of the CML's using ultrasonic scanning or profile radiography
B	Usually Effective	For the total surface area: 1 >75 % visual examination **AND** 2 100% follow-up at locally thinned areas	For the total suspect area: >75% coverage of the CML's using ultrasonic scanning or profile radiography
C	Fairly Effective	For the total surface area: 1 >50% visual examination **AND** 2 100% follow-up at locally thinned areas.	For the total suspect area: >50% coverage of the CML's using ultrasonic scanning or profile radiography
D	Poorly Effective	For the total surface area: 1 >20% visual examination **AND** 2 100% follow-up at locally thinned areas	For the total suspect area: >20% coverage of the CML's using ultrasonic scanning or profile radiography
E	Ineffective	Ineffective inspection technique/plan was utilized	Ineffective inspection technique/plan was utilized

4. Table 01.B.4 Prior Probability for Thinning Corrosion Rate

Damage State	Low Confidence Data	Medium Confidence Data	High Confidence Data
Pr_{P1}^{Thin}	0,5	0,7	0,8
Pr_{P2}^{Thin}	0,3	0,2	0,15
Pr_{P3}^{Thin}	0,2	0,1	0,05

5. Table 01.B.5 Conditional Probability for Inspection Effectiveness

Conditional P. of Inspection	E-None or Ineffective	D-Poorly Effective	C-Fairly Effective	B-Usually Effective	A-Highly Effective
Co_{P1}^{Thin}	0,33	0,4	0,5	0,7	0,9
Co_{P2}^{Thin}	0,33	0,33	0,3	0,2	0,09
Co_{P3}^{Thin}	0,33	0,27	0,2	0,1	0,01

6. Table 01.B.6 Typical Examples of Protective Internal Linings

Lining Series ID	Environtment (Damage mechanism of Base Material)	Example Lining
Alloy Linings	Corrosive (Thinning)	Strip Lined Alloy
Organic Coating	Corrosive (Thinning)	Organic Coating or Lining
Refractory	High Temperature (Thinning, Creep, Erosion)	Castable Refractory
		Plastic Refractory
		Refractory Brick
		Ceramic Fiber Refractory
		Refractory/Alloy Combination
Gas Lined	Corrosive (Thinning)	Glass Lined
Acid Brick	Corrosive (Thinning)	Brick/Mortar

7. Table 01.B.7 Lining Damage Factors – Inorganic Linings

Years Since Last Through Visual Inspection	DF as Fucntion of Inorganic Lining Type					
	Strip Lined Alloy (Resistant)	Castable Refractory	Castable Refractory Severe Condition	Glass Lined	Acid Brick	Fiberglass
1	0,3	0,5	9	3	0,01	1
2	0,5	1	40	4	0,03	1
3	0,7	2	146	6	0,05	1
4	1	4	428	7	0,15	1
5	1	9	1017	9	1	1
6	2	16	1978	11	1	1
7	3	30	3000	13	1	2
8	4	53	3000	16	1	3
9	6	89	3000	20	2	7
10	9	146	3000	25	3	13

8. Table 01.B.8 Susceptibility to SCC

Environmental Severity	Susceptibility to SCC as function of heat treatment					
	As-welded Max Brinnel Hardness			PWHT Max Brinnel Hardness		
	< 200	200-237	>237	< 200	200-237	>237
High	Low	Medium	High	Not	Low	Medium
Moderate	Low	Medium	High	Not	Not	Low
Low	Low	Low	Medium	Not	Not	Not

9. Table 01.B.9 SCC Damage Factors – All SCC Mechanisms

S_{VI}	Inspection Effectiveness												
	E	1 Inspection				2 Inspections				3 Inspections			
		D	C	B	A	D	C	B	A	D	C	B	A
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	10	8	3	1	1	6	2	1	1	4	1	1	1
50	50	40	17	5	3	30	10	2	1	20	5	1	1
100	100	80	33	10	5	60	20	4	1	40	10	2	1
500	500	400	170	50	25	300	100	20	5	200	50	8	1
1000	1000	800	330	100	50	600	200	40	10	400	100	16	2
5000	5000	4000	1670	500	250	3000	1000	250	50	###	500	80	10
S_{VI}	Inspection Effectiveness												
	E	4 Inspections				5 Inspections				6 Inspections			
		D	C	B	A	D	C	B	A	D	C	B	A
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	10	2	1	1	1	1	1	1	1	1	1	1	1
50	50	10	2	1	1	5	1	1	1	1	1	1	1
100	100	20	5	1	1	10	2	1	1	5	1	1	1
500	500	100	25	2	1	50	10	1	1	25	5	1	1
1000	1000	200	50	5	1	100	25	5	1	50	10	1	1
5000	5000	1000	250	25	2	500	125	5	1	250	50	2	1

10. Table 01.B.10 Susceptibility to Cracking – HIC/SOHIC-H2S

Enviromental severity	Susceptibility to Cracking as a Function of Steel Sulfur Content					
	High Sulfur Steel >0.01% S		Low Sulfur Steel < 0.01% S		Product Form – Seamless/Extruded Pipe	
	As-Welded	PWHT	As-Welded	PWHT	As-Welded	PWHT
High	High	High	High	Medium	Medium	Low
Moderate	High	Medium	Medium	Low	Low	Low
Low	Low	Low	Low	Low	Low	Low

11. Table 01.B.11 Corrosion Rates for Calculation of the Damage Factor-External Corrosion

Operating Temperature (^oC)	Corrosion Rate as a Function of Driver (1) (mpy)			
	Marine/Cooling	Temperate	Arid/Dry	Severe
-12	0	0	0	0
-8	0,025	0	0	0
6	0,127	0,076	0,025	0,254
32	0,127	0,076	0,025	0,254
71	0,127	0,051	0,025	0,254
107	0,025	0	0	0,051
121	0	0	0	0

12. Table 01.B.12 LoIE Example for External Damage

Inspection Category	Ispection Effectiveness Category	Inspection
A	Highly effective	Visual inspection of >95% of the exposed surface area with follow-up by UT, RT or pit
B	Usually Effective	exposed surface area with follow-up by UT, RT or pit gauge as required.
C	Fairly Effective	exposed surface area with follow-up by UT, RT or pit gauge as required.
D	Poorly Effective	surface area with follow-up by UT, RT or pit gauge as required.
E	Ineffective	Ineffective inspection technique/plan was utilized

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DOC. NO. 01.C

TABLES TO CALCULATE CONSEQUENCE OF FAILURE

	TABLES TO CALCULATE CONSEQUENCE OF FAILURE	Doc. No:	01.C
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1. **Table 01.C.1 List of Representative Fluids Available for Level 1 Consequence Analysis**

Representative Fluide	Fluid Type	Examples of Applicable Materials
C1 – C2	TYPE 0	Methane, Ethane, Ethylene, LNG, Fuel Gas
C3 – C4	TYPE 0	Propane, Butane, Isobutane, LPG
C5	TYPE 0	Pentane
C6 – C8	TYPE 0	Gasoline, Naphtha, Light Straight Run,
C9 – C12	TYPE 0	Diesel, Kerosene

2. **Table 01.C.2 Properties of the Representative Fluids Used in Level 1 Consequence Analysis**

Fluid	MW	Liquid Density (lb/ft3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	Cp (Ideal Gas Constant)					Auto Ignition Temp. (°F)
						A	B	C	D	E	
C1-C2	23	15,639	-193	Gas	Note 1	12,3	1E+02	-2,87E-05	-1,30E-09	N/A	1036
C3-C4	51	33,61	-6,3	Gas	Note 1	2632	0,3188	-1,35E-04	1,47E-05	N/A	696
C5	72	39,03	97	Liquid	Note 1	-3626	0,4873	-2,60E-04	5,30E-08	N/A	544
C6-C8	100	42,702	210	Liquid	Note 1	-5146	6,E-01	-3,65E-04	7,66E-05	N/A	433
C9-C12	149	45,823	364	Liquid	Note 1	-8,5	1E+00	-5,56E-04	1,18E-04	N/A	406

3. **Table 01.C.3 Release Hole Sizes and Areas Used in Level 1 and 2 Consequences Analysis**

Release Hole Number	Release Hole Sizes	Range of Hole Diameter (mm)	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	$d_4 = \min[D,16]$

4. Table 01.C.4 Assumptions Used When Calculating Liquid Inventories Within Equipment

Equipment Description	Component Type	Examples	Default Liquid Volume Percent
Acumulators and Drums	DRUM	OH Accumulators, Feed Drums, HP/LP Separators, Nitrogen Storage Drums, Steam Condensate Drums, 3-Phase Separators	50% liquid Typically, 2-phase drums are luqiud level controlled at 50%
Knock-out Pots and Driyer	KODRUM	Compresor knock-out, Fuel gas KO Drum (see note 4), Flare Drums, Air Driyers (see note 4)	10% liquid Much less liquid inventory expected in knock-outs drum

5. Table 01.C.5 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

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DOC. NO. 01.D

TABLES TO CALCULATE RISK

1. Table 01.D.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 (m2)
1	Pf(t,Ie) ≤ 3,06E-05	Df total ≤ 1	A	CA ≤ 9,29
2	3,06E-05 < Pf(t,Ie) ≤ 3,06E-04	1 < Df total ≤ 10	B	9,29 < CA ≤ 92,9
3	3,06E-04 < Pf(t,Ie) ≤ 3,06E-03	10 < Df total ≤ 100	C	92,9 < CA ≤ 929
4	3,06E-03 < Pf(t,Ie) ≤ 3,06E-02	100 < Df total ≤ 1000	D	929 < CA ≤ 9290
5	Pf(t,Ie) > 3,06E-02	Df total > 1000	E	CA > 9290

PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

DOC. NO. 02

DAMAGE FACTOR SCREENING QUESTION

<table>
<tr><td rowspan="2">Rev</td><td rowspan="2">Date</td><td rowspan="2">Remark</td><td colspan="2">Prepared by</td><td colspan="2">Approved by</td></tr>
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	DAMAGE FACTOR SCREENING QUESTION	Doc. No:	2
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The basic function of the Damage Factor is to statistically evaluate the amount of damage that may be present as a function of time in service and the effectiveness of an inspection activity. Here are the screening questions to determine the damage factor.

Table 2.1 Damage Factor Screening Questions

No	Damage Factor	Screening Criteria	Yes/No
1.	Thining	All component should be checked for thining	Yes
2.	Component Lining	If the component has organic or inorganic lining, then the component should be evaluated for lining damage	Yes
3.	SCC Damage Factor-Caustic Cracking	If the component's material of construction is carbon or low alloy steel and the process environment contains caustic in any concentration, then the component should be evaluated for susceptibility to caustic cracking.	No
4.	SCC Damage Factor-Amine Cracking	If the component's material of construction is carbon or low alloy steel and process environment contains acid gas treating amines (MEA, DEA, DIPA, MDEA, etc.) in any concentration, then the component should be evaluated for susceptibility to amine cracking.	No
5.	SCC Damage Factor-Sulfide Stress Cracking	If the component's material of construction contains is carbon or low alloy steel and the process environment contains water and H_2S in any concentration, then the component should be evaluated to Sulfide Ctress Cracking (SCC).	Yes
6.	SCC Damage Factor HIC/SOHIC-H_2S	If the component's material of construction contains is carbon or low alloy steel and the process environment contains water and H_2S in any concentration, then the component should be evaluated to HIC/SOHIC-H_2S cracking.	Yes
7.	SCC Damage Factor-Carbonate Stress Corrosion Cracking	If the component’s material of construction is carbon or low alloy steel and the process environment contains sour water at pH > 7.5 in any concentration, then the component should be evaluated for susceptibility to carbonate cracking.	No
		Another trigger would be changes in FCCU feed sulfurr and nitrogen contents particularly when feed changes have reduced sulfur (low sulfur feeds or hydroprocessed feeds) or increased nitrogen.	No
8.	SCC Damage Factor-Polythionic Acid Stress Corrosion Cracking	If the component's material of construction is an austenitic stainless steel or nickel based alloys and the components is exposed to sulfur bearing compunds, then the component should be evaluated for susceptibility to PASCC.	No

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No	Damage Factor	Screening Criteria			Yes/No
9.	SCC Damage Factor-Chloride Stress Corrosion Cracking	If **ALL** of the following are true, then the component should evaluated for suscepibility to CLSCC cracking:			No
		a.	The component's material of construction is an austenitic stainless steel.	N	
		b.	The component is exposed or potentially exposed to chlorides and water also considering upsets and hydrotest water remaining in component, and cooling tower drift (consider both under insulation and process conditions).	N	
		c.	The operating temperature is above 38°C (100°F)	Y	
10.	SCC Damage Factor-Hydrogen Stress Cracking HF	If the component's material of construction is ccarbon or low alloy steel and the component is exposed too hydrofluoric acid in any concentration, then the component should be evaluated for susceptibility to HSC-HF.			No
11.	SCC Damage Factor HIC/SOHIC-HF	If the component's material of construction is ccarbon or low alloy steel and the component is exposed too hydrofluoric acid in any concentration, then the component should be evaluated for susceptibility to HIC/SOHIC-HF.			No
12	External Chloride Stress Corrosion Cracking Damage Factor-Austenitic Component	If **ALL** of the following are true, then the component should evaluated for suscepibility to CLSCC:			No
		a.	The component's material of construction is an austenitic stainless steel.	N	
		b.	The component external surface is exposed to chloride containing fluids, mists, or solids.	N	
		c.	The operating temperature is between 50° C and 150°C (120°F and 300°F) , or the system heats or cools into this range intermittently.	Y	
13	Low Alloy Steel Embrittlement Damage Factor	If **ALL** of the following are true, then the component should be evaluated for susceptibility to low alloy steel embrittlement:			No
		a.	The material is 1Cr--0.5Mo, 1.25Cr-0.5Mo, or 3Cr-1Mo low alloy steel.	N	
		b.	The operating temperature is between 343°C and 577°C (650°F and 1070°F).	N	

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No	Damage Factor	Screening Criteria			Yes/No
14	External Corrosion Damage Factor-Ferritic component	If the component is un-insulated and subject to any of the following , then the component should be evaluated for external damage from corrosion.			Yes
		a.	Areas exposed to mist overspray from cooling towers.	N	
		b.	Areas exposed to steam vents	N	
		c.	Areas exposed to deluge system	N	
		d.	Areas subject to process spills, ingress of moisture, or acid vapors.	N	
		e.	Carbon steel system, operatinng between -12°C and 177°C (10°F and 350°F). External corrosion is particulartly aggressive where operating temperatures cause frequent or continuous condensation and re-evaporation of atmospheric moisture. (Operating Temperature is 185.4 °C.	Y	
		f.	Systems that do not operating in normally temperature between -12°C and 177° (10°F and 350°F) but cool or heat into this range intermitterntly or are subjected to frequent outages.	N	
		g.	Systems with deteoriated coating and/or wrappings.	N	
		h.	Cold service equipment consistently operating below the atmospheric dew point.	N	
		i.	Un-insulated nozzles or other prostrusions components of insulated equipment in cold service conditions.	N	

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No	Damage Factor	Screening Criteria			Yes/No
15	Corrosion Under Insulation Damage Factor-Ferritic Commponent	Specific locations and/or systems as stated below are highly suspect and should be considered during inspection program development. Examples the areas include, but are not limited to, the following:			No
		a.	Penetrations 1. All penetrations or breaches in the insulation jacketing systems, such as dead legs (vents, drains, and other similar items), hangers and other supports, valves and fittings, bolted-on pipe shoes, ladders, and platforms. 2. Steam tracer tubing penetrations. 3. Termination of insulation at flanges and other components. 4. Poorly designed insulation support rings. 5. Stiffener rings	N	
		b.	Damaged Insulation Areas 1. Damaged or missing insulation jacketing. 2. Termination of insulation in a vertical pipe or piece of equipment. 3. Caulking that has hardened, has separated, or is missing. 4. Bulges, staining of the jacketing system or missing bands (bulges may indicate corrosion product build-up). 5. Low points in systems that have a known breach in the insulation system, including low points in long unsupported piping runs. unsupported piping runs 6. Carbon or low alloy steel flanges, bolting, and other components under insulation in high alloy piping.	N	

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No	Damage Factor	Screening Criteria			Yes/No
16	External Chloride Stress Corrosion Cracking Under Insulation Damage Factor-Austenitic Component	If **ALL** of the following are true, then the component should be evaluated for susceptibiity to CUI CLSCC:			No
		a.	The component's material of construction is an austenitic stainless steel.	N	
		b.	The component is insulated	N	
		c.	The component external surface is exposed to chloride containing fluids, mists, or solids.	N	
		d.	The operating temperature is between 50° C and 150°C (120°F and 300°F) , or the system heats or cools into this range intermittently	Y	
17	High Temperature Hydrogen Attack Damage Factor	If **ALL** of the following are true, then the component should be evaluated for susceptibiity to HTHA:			No
		a.	The material is carbon steel, C-$^{1}/_{2}$Mo, or a CrMo low alloy steel (such as $^{1}/_{2}$Cr-$^{1}/_{2}$Mo, 1Cr-$^{1}/_{2}$Mo, 1$^{1}/_{4}$Cr-^{1}/2Mo, 2$^{1}/_{4}$Cr-1Mo, 3Cr-1Mo, 5Cr-1Mo, 7Cr-1Mo, 9Cr-1Mo).	N	
		b.	The operating temperature is greater than 177°C (350°F).	N	
		c.	The operating hydrogen partial presssure is greater than 0.345 Mpa (50 psia).	N	
18	Brittle Fracture Damage Factor	If **BOTH** of the following are true, then the component should be evaluated for susceptibility to brittle fracture:			
		a.	The material is carbon steel or low alloy steel (see Table 20.1).	Y	
		b.	If Minimum Design Metal Temperature (MDMT), T_{MDMT}, or Minimum Allowable Metal Temperature (MAT), T_{MAT}, is unknown, or the component is known to operate at below MDMT or MAT under normal or upset conditions.	N	

No	Damage Factor	Screening Criteria			Yes/No
19.	885°F Embrittlement Damage Factor	If **BOTH** of the following are true, then the component should be evaluated for susceptibiity to 885°F embrittlemet:			No
		a.	The material is high chromium (>12% Cr) ferritic steel	Y	
		b.	The operating temperature is between 371°C and 566°C (700°F and 1050°F).	N	
20.	Sigma Phase Embrittlement Damage Factor	If **BOTH** of the following are true, then the component should be evaluated for susceptibiity to sigma phase embrittlemet:			No
		a.	The component's material of construction is an austenitic stainless steel.	N	
		b.	The operating temperature is between 593°C and 927°C (1100°F and 1700°F).	N	
21.	Piping Mechanical Fatigue Damage Factor	If **BOTH** of the following are true, then the component should be evaluated for susceptibiity to mechanical fatigue:			No
		a.	The component is pipe	N	
		b.	There have been past fatigue failure in this piping system or there is visible/audibble shaking in this piping system or there is a source of cyclic vibration within approximately 15.24 meters (50 feet) and connected to the piping (directly or indirectly via structure). Shaking and source of shaking can be continuous or intermittent. Transient conditions often cause intermittent	N	

PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

DOC. NO. 03

CALCULATION OF PROBABILITY OF FAILURE

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THINNING DAMAGE FACTOR CALCULATION

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REQUIRED DATA

The basic component data required for analysis is given in Table 3.1. Component types and geometry data are shown in Tables 4.2 and 4.3 of API 581, respectively. The data required for determination of the thinning DF is provided in Table 4.4 of API 581.

Table 3.1. Basic Component Data Required for Analysis

Basic Data	Value	Unit	Comments
Start Date	01/06/2014		The date the component was placed in service.
Thickness	78	mm	The thickness used for DF calculation that is either the furnished thickness or the measured thickness.
Corrosion Allowance	5,78	mm	The corrosion allowance is the specified design or actual corrosion allowance upon being placed in the current
Design Tempearture	140	^oF	The design temperature, shell side and tube side for heat exchanger.
Design Pressure	1300	psig	The design pressure, shell side and tubbe side for heat exchanger.
Operating Tempearture	120	^oF	The highest expected operating temperature expected during operation including normal and unusual operating conditions, shell side and tube side for heat exchanger.
Operating Pressure	905	psig	The highest expected operating pressure expected during operation including normal and unusual operating conditions, shell side and tube side for heat exchanger.
Design Code	ASME Sec. VIII Div. 2, 2010 Ed, 2011 Add.		The designing of the component containing the component.
Equipment Type	Production Separator		The type of equipment.
Component Type	Drum		The type of component.
Geometry Data	2:1 Ellipsoidal		Component geometry data depending on the type of component.
Material Specificatio n	SS316L		The specification of the material of construction, the ASME SA or SB specification for pressure vessel components or for ASTM specification for piping and tankage components. Data entry is based on the material specification, grade, year, UNS Number, class/condition/temper/size/thickness; this data is readdily available in the ASME Code.

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Basic Data	**Value**	**Unit**	**Comments**
Yield Strength	205000	Kpa	The design yield strength of the material based on material specification.
Tensile Strength	515000	Kpa	The design tensile strength of the material based on material specification.
Weld Joint Efficiency	1,00		Weld joint efficiency per the Code of construction.
Heat	Yes		Is the component heat traced? (Yes or No)

STEP 1 Determining the furnished thickness, t, and age for the component from the installation date.

t = 3,0709 inch

= 78,000 mm (It is assumed on 2014)

age = 6 years

STEP 2

Determining the corrosion rate for base material, $C_{r,bm}$ based on the material construction and environment, and cladding/weld overlay corrosion rate, $C_{r,cm}$. Based on the explanation from Section 4.5.2 of API 581 that the corrosion rate is calculated using the approach of Annex 2B. Then, first of all, the corrosion screening question must be done as follows:

Table 3.2 Screening Questions for Corrosion Rate Calculations

No.	**Type of Corrosion**	**Screening Question**		**Yes/No**	**Action**
1.	Hydrochloric Acid (HCl) Corrosion	1.	Does the process contain HCl	N	No
		2.	Is free water present in the process stream (including initial condensing condition)?	N	
		3.	Is the pH < 7.0? Actual relatively pH is 5,85	Y	
2.	High Temperature Sulfidic/Naphtenic Acid Corrosion	1.	Does the process contain oil with sulfur compounds?	N	No
		2.	Is the operating temperature > 204°C (400°F)? The operating temperature is 120°F	N	
3.	Sulfuric Acid Corrosion	1.	Does the process contain H_2SO_4?	N	No

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No.	Type of Corrosion		Screening Question	Yes/No	Action
4.	High Temperature H_2S/H_2 Corrosion	1.	Does the process contain H_2 and Hydrogen?	N	No
		2.	Is the operating temperature > 204°C (400°F)?	N	
			The operating temperature is 120°F.		
5.	Hydrifluoric Corrosion	1.	Does the process contain HF?	N	No
6.	Sour Water Corrsion	1.	Is free water with H_2S present?	Y	Yes
			H_2S concentration is 0,1%		
7.	Amine Corrosion	1.	Is equipment exposed to acid gas treaating amines (MEA, DEA, DIPA, or MDEA)?	N	No
8.	High Temperature Oxidation Corrosion	1.	Is the temperature ≥ 482°C (900°F)?	N	No
			The operating temperature is 120°F.		
		2.	Is the oxygen present?	N	
9.	Acid Sour Water Corrosion	1.	Is free water with H_2S present and pH < 7.0?	Y	Yes
			Actual relatively pH is 5,85		
		2.	Does the proocess contain < 50 ppm chlorides?	Y	
			Contains 15,3 ppm of chlorides		
10.	Cooling Water	1.	Is equipment in cooling water service?	N	No
11.	Soil Side Corrosion	1.	Is equipment in contact with soil (buried or partially	N	No
		2.	Is the material of construction carbon steel?	Y	
12.	CO_2 Corrosion	1.	Is the free water with CO_2 present (including consideration for dew point	N	No
		2.	Is the material of construction carbon steel or < 13% Cr?	N	
			Stainless steel with 16% Cr		
13.	AST Bottom	1.	Is the equipment item an AST tank bottom?	N	No

Corrosion Rate Cladding

2.a. Corrosion Rate (Cr) based on the Annex 2B alkaline sour water

The corrosion rate may be determined using the basic data in Table 3.3 in conjunction with the baseline corrosion rates and equations in Table 3.4 to correct for H_2S partial pressure

Table 3.3 Alkaline Sour Water Corrosion – Basic Data Required for Analysis

Basic Data	Comments
NH_4HS concentratio n (wt%)	Determine the NH4HS concentration of the condensed water. It is suggested to determine this value with ionic process models. However, approximate values may be calculated from analyses of H2S and NH3 as follows: • If wt% H_2S < 2 x (wt% NH_3), wt% NH_4HS =1.5 x (wt% H_2S) • If wt% H_2S > 2 x (wt% NH_3), wt% NH_4HS =3.0 x (wt% H_2S)
Stream Velocity	The vapor phase velocity should be used in a two-phase system. The liquid phase velocity should be used in a liquid full system.
H_2S partial pressure, psia [kPa]	Determine the partial pressure of H_2S by multiplying the mole% of H_2S in the gas phase by the total system pressure.

From chemical composition report company, known that:

wt% H_2S = 0,1 wt% NH_3 = 0

2 wt% NH_3 = 0

So wt% H2S > 2 x (wt% NH3), the wt% NH4HS can be calculated by:

wt% NH4HS = 3.0 x (wt% H_2S) (3.1)

wt% NH4HS = 0,3

Table 3.4 Alkaline Sour Water Corrosion – Baseline Corrosion Rates for Carbon Steel (mpy)

NH4HS (wt%)	Velocity (m/s)				
	3,05	4,57	6,1	7,62	9,14
2	0,08	0,1	0,13	0,2	0,28
5	0,15	0,23	0,3	0,38	0,46
10	0,51	0,69	0,89	1,09	1,27
15	1,14	1,78	2,54	3,81	5,08

1. for pH2S < 345 kPa,

$$\text{Adjusted } CR = \max\left[\left\{\left(\frac{Baseline\ CR}{173}\right).(pH2S\ -345)+Baseline\ CR\right\},0\right] \quad (3.2)$$

2. for pH2S ≥ 345 kPa,

$$\text{Adjusted } CR = \max\left[\left\{\left(\frac{Baseline\ CR}{276}\right).(pH2S\ -345)+Baseline\ CR\right\},0\right] \quad (3.3)$$

mole% of H2S in gas phase = 0,1 % pH2S = 6,2398 kPa
Baseline CR = 0,08 mm/year
Adjusted alkaline sour water corrosion rate : 0,000 mm/year

2.b. Corrosion Rate (Cr) based on the Annex 2B acid sour water

The steps required to determine the corrosion rate are shown in Figure 2.B.10.1. If the pH is less than 4.5, then the corrosion rate shall be calculated using paragraph 2.B.2. If the pH is greater than 7, then the corrosion rate is calculated using paragraph 2.B.7. Otherwise, the corrosion rate of carbon steel exposed to acid sour water is computed using Equation (3.4)

$$\text{CR} = CR_{ph}.F_O F_V \quad (3.4)$$

The base corrosion rate, C_{pH} , of carbon steel exposed to acid sour water as a function of pH is provided in Table 2.B.10.2. The modification factor for the corrosion rate as a function of the oxygen content factor, F_O , is provided in Table 2.B.10.3. The corrosion rate also varies with fluid velocity. The modification factor for fluid velocity is given by the following equations.

Fv = 1 *when velocity < 1.83 m/s*
Fv = 0.82 . Velocity -0.5 *when 1,83 m/s ≤ velocity ≤ 6,1 m/s*
Fv = 5 *when velocity > 6,1 m/s*

Table 3.5 Acid Sour Water Corrosion Estimated Corrosion Rates for Carbon and Low Alloy Steel (mm/y) – CRpH

pH	Temperature (°F)			
	100	125	175	200
4,75	1	3	5	7
5,25	0,7	2	3	4
5,75	0,4	1,5	2	3
6,25	0,3	1	1,5	2
6,75	0,2	0,5	0,7	1

Because the operating temperature is normally 120°F, and there is no list of such that temperature. But, it does list values for 100°F and 125°F. Then, we can get the value of corrosion rate based by interpolating the value in between.

Interpolation between 100°F and 125°F

X = 120 °F　　Y = CrPH at 120°F

X_1 = 100 °F　　Y_1 = 0,3

X_2 = 125 °F　　Y_2 = 1

$$Y = Y_1 + [\left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)] \quad (3.5)$$

= 0,86

Table 3.6 Acid Sour Water Corrosion – Basic Data Required for Analysis

Oxygen content	Adjustment factor - F_O
Not significant (≤ 50 pbb)	1,0
High (> 50 pbb)	2,0

CR_{pH} = 0,86　　Fv = 1,000　　F_O = 1,0

So, CR = 0,86000

Acid sour water corrosion rate is : 0,8600 mm/year

Calculated cladding corrosio 0,8600 mm/year

Corrosion Rate Base Material

2.a. Corrosion Rate (Cr) based on the Annex 2B CO_2 Corrosion Calculation

CR = $CR_B . \min[F_{glycol}, F_{inhib}]$

Base Corrosion Rate

$$CR_B = f(T,pH) \cdot f_{CO2}^{0.62} \cdot \left(\frac{S}{19}\right)^{0.146+0.0324\, fco2} \quad (3.6)$$

Where ;

CR_B = Base corrosion rate (mm/y)

f(T,pH = Temperature-pH function tabulated in Table 2.B.13.2

f_{CO2} = CO_2 fugacity

S = Shear stress yo calculate the flow velocity (Pa)

a. Determine the calculated pH

T = 120 °F

= 322,04 K

mole% of CO2 in dry gas = 5 %

P_{CO2} = 45,25 psi

= 0,4525 bar

$$pH = 2.5907 + 0.8668.log_{10}[T] - 0.49log_{10}[p_{CO2}] \quad (3.7)$$

= 3,623264823

b. Determine the CO_2 fugacity

$$log_{10}[f_{CO2}] = log_{10}[p_{CO2}] + \min[250, p_{CO2}].(0.0031\text{-}\frac{1.4}{T+273}) \quad (3.8)$$

$$log_{10}[f_{CO2}] = log_{10}[0,4525] + \min[250; 0,4525].(0.0031\text{-}\frac{1.4}{322,04+273}) \quad (3.9)$$

= ######

c. Determine the flow velocity

To determine the flow velocity, the API 581 reffers to the NORSOK M-506. and both of the Recommended Practice use the fluid flow shear stress, S, to model the effect of flow velocity n the base

$$S = \frac{f.\rho m.um^2}{2} \quad (3.10)$$

In the calculation for the corrosion rate, the shear stress need not exceed 150 Pa.

Where;

f = Friction factor

ρ_m = Mixture mass density kg/m^3

= 63,11 kg/m^3

u_m = Mixture flow velocity m/s

= 0,167 m/s

$$f = 0.001375 [1+ (20000(\frac{e}{D}) + (\frac{10^6}{Re})^{0.33}] \quad (3.11)$$

$\frac{\varepsilon}{D}$ = Relative roughness of the material

0,1

Based on the Table below that for the Carbon Steel (SA 516 GR 70) material of construction which is assumed as slighly corroded is approximately ranging from 0.5-1.5.

Table 3.7 Absolute Roughness

Material	Absolute Roughness(mm)
Weld Steel	0,045
Carbon Steel (New)	0,02-0,05
Carbon Steel (Slightly Corroded)	0,05-0,15
Carbon Steel (Moderately Corroded)	0,15-1
Carbon Steel (Badly Corroded)	1-3

Source by: https://www.nuclear-power.net

$$Re = \frac{D.\rho m.um}{\mu m} \qquad (3.12)$$

Re = Reynolds number
D = Diameter
= 2591 mm
= 2,591 m
µm = Viscosity of the mixture cp
= 0,014 Cp
= 0,000014 Pa s

$$Re = \frac{D.\rho m.um}{\mu m}$$

= 1950536,3

$$f = 0.001375\,[\,1+ (20000(\frac{e}{D}) + (\frac{10^6}{Re})^{0.33}]$$

= 0,017

After the value of relative roughness, Reynolds number, and the friction factor have been determines. Then, the value of the flow velocity can be calculated.

$$S = \frac{f.\rho m.um^2}{2} \qquad (3.13)$$

= 0,014868 Pa

Those calculated pH, CO_2 fugacity, and also flow velocity have been known. So, the value of Base Corrosion Rate (Cr_{base}) can be determined.

$$CR_B = f(T,pH)\,.\,f_{CO2}^{\;0.62}\,.\,(\frac{S}{19})^{0.146+0.0324\,fco2}$$

Where;

f(T,pH = Temperature-pH function tabulated in Table 2.B.13.2
= 2,2

Cr_{base} = 0,8901623 mpy
= 0,0226101 mm/y

Because there is no any mixture for glycol and the other inhibitors inside the Production Separator, then, Cr is equal to Cr_{base}. The glycol or inhibitor is placed in another equipment not being process in the Production Separator itself.

Where;

CR = Cr_{base}
= 0,0226101 mm/y

STEP 3 Determine the time in service, age_{tk}, since the last known inspection, t_{rdi}.

- Shell t_{rdi} = 3,0709 inch
  = 78 mm
- Head t_{rdi} = 70 mm

Last inspection is on: 01/06/2014
RBI Date is on: 01/01/2020
Planned Date is on: 01/01/2024

age_{tk} = 6 years (Last inspection was held on June 2014)
age_{PD} = 10 years Inspection is held 10 years after the last inspection based on API 510

STEP 4 For cladding/weld overlay pressure vessel components, calculate the age from the date starting thickness from STEP 3 required to corrode away the cladding/weld overlay material, age_{rc}, using equation below:

$Cr_{c.m}$ 0,8600 mm/y

$$age_{rc} = \max\left[\left(\frac{t_{rdi} - tbm}{C_{r\,cm}}\right), 0.0\right] \quad (3.15)$$

$$age_{rc} = \max\left[\left(\frac{78-75}{0,86}\right), 0.0\right]$$

age_{rc} = 3 years

STEP 5 Determine the t_{min}

Actually there are 4 methods used to determine the minimum thickness of the equipment (t_{min}). In this condition, the data have been provided by the company.

t_{min} = 72,058 mm
S = 24100 psi
E = 1

STEP 6 Determine the A_{rt} Parameter

For components with cladding/weld overlay (i.e. agerc ≥ 0.0) at the date of the starting thickness from STEP 2 but where agetk > agerc

$$A_{rt} = \frac{Cr_{c,m}.age_{tk} + Cr_{b,m}.(age_{tk} - age_{rc})}{t_{rdi}} \quad (3.16)$$

Where,

$Cr_{b.m}$: Corrosion base material

$Cr_{c.m}$: Corrosion cladding/weld overlay

age_{tk} : Component in-service time since the last inspection

age_{rc} : Remaining life of the cladding/weld overlay

t_{rdi} : Furnished thickness since last inspection

Shell A_{rt} on RBI Date:

$$A_{rt} = \frac{Cr_{c,m}.age_{tk} + Cr_{b,m}.(age_{tk} - age_{rc})}{t_{rdi}}$$

= 0,0621884

Head A_{rt} on RBI Date:

$$A_{rt} = \frac{Cr_{c,m}.age_{tk} + Cr_{b,m}.(age_{tk} - age_{rc})}{t_{rdi}}$$

= 0,0692956

Shell A_{rt} on Plan Date:

$$A_{rt} = \frac{Cr_{c,m}.age_{tk} + Cr_{b,m}.(age_{tk} - age_{rc})}{t_{rdi}}$$

= 0,1074505

Head A_{rt} on Plan Date:

$$A_{rt} = \frac{Cr_{c,m}.age_{tk} + Cr_{b,m}.(age_{tk} - age_{rc})}{t_{rdi}}$$

= 0,1197305

STEP 7 Calculate the Flow Stress FS^{Thin} , using E from STEP 5 and equation below.

$$FS^{Thin} = \frac{(YS+TS)}{2}.\,E.1{,}1 \quad (3.17)$$

Where;

YS = 205000 KPa

TS = 515000 KPa

E = 1,00

$$FS^{Thin} = \frac{(YS+TS)}{2}.\,E.1{,}1$$

= 396000

STEP 8 Calculate the strength ratio parameter, SR_P^{Thin} , using the appropriate

$$SR_P^{Thin} = \frac{S.E}{FS^{Thin}}.\frac{Max\,(t_{min},t_c)}{t_{rdi}} \quad (3.18)$$

Where;

t_c = is the minimum structural thickness of the component base material

= 2,8369291 inch

= 72,058 mm

$$SR_P^{Thin} = \frac{S.E}{FS^{Thin}}.\frac{Max\,(t_{min},t_c)}{t_{rdi}}$$

= 0,0562224 **(Shell)**

$$SR_P^{Thin} = \frac{S.E}{FS^{Thin}}.\frac{Max\,(t_{min},t_c)}{t_{rdi}}$$

= 0,0626478 **(Head)**

STEP 9 Determine the number of inspections for each of the correspondesing inspection effectiveness, $N_A^{Thin} N_B^{Thin} N_C^{Thin}\ N_D^{Thin}$, using Section 4.5.6 of the API RP 581 Part 2 for past inspections performed during in-service time.

N_A^{Thin} = 0

N_B^{Thin} = 0

N_C^{Thin} = 0

N_D^{Thin} = 0

STEP 10 Calculate the inspection effectiveness factors, $I_1^{Thin} I_2^{Thin}\ I_3^{Thin}$, using equation 61 below, prior probabilities, $Pr_{P1}^{Thin} Pr_{P2}^{Thin} Pr_{P3}^{Thin}$, from Table 4.5. The Conditional Probabilities (for each inspection effectiveness level), from Table 4.6, and the number of inspection in each effectiveness level from

$$I_1^{Thin} = Pr_{P1}^{Thin}(Co_{P1}^{ThinA})^{N_A^{Thin}}(Co_{P1}^{ThinB})^{N_B^{Thin}}(Co_{P1}^{ThinC})^{N_C^{Thin}}(Co_{P1}^{ThinD})^{N_D^{Thin}} \quad (3.19)$$

$$I_2^{Thin} = Pr_{P2}^{Thin}(Co_{P2}^{ThinA})^{N_A^{Thin}}(Co_{P2}^{ThinB})^{N_B^{Thin}}(Co_{P2}^{ThinC})^{N_C^{Thin}}(Co_{P2}^{ThinD})^{N_D^{Thin}} \quad (3.20)$$

$$I_3^{Thin} = Pr_{P3}^{Thin}(Co_{P3}^{ThinA})^{N_A^{Thin}}(Co_{P3}^{ThinB})^{N_B^{Thin}}(Co_{P3}^{ThinC})^{N_C^{Thin}}(Co_{P3}^{ThinD})^{N_D^{Thin}} \quad (3.21)$$

Table 3.8 Prior Probability for Thinning Corrosion Rate

Damage State	Low Confidence Data	Medium Confidence Data	High Conf. Data
Pr_{P1}^{Thin}	0,5	0,7	0,8
Pr_{P2}^{Thin}	0,3	0,2	0,15
Pr_{P3}^{Thin}	0,2	0,1	0,05

Table 3.9 Conditional Probability for Inspection Effectiveness

Conditional P. of Inspection	E-None or Ineffective	D-Poorly Effective	C-Fairly Effective	B-Usually Effective	A-Highly Effective
Co_{P1}^{Thin}	0,33	0,4	0,5	0,7	0,9
Co_{P2}^{Thin}	0,33	0,33	0,3	0,2	0,09
Co_{P3}^{Thin}	0,33	0,27	0,2	0,1	0,01

$$I_1^{Thin} = Pr_{P1}^{Thin}(Co_{P1}^{ThinA})^{N_A^{Thin}}(Co_{P1}^{ThinB})^{N_B^{Thin}}(Co_{P1}^{ThinC})^{N_C^{Thin}}(Co_{P1}^{ThinD})^{N_D^{Thin}}$$

= 0,50

$$I_2^{Thin} = Pr_{P2}^{Thin}(Co_{P2}^{ThinA})^{N_A^{Thin}}(Co_{P2}^{ThinB})^{N_B^{Thin}}(Co_{P2}^{ThinC})^{N_C^{Thin}}(Co_{P2}^{ThinD})^{N_D^{Thin}}$$

= 0,30

$$I_3^{Thin} = Pr_{P3}^{Thin}(Co_{P3}^{ThinA})^{N_A^{Thin}}(Co_{P3}^{ThinB})^{N_B^{Thin}}(Co_{P3}^{ThinC})^{N_C^{Thin}}(Co_{P3}^{ThinD})^{N_D^{Thin}}$$

= 0,20

STEP 11 Calculate the Posteroir Probability, Po_{p1}^{Thin} Po_{p2}^{Thin} Po_{p3}^{Thin} , using equations:

$$Po_{p1}^{Thin} = \frac{I_1^{Thin}}{I_1^{Thin} + I_2^{Thin} + I_3^{Thin}} \quad (3.22)$$

= 0,5

$$Po_{p2}^{Thin} = \frac{I_2^{Thin}}{I_1^{Thin} + I_2^{Thin} + I_3^{Thin}} \quad (3.23)$$

= 0,3

$$Po_{p3}^{Thin} = \frac{I_3^{Thin}}{I_1^{Thin} + I_2^{Thin} + I_3^{Thin}} \quad (3.24)$$

= 0,2

STEP 12 Calculate the parameters, $ß_1$, $ß_2$, and $ß_3$ using equation below and also assigning $COV_{\Delta t}$ = 0.20, COV_{sf} = 0.20, and COV_P = 0.05.

$$ß_1^{Thin} = \frac{1 - D_{S1}.A_{rt} - SR_P^{Thin}}{\sqrt{D_{S1}{}^2.A_{rt}{}^2.COV_{\Delta t}{}^2 + (1 - D_{S1}.A_{rt})^2.COV_{sf}{}^2 + (SR_P^{Thin})^2.(COV_P)^2}} \quad (3.25)$$

$$ß_2^{Thin} = \frac{1 - D_{S2}.A_{rt} - SR_P^{Thin}}{\sqrt{D_{S2}{}^2.A_{rt}{}^2.COV_{\Delta t}{}^2 + (1 - D_{S2}.A_{rt})^2.COV_{sf}{}^2 + (SR_P^{Thin})^2.(COV_P)^2}} \quad (3.26)$$

$$ß_3^{Thin} = \frac{1 - D_{S3}.A_{rt} - SR_P^{Thin}}{\sqrt{D_{S3}{}^2.A_{rt}{}^2.COV_{\Delta t}{}^2 + (1 - D_{S3}.A_{rt})^2.COV_{sf}{}^2 + (SR_P^{Thin})^2.(COV_P)^2}} \quad (3.27)$$

Where;

$COV_{\Delta t}$ = The thinning coefficient of variance ranging from 0.1 ≤ $COV_{\Delta t}$ ≤ 0.2
= 0,2

COV_{sf} = The flow stress coefficient of variance
= 0,2

COV_P = Pressure coeffficient of variance
= 0,05

D_{s1} = Damage State 1
= 1

D_{s2} = Damage State 2
= 2

D_{s3} = Damage State 3
= 4

RBI DATE:

Shell section:

$ß_1^{Thin}$ = 4,6894

$ß_2^{Thin}$ = 4,6319

$ß_3^{Thin}$ = 4,3906

Head section:

$ß_1^{Thin}$ = 4,6499

$ß_2^{Thin}$ = 4,5768

$ß_3^{Thin}$ = 4,263

PLANNED DATE:

Shell section:

$ß_1^{Thin}$ = 4,6509

$ß_2^{Thin}$ = 4,4766

Head section:

$ß_1^{Thin}$ = 4,6011

$ß_2^{Thin}$ = 4,3755

$ß_3^{Thin}$ = 3,5984 $ß_3^{Thin}$ = 3,2379

STEP 13 For tank bottom components, determine the base damage factor for thining using Table 4.8. and based on A_{rt} parameter from STEP 6.

Because component observed in this case of analysis is including into Pressure Vessel, then this step of calculation can be skipped.

STEP 14 For all components (excluding tank bottoms covered in STEP 13), calculate the base damage factor, .

$$D_{fb}^{Thin} = [\frac{\left(Po_{P1}^{Thin}\Phi(-\beta_1^{Thin})\right)+\left(Po_{P2}^{Thin}\Phi(-\beta_2^{Thin})\right)+\left(Po_{P3}^{Thin}\Phi(-\beta_3^{Thin})\right)}{1.56E-0.4} \quad (3.28)$$

RBI DATE:

Shell section:

D_{fb}^{Thin} = 0,0151198

Head section:

D_{fb}^{Thin} = 0,0227914

PLANNED DATE:

Shell section:

D_{fb}^{Thin} = 0,2178635

Head section:

D_{fb}^{Thin} = 0,7902067

STEP 15 Determine the DF for thinning, D_f^{Thin} , using equation equation below.

$$D_f^{Thin} = \text{Max}[(\frac{(D_{fb}^{Thin}.F_{IP}.F_{DL}.F_{WD}.F_{AM}.F_{SM})}{F_{OM}}),0.1] \quad (3.29)$$

Where;

F_{IP} = DF adjustent for injection points (for piping circuit)
= 0

F_{DL} = DF adjustment for dead legs (for piping only used to intermittent servi
= 0

F_{WD} = DF adjustment for welding construction (for only AST Bottom)
= 0

F_{AM} = DF adjustment for AST maintenance per API STD 653 (for only AST)
= 0

F_{SM} = DF adjustment for settlement (for only AST Bottom)
= 0

F_{OM} = DF adjustment for online monitoring based on Table 4.8 API RP 581
= 10

RBI DATE:

Shell section: $D_f^{Thin} =$ 0,1000000

Head section: $D_f^{Thin} =$ 0,1000000

PLANNED DATE:

Shell section: $D_f^{Thin} =$ 0,1000000

Head section: $D_f^{Thin} =$ 0,1000000

DAMAGE FACTOR FOR THINNING

The governing thinning DF is determined based on the presence of an internal liner using equation below. There is no any presence of liner, then, we can consider to use the second governing thinning DF calculation.

$D_{f-gov}^{Thin} = \min(D_f^{Thin};\ D_f^{elin})$ When internal liner is present

RBI DATE:

Shell section: D_{f-gov}^{Thin} = 0,1000000

Head section: D_{f-gov}^{Thin} = 0,1000000

PLANNED DATE:

Shell section: D_{f-gov}^{Thin} = #########

Head section: D_{f-gov}^{Thin} = #########

TYPE OF THINNING

The type of thinning (wheter it is local or general) can be determined from table

Table 3.10 Type of Thinning

Thinning Mechanism	Condition	Type of Thinning
Hydrochloric Acid (HCl) Corrosion	----	Local
High Temperature Sulfidic/Naphthenic Acid Corrosion	TAN ≤ 0,5	General
	TAN > 0,5	Local
Sulfuric Acid (H2SO4) Corrosion	Low Velocity ≤ 0,61m/s (2ft/s) for carbon steel ≤ 1,22m/s (4ft/s) for SS and ≤ 1,83m/s (6ft/s) for higher alloys	General
	High Velocity ≥ 0,61m/s (2ft/s) for carbon steel ≥ 1,22m/s (4ft/s) for SS and ≥ 1,83m/s (6ft/s) for higher alloys	Local

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Thinning Mechanism	Condition	Type of Thinning
High Temperature H2S/H2 Corrosion	----	General
Hydrochloric Acid (HF) Corrosion	----	Local
Sour Water Corrosion	Low velocity ≤ 6,1m/s (20ft/s) for carbon steel	General
	High velocity ≥ 6,1m/s (20ft/s) for carbon steel	Local
Amine Corrosion	Low Velocity < 1,5m/s (5ft/s) rich amine < 6,1m/s (20ft/s) lean amine	General
	High Velocity > 1,5m/s (5ft/s) rich amine > 6,1m/s (20ft/s) lean amine	Local
High Temperature Oxidation	----	General
Acid Sour Water Corrosion	< 1,83m/s (6ft/s)	General
	≥ 1,83m/s (6ft/s)	Local
Cooling Water Corrosion	≤ 0,91m/s (3ft/s)	Local
	0,91-2,74m/s (3-9ft/s)	General
	> 2,74m/s (9ft/s)	Local
Soil Side Corrosion	----	Local
CO2 Corrosion	----	Local
AST Bottom	Product Side	Local
	Soil Side	Local

The thinning mechanisms are sour water, acid sour water & CO2 Corrosion.
If both general and localized thinning mechanisms are possible, then the type of thinning should be designated as localized. The type of thinning designated will be used to determine the effectiveness of inspection performed.

So, the thinning damage is designatec localized

COMPONENT LINING DAMAGE FACTOR CALCULATION

STEP 1 Determine the lining type and time in-service, age, of the lining based on the lining installation

Table 3.11 Typical Examples of Protective Internal Linings

Lining Series ID	Environtment (Damage mechanism of Base Material)	Example Lining
Alloy Linings	Corrosive (Thinning)	Strip Lined Alloy
Organic Coating	Corrosive (Thinning)	Organic Coating or Lining
Refractory	High Temperature (Thinning, Creep, Erosion)	Castable Refractory
		Plastic Refractory
		Refractory Brick
		Ceramic Fiber Refractory
		Refractory/Alloy Combination
Gas Lined	Corrosive (Thinning)	Glass Lined
Acid Brick	Corrosive (Thinning)	Brick/Mortar

lining type = striped lined alloy

age_{tk} = 6 years 2014)

age_{PD} = 10 years Inspection is held 10 years after the last inspection based on API 510

STEP 2 Determine the base value of the lining DF, DF_{fB}^{elin} , using Tables 3.12 as applicable, based on the age and lining type from STEP 1.

Table 3.12 Lining Damage Factors – Inorganic Linings

Years Since Last Through Visual Inspection	DF as Fucntion of Inorganic Lining Type					
	Strip Lined Alloy (Resistant)	Castable Refractory	Castable Refractory Severe Condition	Glass Lined	Acid Brick	Fiberglass
1	0,3	0,5	9	3	0,01	1
2	0,5	1	40	4	0,03	1
3	0,7	2	146	6	0,05	1
4	1	4	428	7	0,15	1
5	1	9	1017	9	1	1
6	2	16	1978	11	1	1
7	3	30	3000	13	1	2

Years Since Last Through Visual Inspection	DF as Fucntion of Inorganic Lining Type					
	Strip Lined Alloy (Resistant)	Castable Refractory	Castable Refractory Severe Condition	Glass Lined	Acid Brick	Fiberglass
8	4	53	3000	16	1	3
9	6	89	3000	20	2	7
10	9	146	3000	25	3	13

RBI Date:

DF_{fB}^{elin} = 2 (Shell)

DF_{fB}^{elin} = 2 (Head)

Plan Date:

DF_{fB}^{elin} = 9 (Shell)

DF_{fB}^{elin} = 9 (Head)

STEP 3 Determine the DF for lining damage, DF_f^{elin}, using Equation (3.30)

$$DF_f^{elin} = DF_{fB}^{elin} \times F_{LC} \times F_{OM} \quad (3.30)$$

Where:

F_{LC} = the DF adjustment for lining condition

F_{OM} = is the DF adjustment for online monitoring

a. Adjustment for Lining Condition

Table 3.13 Lining Condition Adjustment

Qualitative Condition	Description	Adjustment Multiplier - FLC
Poor	The lining has either had previous failures or exhibits conditions that may lead to failure in the near future. Repairs to previous failures are not successful or are of poor quality	10
Average	The lining is not showing signs of excessive attack by any damage mechanisms. Local repairs may have been performed, but they are of good quality and have successfully corrected the lining condition.	2
Good	The lining is in “like new” condition with no signs of attack by any damage mechanisms. There has been no need for any repairs to the lining.	1

b. Adjustment for On-Line Monitoring

Some lined components have monitoring to allow early detection of a leak or other failure of the lining. The monitoring allows orderly shutdown of the component before failure occurs. If on-line monitoring is used, and it is known to be effective at detecting lining deterioration, FOM = 0,1 ; otherwise FOM =1,0.

F_{LC} = 2

F_{OM} = 1

$DF_{f}^{elin} = DF_{fB}^{elin} \times F_{LC} \times F_{OM}$

RBI Date:

DF_{f}^{elin} = 4 (Shell)

DF_{f}^{elin} = 4 (Head)

Plan Date:

DF_{f}^{elin} = 18 (Shell)

DF_{f}^{elin} = 18 (Head)

SCC DAMAGE FACTOR - SULFIDE STRESS CRACKING CALCULATION

REQUIRED DATA

The basic component data required for analysis is given in Table 3.1 and the specific data required for determination of the sulfide stress cracking DF is provided in Table 8.1 of API 581.

STEP 1 Determine the environmental severity (potential level of hydrogen flux) for cracking based on the H_2S content of the water and its pH using Table 3.14.

Table 3.14 Environmental Severity – SSC

pH of water	Environmental severity as a function of H_2S content of water			
	< 50 ppm	50 to 1000 ppm	1000 to 10000 ppm	>10000 ppm
< 5.5	Low	Moderate	High	High
5.5 to 7.5	Low	Low	Low	Moderate
7.6 to 8.3	Low	Moderate	Moderate	Moderate
8.4 to 8.9	Low	Moderate	Moderate	High*
> 9.0	Low	Moderate	High*	High*
Note: *If cyanides are present, increase the susceptibility to SSC one category for pH > 8.3 and H2S Concentrations greater than				

pH: 5,85 H_2S concentration: 1000 ppm

Based on table 3.14 the environmental severity: **Low**

STEP 2 Determine the susceptibility for cracking using Figure 8.1of API RP 581 and Table 3.15 based on the environmental severity from STEP 1, the maximum Brinnell hardness of weldments, and knowledge of whether the component was subject to PWHT. Note that a HIGH susceptibility should be used if cracking is confirmed to be present.

Table 3.15 Susceptibility to SCC

Environmental Severity	Susceptibility to SCC as function of heat treatment					
	As-welded Max Brinnel Hardness			PWHT Max Brinnel Hardness		
	< 200	200-237	>237	< 200	200-237	>237
High	Low	Medium	High	Not	Low	Medium
Moderate	Low	Medium	High	Not	Not	Low
Low	Low	Low	Medium	Not	Not	Not

Max Brinnell Hardness: TS (psi) = 500 x HB
HB = 149,39

Shell subjects to PWHT: Yes Head subjects to PWHT: Yes

Shell susceptibility to SSC as a Function of Heat Treatment: **Not**

Head susceptibility to SSC as a Function of Heat Treatment: **Not**

STEP 3 Based on the susceptibility in STEP 3, determine the severity index, S_{VI} , from

Table 3.16 Determination of Severity Index – SSC

Susceptibility	Severity Index - S_{VI}
High	100
Medium	10
Low	1
None	0

Severity Index (S_{VI}) of Shell = 0 Severity Index (S_{VI}) of Head = 0

STEP 4 Determine the time in-service, age_{tk} , since the last Level A, B or C inspection was performed with no cracking detected or cracking was repaired. Cracking detected but not repaired should be evaluated and future inspection recommendations based upon FFS evaluation.

age_{PD} = 10 years Last inspection is on 01/06/2014

RBI Date is on: 01/01/2020

age_{tk} = 6 years Planned Date is on: 01/01/2024

STEP 5 Determine the number of inspections, and the corresponding inspection effectiveness category using Section 8.6.2 for past inspections performed during the in service time. Combine the inspections to the highest effectiveness performed using Section 3.4.3.

Inspections are ranked according to their expected effectiveness at detecting SSC. Examples of inspection activities that are both intrusive (requires entry into the equipment) and non-intrusive (can be performed externally), are provided in Annex 2.C, Table 2.C.9.6 (Section 8.6.2 API RP 3rd Edition Part 2)

Table 3.17 Inspection Effectiveness Categories

Inspection effectiveness category	Ispection 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 case (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)

If multiple inspections have been performed, equivalent relationships are used for SCC, External Damage (external chloride stress corrosion cracking, external chloride stress corrosion cracking under insulation) and HTHA. Inspections of different grades (A, B, C and D) are approximated as equivalent inspection effectiveness in accordance with the following relationships (Section 3.4.3 API RP 3rd Edition Part 2):

a) 2 Usually Effective (B) Inspections = 1 Highly Effective (A) Inspection,

b) 2 Fairly Effective (C) Inspections = 1 Usually Effective (B) inspection, or

c) 2 Poorly Effective (D) Inspections = 1 Fairly Effective (C) inspection, or

Note:

1. Equivalent inspection valuesare not used for Thinning and External Corrosion DF calculations.
2. The equivalent higher inspection rules shall not be applied to No

Number of inspections: 0 Effectiveness category: Ineffective (E)
Inspection effectiveness: **E**

STEP 6 Determine the base DF for sulfide stress cracking, D_{fb}^{scc} using Table 3.18 based on the number of, and the highest inspection effectiveness determined in STEP 5, and the severity index, S_{VI} , from STEP 3.

Table 3.18 SCC Damage Factors – All SCC Mechanisms

S_{VI}	Inspection Effectiveness												
	E	1 Inspection				2 Inspections				3 Inspections			
		D	C	B	A	D	C	B	A	D	C	B	A
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	10	8	3	1	1	6	2	1	1	4	1	1	1
50	50	40	17	5	3	30	10	2	1	20	5	1	1
100	100	80	33	10	5	60	20	4	1	40	10	2	1
500	500	400	170	50	25	300	100	20	5	200	50	8	1
1000	1000	800	330	100	50	600	200	40	10	400	100	16	2
5000	5000	4000	1670	500	250	3000	1000	250	50	2000	500	80	10

S_{VI}	Inspection Effectiveness												
	E	4 Inspections				5 Inspections				6 Inspections			
		D	C	B	A	D	C	B	A	D	C	B	A
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	10	2	1	1	1	1	1	1	1	1	1	1	1
50	50	10	2	1	1	5	1	1	1	1	1	1	1
100	100	20	5	1	1	10	2	1	1	5	1	1	1
500	500	100	25	2	1	50	10	1	1	25	5	1	1
1000	1000	200	50	5	1	100	25	5	1	50	10	1	1
5000	5000	1000	250	25	2	500	125	5	1	250	50	2	1

Number of inspection = 0 Effectiveness = E

Base damage factor (D_{fb}^{scc}):
For shell section: 0 For head section: 0

STEP 7 Calculate the escalation in the DF based on the time in service since the last inspection using the age from STEP 4 and Equation (3.31). In this equation, it is assumed that the probability for cracking will increase with time since the last inspection as a result of increased exposure to upset conditions and other non-normal conditions.

$$D_f^{scc} = D_{fB}^{scc}.(Max[age, 1.0])^{1.1} \qquad (3.31)$$

RBI DATE:

Shell section:

$D_f^{scc} = 0.(Max[6,1.0])^{1.1}$

$D_f^{scc} = 0,0000$

Head section:

$D_f^{scc} = 0.(Max[6,1.0])^{1.1}$

$D_f^{scc} = 0,0000$

PLANNED DATE:

Shell section:

$D_f^{scc} = 0.(Max[10,1.0])^{1.1}$

$D_f^{scc} = 0,0000$

Head section:

$D_f^{scc} = 0.(Max[10,1.0])^{1.1}$

$D_f^{scc} = 0,0000$

	PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

SCC DAMAGE FACTOR - HIC/SOHIC - H2S CALCULATION

REQUIRED DATA

The basic component data required for analysis is given in Table 3.1 and the specific data required for determination of the HIC/SOHIC-H_2S cracking DF is provided in Table 9.1 of API 581.

STEP 1 Determine the environmental severity (potential level of hydrogen flux) for cracking based on the H_2S content of the water and its pH using Table 3.19. Note that a HIGH environmental severity should be used if cracking is confirmed to be present.

Table 3.19 Environmental Severity – SSC

pH of water	Environmental severity as a function of H_2S content of water			
	< 50 ppm	50 to 1000 ppm	1000 to 10000 ppm	>10000 ppm
< 5.5	Low	Moderate	High	High
5.5 to 7.5	Low	Low	Low	Moderate
7.6 to 8.3	Low	Moderate	Moderate	Moderate
8.4 to 8.9	Low	Moderate	Moderate	High*
> 9.0	Low	Moderate	High*	High*
Note: *If cyanides are present, increase the susceptibility to SSC one category for pH > 8.3 and H2S Concentrations greater than				

pH: 5,85 H_2S concentration: 1000 ppm

Based on table 3.19 the environmental severity: **Low**

STEP 2 Determine the susceptibility for cracking using Figure 9.1 of API 581 and Table 3.20 based on the environmental severity from STEP 1, the sulfur content of the carbon steel, product form and knowledge of whether the component was subject to PWHT.

Table 3.20 Susceptibility to Cracking – HIC/SOHIC-H2S

Enviromental severity	Susceptibility to Cracking as a Function of Steel Sulfur Content					
	High Sulfur Steel >0.01% S		Low Sulfur Steel < 0.01% S		Product Form – Seamless/Extruded Pipe	
	As-Welded	PWHT	As-Welded	PWHT	As-Welded	PWHT
High	High	High	High	Medium	Medium	Low
Moderate	High	Medium	Medium	Low	Low	Low
Low	Low	Low	Low	Low	Low	Low

Steel sulfur content: 0,03 %

https://www.upmet.com

Environmental severity: 0

Post Weld Heat Treatment (PWHT) for Shell section: Yes

Post Weld Heat Treatment (PWHT) for Head section: Yes

Shell section susceptibility for Cracking: **Low**

Head section susceptibility for Cracking: **Low**

STEP 3 Based on the susceptibility in STEP 2, determine the severity index, SVI ,

Table 3.21 Determination of Severity Index – HIC/SOHIC-H2S Cracking

Susceptibility	Severity Index - S_{VI}
High	100
Medium	10
Low	1
None	0

Severity Index (S_{VI}) for shell section 1

Severity Index (S_{VI}) for head section 1

STEP 4 Determine the time in-service, age , since the last Level A, B or C inspection was performed performed with no cracking detected or cracking was repaired. Cracking detected but not repaired should be evaluated and future inspection recommendations based upon FFS evaluation.

age_{PD}	=	10	year	Last inspection is on	01/06/2014
				RBI Date is on:	01/01/2020
age_{tk}	=	6	year	Planned Date is on:	01/01/2024

STEP 5 Determine the number of inspections, and the corresponding inspection effectiveness category using Section 9.6.2 for past inspections performed during the in service time. Combine the inspections to the highest effectiveness performed using Section 3.4.3.

Inspections are ranked according to their expected effectiveness at detecting SSC. Examples of inspection activities that are both intrusive (requires entry into the equipment) and non-intrusive (can be performed externally), are provided in Annex 2.C, Table 2.C.9.6 (Section 8.6.2 API RP 3rd Edition Part 2)

Table 3.22 Inspection Effectiveness Categories

Inspection effectiveness category	Ispection 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 case (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)

If multiple inspections have been performed, equivalent relationships are used for SCC, External Damage (external chloride stress corrosion cracking, external chloride stress corrosion cracking under insulation) and HTHA. Inspections of different grades (A, B, C and D) are approximated as equivalent inspection effectiveness in accordance with the following relationships (Section 3.4.3 API RP 3rd Edition Part 2):

a) 2 Usually Effective (B) Inspections = 1 Highly Effective (A) Inspection,
b) 2 Fairly Effective (C) Inspections = 1 Usually Effective (B) inspection, or
c) 2 Poorly Effective (D) Inspections = 1 Fairly Effective (C) inspection, or

Note:

1. Equivalent inspection valuesare not used for Thinning and External Corrosion DF calculations.
2. The equivalent higher inspection rules shall not be applied to No

Number of inspections: 0 Effectiveness category: Ineffective (E)

Inspection effectiveness: E

STEP 6 Determine the base DF for HIC/SOHIC-H_2S cracking, $D_{fB}^{HIC/SOHIC-H_2S}$, using Table 3.23 based on the number of, and the highest inspection effectiveness determined in STEP 5, and the severity index, S_{VI}, from STEP

Table 3.23 SCC Damage Factors – All SCC Mechanisms

S_{VI}	Inspection Effectiveness												
	E	1 Inspection				2 Inspections				3 Inspections			
		D	C	B	A	D	C	B	A	D	C	B	A
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	10	8	3	1	1	6	2	1	1	4	1	1	1
50	50	40	17	5	3	30	10	2	1	20	5	1	1
100	100	80	33	10	5	60	20	4	1	40	10	2	1
500	500	400	170	50	25	300	100	20	5	200	50	8	1
1000	1000	800	330	100	50	600	200	40	10	400	100	16	2
5000	5000	4000	1670	500	250	3000	1000	250	50	2000	500	80	10
S_{VI}	Inspection Effectiveness												
	E	4 Inspections				5 Inspections				6 Inspections			
		D	C	B	A	D	C	B	A	D	C	B	A
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	10	2	1	1	1	1	1	1	1	1	1	1	1
50	50	10	2	1	1	5	1	1	1	1	1	1	1
100	100	20	5	1	1	10	2	1	1	5	1	1	1
500	500	100	25	2	1	50	10	1	1	25	5	1	1
1000	1000	200	50	5	1	100	25	5	1	50	10	1	1
5000	5000	1000	250	25	2	500	125	5	1	250	50	2	1

S_{VI} = 1 Number of inspection = 0 Effectiveness = E

Base damage factor ($D_{fB}^{HIC/SOHIC-H_2S}$) for shell section: **1**

Base damage factor ($D_{fB}^{HIC/SOHIC-H_2S}$) for head section: **1**

STEP 7 Determine the on-line adjustment factor, F_{OM} , from Table 3.24

Table 3.24 On-Line Monitoring Adjustment Factors for HIC/SOHIC-H2S

On-Line Monitoring Method	Adjustment Factors as a Function of On-line Monitoring - F_{om}
Key Process Variables	2
Hyrogen Probes	2
Key Process Variables & Hydrogen probes	4

On-Line monitoring adjustment factor (F_{OM}): 2

STEP 8 Calculate the final DF accounting for escalation based on the time in-service since the last inspection using the age from STEP 4 and Equation (3.32). In this equation, it is assumed that the probability for cracking will increase with time since the last inspection as a result of increased exposure to upset conditions and other non-normal conditions. The equation also applies the adjustment factor for online monitoring

$$D_f^{HIC/SOHIC-H_2S} = \frac{D_{fB}^{HIC/SOHIC-H_2S} . (Max[age, 1.0])^{1.1}}{F_{OM}} \quad (3.32)$$

RBI DATE:

Shell section:

$D_{fB}^{HIC/SOHIC-H_2S} =$ 3,3168

Head section:

$D_{fB}^{HIC/SOHIC-H_2S} =$ 3,3168

PLANNED DATE:

Shell section:

$D_{fB}^{HIC/SOHIC-H_2S} =$ 6,008

Head section:

$D_{fB}^{HIC/SOHIC-H_2S} =$ 6,008

DAMAGE FACTOR FOR STRESS CORROSION CRACKING

Calculation of damage factor for stress corrosion cracking (SCC) explained in section 3.4.2 - API RP 581 Part 2 3rd Edition. For multipe SCC damage factor mechanisms case, determined using equation (3.33).

$$D_{f-gov}^{scc} = max\begin{bmatrix} D_f^{caustic}, D_f^{amine}, D_f^{scc}, D_f^{HIC/SOHIC-H_2S}, D_f^{ACSCC}, \\ D_f^{PASCC}, D_f^{CLSCC}, D_f^{HSC\_HF}, D_f^{HIC/SOHIC-HF} \end{bmatrix} \quad (3.33)$$

RBI DATE:

$D_{f-gov}^{scc} =$ 3,3168 (Shell)

$D_{f-gov}^{scc} =$ 3,3168 (Head)

PLANNED DATE:

$D_{f-gov}^{scc} =$ 6,008 (Shell)

$D_{f-gov}^{scc} =$ 6,008 (Head)

EXTERNAL CORROSION DAMAGE FACTOR CALCULATION

REQUIRED DATA

The basic component data required for analysis is given in Table 3.1 and the specific data required for determination of the External Corrosion DF is provided in Table 15.1 of API 581.

STEP 1 Determining the furnished thickness, t, and age for the component from the installation date.

t = 3,0709 inch
= 78 mm (it is assumed from 2014).
age = 6 years

STEP 2 Determining the base corrosion rate, C_{rB} based on the driver and operating temperature using Table 3.25.

Table 3.25 Corrosion Rates for Calculation of the Damage Factor-External Corrosion

Operating Temperature (°C)	Corrosion Rate as a Function of Driver (1) (mpy)			
	Marine/Cooling	Temperate	Arid/Dry	Severe
-12	0	0	0	0
-8	0,025	0	0	0
6	0,127	0,076	0,025	0,254
32	0,127	0,076	0,025	0,254
71	0,127	0,051	0,025	0,254
107	0,025	0	0	0,051
121	0	0	0	0

t = Operating temperature
= 120 F
= 48,889 C
= 322,04 K
1 mpy = 0,025 mm/y

Because the operating temperature is normally 48,8°C, and there is no list of such that temperature. But, it does list values for 32°C and 71°C. Then, we can get the value of corrosion rate based by interpolating the value in between.

INTERPOLATION BETWEEN 32°C and 71°C

X = 48,9 C Y = Crb at 48,9°C
X_1 = 32 C Y_1 = 0,025   Corrosion rate at arid/dry condition
X_2 = 71 C Y_2 = 0,025

$$Y = Y_1 + [\left(\frac{X - X_1}{X_2 - X_1}\right)(Y_2 - Y_1)] \quad (3.34)$$
= 0,025

STEP 3 Calculate the final corrosion rate, Cr, using equation below.

$$C_r = C_{rB}\,.max[(F_{EQ}\,, F_{IF})] \quad (3.35)$$

F_{EQ} = Adjustment for equation design or fabrication
= 2

F_{IF} = Adjustment fo interface
= 2

$$C_r = C_{rB}\,.max[(F_{EQ}\,, F_{IF})]$$
= 0,05 mm/y

STEP 4 Determine the time in service, age_{tk}, since the last known inspection, t_{rde}.
The thickness used in this calculation is coming from the data sheet of the Production Separator.

- Shell t_{rdi} = 3,0709 inch = 78 mm
- Head t_{rdi} = 70 mm

Last inspection is on: 01/06/2014
RBI Date is on: 01/01/2020
Planned Date is on: 01/01/2024

age_{tk} = 6 years (Last inspection was held on June 2014)

age_{PD} = 10 years Inspection is held 10 years after the last inspection based on API 510

STEP 5 Determine the time in-service, age_{coat}, since the coating has been installed using equation (3.36) below.

$$Age_{Coat} = Calculation\ Date\ - Coating\ Installation\ Date \quad (3.36)$$

Calc. date = 01/01/2020
CI.Date = 01/06/2014
Planned Dat = 01/01/2024

RBI Date

$$Age_{Coat} = Calculation\ Date\ - Coating\ Installation\ Date$$
= 6 years

Planned Date

$$Age_{Coat} = Planned\ Date\ - Coating\ Installation\ Date$$
= 10 years

STEP 6 Determine coating adjustment, $coat_{adj}$, using one of below equations.

If $Age_{tk} \geq Age_{coat}$

$Coat_{adj} = 0$ If No or Poor Coating Quality (3.37)

$Coat_{adj} = \min[5, Age_{coat}]$ If Medium Coating Quality (3.38)

$Coat_{adj} = \min[15, Age_{coat}]$ If High Coating Qua (3.39)

If $Age_{tk} < Age_{coat}$

$Coat_{adj} = 0$ No/Poor (3.40)

$Coat_{adj} = \min[5, Age_{coat}] - \min[5, age_{coat} - age_{tk}]$ Medium (3.41)

$Coat_{adj} = \min[15, Age_{coat}] - \min[15, age_{coat} - age_{tk}]$ High (3.42)

It is assumed that the coating that the company has ever had is categorized as Medium coating and the result shows the age_{tk} is same as the age_{coat}. So, the most suitable equation for calculating this 6^{th} section is equation below.

RBI Date

$Coat_{adj} = \min[5, Age_{coat}]$

$= 5$

Planned Date

$Coat_{adj} = \min[5, Age_{coat}]$

$= 5$

STEP 7 Determine the in-service time, age, over which external corrosion may have occurred using equation below.

RBI Date		Planed Date	
$age = age_{tk} - Coat_{adj}$		$age = age_{tk} - Coat_{adj}$	(3.43)
$= 1$		$= 5$	

STEP 8 Determine the allowable stress, S, weld joint efficiency, E, and minimum required thickness, t_{min}, per the original construction code or API 579-

t_{min} = 2,8369291 inch

= 72,058 mm

S = 24100 psig

= 166163716 Pa

= 166163,72 Kpa

E = 1

STEP 9 Determine the A_{rt} Parameter

Shell A_{rt} on RBI Date:

$$A_{rt} = \frac{Cr.age}{t_{rde}} \quad (3.44)$$

= 0,000641

Head A_{rt} on RBI Date:

$$A_{rt} = \frac{Cr.age}{t_{rde}}$$

= 0,000714

Shell A_{rt} on Planned Date:

$$A_{rt} = \frac{Cr.age}{t_{rde}}$$

= 0,003205

Head A_{rt} on Planned Date:

$$A_{rt} = \frac{Cr.age}{t_{rde}}$$

= 0,003571

STEP 10 Calculate the Flow Stress, $FS^{extcorr}$, using E from STEP 5 and equation

$$FS^{extcorr} = \frac{(YS+TS)}{2}. \text{E.1,1} \quad (3.45)$$

Where;

YS = 260000 KPa

TS = 485000 KPa

E = 1

$$FS^{extcorr} = \frac{(YS+TS)}{2}. \text{E.1,1}$$

= 409750

STEP 11 Calculate the strength ratio parameter, $SR_P^{extcorr}$, using the appropriate

$$SR_P^{extcorr} = \frac{S.E}{FS^{extcorr}} . \frac{Max\,(t_{min}, t_c)}{t_{rde}} \quad (3.46)$$

Where;

t_c = is the minimum structural thickness of the component base material

= 2,8369291 inch

= 72,058 mm

$$SR_P^{extcorr} = \frac{S.E}{FS^{extcorr}} . \frac{Max\,(t_{min},t_c)}{t_{rde}}$$

= 0,374632 (Shell)

$$SR_P^{extcorr} = \frac{S.E}{FS^{extcorr}} . \frac{Max\,(t_{min},t_c)}{t_{rde}}$$

= 0,4174471 (Head)

STEP 12 Determine the number of inspections for each of the correspondesing inspection effectiveness, $N_A^{extcorr} N_B^{extcorr} N_C^{extcorr} N_D^{extcorr}$, using Section 15.6.2 of the API RP 581 Part 2 for past inspections performed during in-

$N_A^{extcorr}$ = 0

$N_B^{extcorr}$ = 0

$N_C^{extcorr}$ = 0

$N_D^{extcorr}$ = 0

Table 3.26 LoIE Example for External Damage

Inspection Category	Ispection Effectiveness Category	Inspection
A	Highly effective	Visual inspection of >95% of the exposed surface area with follow-up by UT, RT or pit
B	Usually Effective	exposed surface area with follow-up by UT, RT or pit gauge as required.
C	Fairly Effective	exposed surface area with follow-up by UT, RT or pit gauge as required.
D	Poorly Effective	surface area with follow-up by UT, RT or pit gauge as required.
E	Ineffective	Ineffective inspection technique/plan was utilized

STEP 13 Calculate the inspection effectiveness factors, $I_1^{extcorr}$ $I_2^{extcorr}$ $I_3^{extcorr}$, using equation (3.47), (3.48), (3.49) below, prior probabilities, $Pr_{P1}^{extcorr} Pr_{P2}^{extcorr} Pr_{P3}^{extcorr}$, from Table 3.27. The Conditional Probabilities (for each inspection effectiveness level), $Co_{P1}^{extcorr}$ $Co_{P2}^{extcorr}$ $Co_{P3}^{extcorr}$, from Table 3.28, and the number of inspection, $N_A^{extcorr} N_B^{extcorr} N_C^{extcorr} N_D^{extcorr}$, in each effectiveness level from STEP 12.

$$I_1^{extcorr} = Pr_{P1}^{extcorr} (Co_{P1}^{extcorrA})^{N_A^{extcorr}} (Co_{P1}^{extcorrB})^{N_B^{extcorr}} (Co_{P1}^{extcorrC})^{N_C^{extcorr}} (Co_{P1}^{extcorrD})^{N_D^{extcorr}} \quad (3.47)$$

$$I_2^{extcorr} = Pr_{P2}^{extcorr} (Co_{P2}^{extcorrA})^{N_A^{extcorr}} (Co_{P2}^{extcorrB})^{N_B^{extcorr}} (Co_{P2}^{extcorrC})^{N_C^{extcorr}} (Co_{P2}^{extcorrD})^{N_D^{extcorr}} \quad (3.48)$$

$$I_3^{extcorr} = Pr_{P3}^{extcorr} (Co_{P3}^{extcorrA})^{N_A^{extcorr}} (Co_{P3}^{extcorrB})^{N_B^{extcorr}} (Co_{P3}^{extcorrC})^{N_C^{extcorr}} (Co_{P3}^{extcorrD})^{N_D^{extcorr}} \quad (3.49)$$

Table 3.27 Prior Probability for Thinning Corrosion Rate

Damage State	Low Confidence Data	Medium Confidence Data	High Conf. Data
Pr_{P1}^{Thin}	0,5	0,7	0,8
Pr_{P2}^{Thin}	0,3	0,2	0,15
Pr_{P3}^{Thin}	0,2	0,1	0,05

Table 3.28 Conditional Probability for Inspection Effectiveness

Conditional P. of Inspection	E-None or Ineffective	D-Poorly Effective	C-Fairly Effective	B-Usually Effective	A-Highly Effective
Co_{P1}^{Thin}	0,33	0,4	0,5	0,7	0,9
Co_{P2}^{Thin}	0,33	0,33	0,3	0,2	0,09
Co_{P3}^{Thin}	0,33	0,27	0,2	0,1	0,01

$$I_1^{extcorr} = Pr_{P1}^{extcorr} (Co_{P1}^{extcorrA})^{N_A^{extcorr}} (Co_{P1}^{extcorrB})^{N_B^{extcorr}} (Co_{P1}^{extcorrC})^{N_C^{extcorr}} (Co_{P1}^{extcorrD})^{N_D^{extcorr}}$$
$$= 0,50$$

$$I_2^{extcorr} = Pr_{P2}^{extcorr} (Co_{P2}^{extcorrA})^{N_A^{extcorr}} (Co_{P2}^{extcorrB})^{N_B^{extcorr}} (Co_{P2}^{extcorrC})^{N_C^{extcorr}} (Co_{P2}^{extcorrD})^{N_D^{extcorr}}$$
$$= 0,30$$

$$I_3^{extcorr} = Pr_{P3}^{extcorr} (Co_{P3}^{extcorrA})^{N_A^{extcorr}} (Co_{P3}^{extcorrB})^{N_B^{extcorr}} (Co_{P3}^{extcorrC})^{N_C^{extcorr}} (Co_{P3}^{extcorrD})^{N_D^{extcorr}}$$
$$= 0,20$$

STEP 14 Calculate the Posteroir Probability, $Po_{p1}^{extcorr}$ $Po_{p2}^{extcorr}$ $Po_{p3}^{extcorr}$, using equation (3.50), (3.51), (3.52) with $I_1^{extcorr} I_2^{extcorr} I_3^{extcorr}$ in STEP 12.

$$Po_{p1}^{extcorr} = \frac{I_1^{extcorr}}{I_1^{extcorr} + I_2^{extcorr} + I_3^{extcorr}} \quad (3.50)$$

= 0,5

$$Po_{p2}^{extcorr} = \frac{I_2^{extcorr}}{I_1^{extcorr} + I_2^{extcorr} + I_3^{extcorr}} \quad (3.51)$$

= 0,3

$$Po_{p3}^{extcorr} = \frac{I_3^{extcorr}}{I_1^{extcorr} + I_2^{extcorr} + I_3^{extcorr}} \quad (3.52)$$

= 0,2

STEP 15 Calculate the parameters, ß$_1$, ß$_2$, and ß$_3$ using equation (3.53), (3.54), (3.55) and also assigning $COV_{\Delta t}$ = 0.20, COV_{sf} = 0.20, and COV_P = 0.05.

$$ß_1^{extcorr} = \frac{1-D_{S1} .A_{rt}-SR_P^{extcorr}}{\sqrt{D_{S1}{}^2.A_{rt}{}^2.COV_{\Delta t}{}^2+(1-D_{S1}.A_{rt})^2.COV_{sf}{}^2+(SR_P^{extcorr})^2.(COV_P)^2}} \quad (3.53)$$

$$ß_2^{extcorr} = \frac{1-D_{S2} .A_{rt}-SR_P^{extcorr}}{\sqrt{D_{S2}{}^2.A_{rt}{}^2.COV_{\Delta t}{}^2+(1-D_{S2}.A_{rt})^2.COV_{sf}{}^2+(SR_P^{extcorr})^2.(COV_P)^2}} \quad (3.54)$$

$$ß_3^{extcorr} = \frac{1-D_{S3} .A_{rt}-SR_P^{extcorr}}{\sqrt{D_{S3}{}^2.A_{rt}{}^2.COV_{\Delta t}{}^2+(1-D_{S3}.A_{rt})^2.COV_{sf}{}^2+(SR_P^{extcorr})^2.(COV_P)^2}} \quad (3.55)$$

Where:

$COV_{\Delta t}$ = The thinning coefficient of variance ranging from $0.1 \le COV_{\Delta t} \le 0.2$
= 0,2

COV_{sf} = The flow stress coefficient of variance
= 0,2

COV_P = Pressure coeffficient of variance
= 0,05

D_{s1} = Damage State 1
= 1

D_{s2} = Damage State 2
= 2

D_{s3} = Damage State 3
= 4

Shell section:

$\beta_1^{extcorr}$ = 3,112001

$\beta_2^{extcorr}$ = 3,110784

$\beta_3^{extcorr}$ = 2,922662

Head section:

$\beta_1^{extcorr}$ = 3,111862

$\beta_2^{extcorr}$ = 3,110506

$\beta_3^{extcorr}$ = 2,922037

PLANNED DATE

Shell section:

$\beta_1^{extcorr}$ = 3,107116

$\beta_2^{extcorr}$ = 3,100945

$\beta_3^{extcorr}$ = 3,088386

Head section:

$\beta_1^{extcorr}$ = 3,106418

$\beta_2^{extcorr}$ = 3,099524

$\beta_3^{extcorr}$ = 3,085474

STEP 16 Calculate D_f^{extcor} using equation (3.56).

$$D_f^{extcor} = [\frac{\left(Po_{P1}^{extcorr}\Phi(-\beta_1^{extcorr})\right)+\left(Po_{P2}^{extcorr}\Phi(-\beta_2^{extcorr})\right)+\left(Po_{P3}^{extcorr}\Phi(-\beta_3^{extcorr})\right)}{1.56E-0.4} \quad (3.56)$$

RBI DATE

D_f^{extcor} = 0,0017575 (Shell)

D_f^{extcor} = 0,0017594 (Head)

PLANNED DATE

D_f^{extcor} = 0,0015505 (Shell)

D_f^{extcor} = 0,0015577 (Head)

PROBABILITY OF FAILURE CALCULATION

The probability of failure can be calculated using the equation of;

$$Pf(t) = gff \cdot Fms \cdot Df(t)$$

Where,

pf (t) = The PoF as a function of time
gff = General failure frequency
Fms = Management system factor
Df (t) = Total damage factor

DETERMINING DAMAGE FACTOR (Df)

In the case of multiple damage mechanisms, the combination of those damage mechanims is explained in section 3.4.2 API RP 581 Part 2 3rd Edition. Total DF, $D_{f\text{-total}}$ - If more than one damage mechanism is present, the following rules are used to combine the DFs. The total DF is given by Equation (3.57) when the external and/or thinning damage are classified as local and therefore, unlikely to occur at the same location.

$$D_{f-total} = max\left[D_{f-gov}^{thin}, D_{f-gov}^{extd}\right] + D_{f-gov}^{scc} + D_{f}^{htha} + D_{f-gov}^{brit} + D_{f}^{mfat} \quad (3.57)$$

If the external and thinning damage are general, then damage is likely to occur at the same location and the total DF is given by Equation (3.58).

$$D_{f-total} = D_{f-gov}^{thin} + D_{f-gov}^{extd} + D_{f-gov}^{scc} + D_{f}^{htha} + D_{f-gov}^{brit} + D_{f}^{mfat} \quad (3.58)$$

Note that the summation of DFs can be less than or equal to 1.0. This means that the component can have a POF less than the generic failure frequency.
Acccording to the observation and last inspection to Production Separator equipment is categorized as local thinning and also it does not likely occur at the same location. So, we used equation correlated to local thinning.

RBI DATE:

Shell section:

$D_{f\text{-total}}$ = 3,4185167

Head section:

$D_{f\text{-total}}$ = 3,4185186

PLANNED DATE:

Shell section:

$D_{f\text{-total}}$ = 6,1095803

Head section:

$D_{f\text{-total}}$ = 6,1095875

DETERMINING GENERAL FAILURE FREQUENCY (gff)

To determine the value of gff, we can use the recommended list from table 3.29

Table 3.29 Suggested Component Generic Failure Frequencies

Equipment Type	Component Type	f as a Function of Hole Size (failure/y				gff total (failure/yr)
		Small	Medium	Large	Rupture	
Vessel/FinFan	KODRUM COLBTM FINFAN FILTER DRUM REACTOR COLTOP COLMID	8,0E-06	2,0E-05	2,0E-06	6,0E-07	3,06E-05

gff : 3,06,E-05

DETERMINING MANAGEMENT SYSTEM FACTOR (fms)

To determine the value of Fms, we use a series of question and survey given by API RBI 581 to determine Fms value

The scale recommended for converting a management systems evaluation score to a management systems factor is based on the assumption that the "average" plant would score 50% (500 out of a possible score of 1,000) on the management systems evaluation.

Management system factor score according from the survey, the score is

fms = 500

$$pscore = \frac{Score}{1000} \,.100 \text{ [unit is 100\%]} \quad (3.59)$$

based on assumption, the $pscore$ is = 50 %

To determine the value of Fms we can use the equation:

$$Fms = 10^{(-0.02\,.pscore+1)} \quad (3.60)$$

$$Fms = 10^{(-0.02\,.86.95+1)}$$

$$Fms = 1$$

CALCULATING PROBABILITY OF FAILURE

Pf (t) = gff x Fms x D f (t) (3.61)

RBI DATE:

- ***Pf (t) = 3,06,E−0,5 x 1 x 3,418516705***
  Pf (t) = 1,05,E-04 (Shell)
- ***Pf (t) = 3,06,E−0,5 x 1 x 3,418518605***
  Pf (t) = 1,05,E-04 (Head)

PLANNED DATE:

- ***Pf (t) = 3,06,E−0,5 x 1 x 6,109580274***
  Pf (t) = 1,87,E-04 (Shell)
- ***Pf (t) = 3,06,E−0,5 x 1 x 6,109587501***
  Pf (t) = 1,87,E-04 (Head)

PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

DOC. NO. 04

CALCULATION OF CONSEQUENCE OF FAILURE

<table>
<tr><td rowspan="2">Rev</td><td rowspan="2">Date</td><td rowspan="2">Remark</td><td colspan="2">Prepared by</td><td colspan="2">Approved by</td></tr>
<tr><td>Name</td><td>Sign</td><td>Name</td><td>Sign</td></tr>
<tr><td></td><td></td><td></td><td rowspan="4">Ni Luh Triska Adelia</td><td rowspan="4"></td><td rowspan="2">Ir. Dwi Priyanta, M.SE</td><td rowspan="2"></td></tr>
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<tr><td></td><td></td><td></td><td rowspan="2">Nurhadi Siswantoro, S.T., M.T</td><td rowspan="2"></td></tr>
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	CONSEQUENCE OF FAILURE	Doc. No:	4
	PART 1: DETERMINE THE REPRESENTATIVE FLUID AND ASSOCIATED PROPERTIES	Page:	1

1.1 REPRESENTATIVE FLUIDS

A representative fluid that most closely matches the fluid contained pressurized system being evaluated is selected from the representative fluids table shown in Table 4.1 API 581 Part 3 of COF.

1.2 FLUID PROPERTIES

The required fluid properties estimated for each representattive fluids are provided in the Table 4.2 API 581 Part 3 of COF and are dependent on the stored phase of the fluid below:

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

1.3 RELEASE PHASE

The dispersion characteristics of fluids and probability of consequence outcomes (events) after release are strongly dependent on the phase (gas, liquid, or two-phase) of the fluid after it is released into the environment. Guidelines for determining the phase of the released fluid can be seen on Table 4.3 API 581 Part 3 of COF. For this, the release phase is gas/vapor.

STEP 1.1 Select the representative fluid group from Table 4.2 below.

Table 4.1 Chemical Composition

Composition	% Mol	Composition	% Mol
H2S	0,1	*n-Heptane*	0,1434
CO2	5	*n-Octane*	0.5205
Methane	81,344	*n-Nonane*	0,3375
Nitrogen	0,7929	*n-Decane*	0,2183
Ethane	3,9499	*C11+*	0,4
Propane	2,0128	*TEGlycol*	0
H2O	2,3129	*CS2*	0,0002
i - Butane	0,5095	*-B-Mercaptan*	0,0002
n- Butane	0,7434	*Benzene*	0,0336
i - Pentane	0,4269	*Toluene*	0,3663
n - Pentane	0,3534	*p-Xylene*	0
n - Hexane	0,4341	*aMDEA*	0

Table 4.2 List of Representative Fluids Available for Level 1 Consequence Analysis

Representative Fluide	Fluid Type	Examples of Applicable Materials
C1 – C2	TYPE 0	Methane, Ethane, Ethylene, LNG, Fuel Gas
C3 – C4	TYPE 0	Propane, Butane, Isobutane, LPG
C5	TYPE 0	Pentane
C6 – C8	TYPE 0	Gasoline, Naphtha, Light Straight Run,
C9 – C12	TYPE 0	Diesel, Kerosene

The representative fluid is Methane

STEP 1.2 Determine the stored fluid phase

The Production Separator is design as three phase separator. Then, to determine the stored fluid phase is assumed with gaseous fluid, because the gaseous constituent is dominant.

STEP 1.3 Determine the stored fluid properties

For a stored vapor or gas fluid, the properties are dependent on these parameters such as:

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

The stored vapor Molecular Weight (MW) can be estimated from Table 4.2 API 581

MW = 23,00 (kg/kg-mol)

2). Auto-Ignition Temperature, K

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)

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-05 J/kmol-K

Cp_D = -1,30E-09 J/kmol-K

T = 120 °F

T = 322,038889 K

R = 8,314 J/kg-mol-K

$$Cp = A + BT + CT^2 + DT^3 \quad (4.1)$$

$= 12{,}3 + (1{,}15\text{x}10^{-1} \text{ x } 322{,}038) + (-2{,}87\text{x}10^{-5} \text{ x } 322{,}038)^2 + (-1{,}30\text{x}10^{-9} \text{ x } 322{,}038)^3$

= 4,93E+01 J/kmol-K

$$k = \frac{Cp}{Cp - R} \quad (4.2)$$

$$= \frac{4{,}93x10^1}{4{,}93x10^1 - 8{,}314}$$

$$= 1{,}202679$$

STEP 1.4 Determine the steady state phase of the fluid after release to the atmosphere

Determining the steady state phase of the fluid after release to the atmosphere can be adopted from the Table 4.3 shown below:

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) Conditions	Determination of Final Phase of Consequence Calculation
Gas	Gas	Model as gas
Gas	Liquid	Model as gas
Liquid	Gas	Model as gas unless the fluid boiling point at ambient conditions is greater than 80^o F, then model as a liquid
Liquid	Liquid	Model as liquid

SUMMARY of STEP 1:

1 According the data of Company chemical analysis, the major fluids are Methane which has the percentage of 81.3444%.

2 The fluid stored in the pressure vessel (Production Separator) is assumed as gas, because the gaseous constituent is dominant.

3 Fluid properties id based on the STEP 1.3 which has been adjusted by using Table 4.2 in API RP 581 Part 3 of COF

MW	=	23,00	(kg/kg-mol)
AIT	=	830,93	(K)
T	=	322,04	(K)
Cp	=	4,9E+01	(J/kmol-K)
k	=	1,2027	

4 The steady state phase after release to the atmoshpere is gaseous type.

2.1 RELEASE HOLE SIZE SELECTION

A discrete set of release events or release hole sizes are used since it would be impractical to perform the consequence analysis for a continous spectrum of release hole sizes. Limiting the number of of release hole sizes allows for an analysis that is manageable, yet still reflects the range of possible outcomes.

STEP 2.1 Calculate of release hole sizes by determining each diameter (d_n)

The following steps are repeated of each release hole size, typically four hole sizes are evaluated.

According to Annex 3.A of API 581 Chapter 3.2.3 committs that the standard four release hole sizes are assumed for all sizes in pressure vessel type.

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 (mm)	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 generic failure frequency gff_n, for the n^{th} release hole size

Determining the generic failure frequency (gff_n), for the n^{th} release hole size can be seen from table 4.5

Table 4.5 Suggested Component Generic Failure Frequency

Equipment Type	Component Type	gff as a Function of Hole Size (failure/yr)				gff total (failure/yr)
		Small	Medium	Large	Rupture	
Vessel/FinFan	KODRUM	8,0E-06	2,0E-05	2,0E-06	6,0E-07	3,06E-05
	COLBTM					
	FINFAN					
	FILTER					
	DRUM					
	REACTOR					
	COLTOP					
	COLMID					

The total of generic failuure frequency (gff) can be taken from the table value or calculated using the equation (4.3):

$$gff_{total} = \sum_{n=1}^{4} gffn \quad (4.3)$$

Because the total vallue of generic failure frequency has been availabled from the table. So, we can directly put the value from the table into the calculation.

gff_{total} = 0,0000306 failures/year
gff_{small} = 0,000008 failures/year
gff_{medium} = 0,00002 failures/year
gff_{large} = 0,000002 failures/year
$gff_{rupture}$ = 0,0000006 failures/year

SUMMARY of Step 2:

1. According to Annex 3.A Part 3 of API RP 581 committs that for pressure vessels, all of model of release hole size must be assumed.
2. The total generic failure frequency per years for every type of pressure vessel has been adjusted by the Table of 3.1 in Part 2 of API RP 581.

   gff_{small} = 0,000008 failures/year
   gff_{medium} = 0,00002 failures/year
   gff_{large} = 0,000002 failures/year
   $gff_{rupture}$ = 0,0000006 failures/year

3.1 RELEASE RATE

Release rate depend upon the physical properties of the material, the initial phase, the process operating conditions, and the assigned release hole sizes. As we know that initial phase is the phase of the stored fluid prior contacting to the atmosphere. for special case, two-phases systems which contain gaseous and liquid containmment inside the pressure vessel, so, according to the API 581 Part 3, choosing liquid as the initial state inside the equipment is more conservative and may be preferred.

3.2 VAPOR RELEASE RATE EQUATIONS

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 equation (4.4).

P_{atm} = 14,696 psi

k = 1,2027

$$P_{trans} = Patm \left(\frac{k+1}{2}\right)^{\frac{k}{k-1}} \qquad (4.4)$$

$$P_{trans} = 14{,}69 \left(\frac{1{,}20268+1}{2}\right)^{\frac{1{,}20268}{1{,}20268-1}}$$

= 26,0587957 psi

STEP 3.1 Select the appropriate release rate equation

Because of the phase inside the Production Separator is gaseous phase and the storage pressure (P_s) within the equipment item is greater than the transition pressure (P_{trans} so the equation chosen is shown below:

$$W_n = \frac{Cd}{C2}\ x\ An \text{ x } Ps \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \qquad (4.5)$$

Abbreviation list :

C_d	=	Discharge coefficient, for turbulent liquid 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			
P_s	=	Storage operating pressure	=	905	psi
P_{at}	=	Atmosphere pressure	=	14,696	psi
k	=	Ideal gas specific heat capacity ratio	=	1,2027	
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 operating temperature = 120 °F
= 322,04 K

STEP 3.2 For every release hole size, calculate the release hole size area based on d_n

Table 4.6 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]

The release hole size area can be determined by formulating equation (4.6):

$$An = \frac{\pi dn^2}{4} \qquad (4.6)$$

1). SMALL RELEASE HOLE SIZE AREA

d_1 = 0,25 inch
= 0,0064 m
π = 3,14

$$An = \frac{\pi dn^2}{4} = \frac{3.14\ x\ (0.25)^2}{4}$$

= 0,0491 $inch^2$
= 3E-05 m^2

2). MEDIUM RELEASE HOLE SIZE AREA

d_1 = 1 inch
= 0,0254 m
π = 3,14

$$An = \frac{\pi dn^2}{4} = \frac{3.14\ x\ (1)^2}{4}$$

= 0,785 $inch^2$
= 0,0005 m^2

3). LARGE RELEASE HOLE SIZE AREA

d_1 = 4 inch
= 0,1016 m
π = 3,14

$$An = \frac{\pi dn^2}{4} = \frac{3.14\ x\ (4)^2}{4}$$

= 12,56 $inch^2$

= 0,0081 m^2

4). RUPTURE RELEASE HOLE SIZE AREA

d_1 = 16 inch

= 0,4064 m

π = 3,14

$$An = \frac{\pi dn^2}{4} = \frac{3.14\ x\ (16)^2}{4}$$

= 200,96 $inch^2$

= 0,1297 m^2

STEP 3.3 For liquid releases, for each release hole size, calculate the viscosity correction factor

Viscosity Correction Factor ($K_{v,n}$) can be determined using both equation below, which have been printed from API Standard 520 Part 1. Another option, the conservative value of viscosity correction factor may be used the value of 1.0

$$K_{v,n} = \left(0.9935 + \frac{2.878}{Ren^{0.5}} + \frac{342.75}{Ren^{1.5}}\right)^{-1} \quad (4.7)$$

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 = 1,20267886

A_{n1} = 3,1653E-05 m^2

A_{n2} = 0,00050645 m^2

A_{n3} = 0,00810321 m^2

A_{n4} = 0,12965135 m^2

Ps = 6239,75535 Kpa

P_{atm} = 101,325 KPa

C_2 = 1

R = 8,314 J/(kg-mol-K)

g_c = 9,8 m/s^2

T_s = 322,038889 K

MW = 23,00 (kg/kg-mol)

1). SMALL RELEASE HOLE SIZE AREA

$$W_n = \frac{Cd}{C2}\ x\ An \ \text{x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_n = \frac{0.9}{1}\ x\ 0{,}00316532 \ \text{x}\ 6239{,}75 \sqrt{\left(\frac{1{,}20\ x\ 23\ x\ 9{,}8}{8{,}314\ x\ 322{,}03}\right)\left(\frac{2}{1{,}20+1}\right)^{\frac{1{,}20+1}{1{,}20-1}}}$$

= 0,01065164 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$W_n = \frac{Cd}{C2}\ x\ An \ \text{x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_n = \frac{0.9}{1}\ x\ 0{,}000506451 \ \text{x}\ 6239{,}75 \sqrt{\left(\frac{1{,}20\ x\ 23\ x\ 9{,}8}{8{,}314\ x\ 322{,}03}\right)\left(\frac{2}{1{,}20+1}\right)^{\frac{1{,}20+1}{1{,}20-1}}}$$

= 0,17042617 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$W_n = \frac{Cd}{C2}\ x\ An \ \text{x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_n = \frac{0.9}{1}\ x\ 0{,}00810321 \ \text{x}\ 6239{,}75 \sqrt{\left(\frac{1{,}20\ x\ 23\ x\ 9{,}8}{8{,}314\ x\ 322{,}03}\right)\left(\frac{2}{1{,}20+1}\right)^{\frac{1{,}20+1}{1{,}20-1}}}$$

= 2,72681878 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$W_n = \frac{Cd}{C2}\ x\ An \ \text{x Ps} \sqrt{\left(\frac{k\ x\ MW\ x\ gc}{R\ x\ Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$$W_n = \frac{0.9}{1}\ x\ 0{,}129651354 \ \text{x}\ 6239{,}75 \sqrt{\left(\frac{1{,}20\ x\ 23\ x\ 9{,}8}{8{,}314\ x\ 322{,}03}\right)\left(\frac{2}{1{,}20+1}\right)^{\frac{1{,}20+1}{1{,}20-1}}}$$

= 43,6291005 kg/s

SUMMARY :

1 The chosen equation for determining the theoretical release rate (W_n) is using equation below because, the release fluid is modeled as gas-gas and the storage pressure is greater than the transition pressure.

$$W_n = \frac{Cd}{C2} \; x \; An \text{ x } Ps \sqrt{\left(\frac{k \; x \; MW \; x \; gc}{R \; x \; Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

2 For calculating the release hole size area (A_n), all of assumed size of release hole for the pressure vessel (production separator) must be considered to determine theoretical release rate.

3 It is no need to calculate the viscosity correction factor because the release fluid is modeled as gas-gas. The voscosity correction factor calculation is adjusted for only the liquid phase.

4 After determining each release hole sie are from the small until the rupture, then, the theoretical release rate can be calculated.

W_{n1} = 0,01065164 kg/s

W_{n2} = 0,17042617 kg/s

W_{n3} = 2,72681878 kg/s

W_{n4} = 43,6291005 kg/s

4.1 RELEASE RATE

The leaking component's inventory is combined with inventory with the other attached components that can contribute fluid mass.

Table 4.7 Assumptions Used When Calculating Liquid Inventories Within Equipment

Equipment Description	Component Type	Examples	Default Liquid Volume Percent
Acumulators and Drums	DRUM	OH Accumulators, Feed Drums, HP/LP Separators, Nitrogen Storage Drums, Steam Condensate Drums, 3-Phase Separators	50% liquid Typically, 2-phase drums are luqiud level controlled at 50%
Knock-out Pots and Driyer	KODRUM	Compresor knock-out, Fuel gas KO Drum (see note 4), Flare Drums, Air Driyers (see note 4)	10% liquid Much less liquid inventory expected in knock-outs drum

4.2 MAXIMUM MASS AVAILABLE FOR RELEASE

The available mass for release is estimated for each release hole size as the lesser of two quantities:

INVENTORY GROUP MASS

The component being evaluated is part of a larger group of components that can be expected to provide fluid inventory to the release. The inventory calculation as presented here is used as an upper-limit and does not indicate that this amount of fluid would be released in all leak scenarios. The inventory group mass can be calculated using equation (4.8):

$$Mass_{inv} = \sum_{i=1}^{N} \left(Mass_{comp,i}\right) \tag{4.8}$$

COMPONENT MASS

It is assumed that for large leaks and above, operator intervention will occur within 3 minutes, thereby limiting the amount of release material. Therefore, the amount of available mass for the release is limmited to the mass of the component plus an additional mass, $mass_{add,n}$, that is calculated based on three minutes of leakage from the component's inventory group.

STEP 4.1 Group components and equipment items into inventory groups

This step of determining the group components and equipment items can be referred to API 581 Part 3 Annex 3.A.3.3 says that in theory**, the total amount of fluid that can be released is the amount that is held within pressure containing equiment between isolation valves that can be quickly closed.** When a component or equipment type is evaluated, the inventory of the component is combined with inventory from associated equipment that can contribute fluid mass to the leaking component.

STEP 4.2 Calculate the fluid mass, $mass_{comp}$, in the component being evaluated

OD	=	2591	mm	L	=	6706	mm
V_{tot}	=	35,34	m^3	V_{gas}	=	17,67	m^3
		1248	ft^3			624,01	ft^3
ρ_{gas}	=	0,668	kg/m^3	V_{liq}	=	17,67	m^3
		0,0417	lb/ft^3			624,01	ft^3
				ρ_{liq}	=	992,3	kg/m^3

$Mass_{comp}$ = 17534,0 kg

STEP 4.3 Calculate the fluid mass in each of the other component that are included in the inventory group mass

Based on the design of the gas plant, there is no other component or equipment type that can be combined to contribute the fluid mass to the leaking components.

STEP 4.4 Calculate the fluid mass in the inventory group, $mass_{inv}$

$$Mass_{inv} = \sum_{i=1}^{N} \left(Mass_{comp,i}\right)$$

Where

$Mass_{com}$ = 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]

= 17534,0 kg

STEP 4.5 Calculate the flow rate from a 203 mm (8 inch) diameter hole, W_{max8}

Calculate the flow rate from a 203 mm (8 inch) diameter hole, Wmax8, using the equation below as applicable with $A_n = A_8$ = 32.450 mm^2 (50.3 $inch^2$). This is the maximum flow rate that can be added to the equipment fluid mass from the surrounding equipment in the inventory group.

$$W_n = \frac{Cd}{C2} \, x \, An \, \text{x Ps} \sqrt{\left(\frac{k \; x \; MW \; x \; gc}{R \; x \; Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad (4.9)$$

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	$inch^2$
			=	32450	mm^2
			=	0,0325	m^2
P_s	=	Storage operating pressure	=	905	psi
			=	6239,8	Kpa
P_{atm}	=	Atmosphere pressure	=	14,696	psi
			=	101,33	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	=	120	°F
			=	322,04	K
C_2	=	SI and US customary conversion factors	=	1	
k	=	Ideal gas specific heat ratio	=	1,2027	

So,

$$W_{max8} = \frac{Cd}{C2} \; x \; An \; x \; Ps \sqrt{\left(\frac{k \; x \; MW \; x \; gc}{R \; x \; Ts}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \quad (4.10)$$

$$W_{max8} = \frac{0,9}{1} \; x \; 0,03245 \; x \; 6239,76 \sqrt{\left(\frac{1,2027 \; x \; 23 \; x \; 9,8}{8,314 \; x \; 322,09}\right)\left(\frac{2}{1,2027+1}\right)^{\frac{1,2027+1}{1,2027-1}}}$$

= 10,91978042 kg/s

STEP 4.6 Calculate the added fluid mass $mass_{add,n}$ for each release hole size

Determining the additional fluid mass for each release hole size resulting from three minutes of flow from the inventory group using equation (4.11):

$$Mass_{add\ n} = 180 \, . \min[W_n, W_{max8}] \quad (4.11)$$

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_{add\ n} = 180 \, . \, min[W_n, W_{max8}]$$

$$Mass_{add\ 1} = 180 \, . \, min[0,01065164; 10,91978042]$$

= 1,9173 kgs

2). MEDIUM RELEASE HOLE SIZE AREA

$Mass_{add\ n} = 180 . min[W_n , W_{max8}]$

$Mass_{add\ 2} = 180 . min[0,170426174; 10,91978042$

$= 30,677$ kgs

3). LARGE RELEASE HOLE SIZE AREA

$Mass_{add\ 3} = 180 . min[W_n , W_{max8}]$

$Mass_{add\ 3} = 180 . min [2,726818784; 10,91978042]$

$= 490,83$ kgs

4). RUPTURE RELEASE HOLE SIZE AREA

$Mass_{add\ 4} = 180 . min[W_n , W_{max8}]$

$Mass_{add\ 4} = 180 . min[43,62910055; 10,91978042]$

$= 1965,6$ kgs

STEP 4.7 Calculate the available mass for release for each hole size

For each release hole size, calculate the available mass for release usinng this below equation:

$$Mass_{avail\ n} = min . [\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}] \quad (4.12)$$

1). SMALL RELEASE HOLE SIZE AREA

$Mass_{avail\ n} = min . [\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$

$Mass_{avail\ 1} = min . [\{17534+1,91729\}, 17534]$

$= 17534,0$ kgs

2). MEDIUM RELEASE HOLE SIZE AREA

$Mass_{avail\ n} = min . [\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$

$Mass_{avail\ 2} = min . [\{17534+30,6767\}, 17534]$

$= 17534,0$ kgs

3). LARGE RELEASE HOLE SIZE AREA

$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$

$Mass_{avail\ 3} = min.[\{17534+490,827\},17534]$

$= 17534,0$ kgs

4). RUPTURE RELEASE HOLE SIZE AREA

$Mass_{avail\ n} = min.[\{Mass_{comp} + Mass_{add,n}\}, Mass_{inv}]$

$Mass_{avail\ 4} = min.[\{17534+1965,56\},17534]$

$= 17534,0$ kgs

SUMMARY:

1 For group inventory, theoritically, the total amount of fluid that can be released is the amount that is held within pressure containing equiment between isolation valves that can be quickly closed.

2 Calculating the fluid mass and the mass of component to determine the mass inventory.

3 There is no other components contributing the mass of the equipment evaluated.

4 $Mass_{inv}$ = 17534 kg

5 Determining the maximum flow rate of a hole size within the diameter of 203 mm (8 inch) with the hole size area of 32.450 mm^2 (50.3 $inch^2$).

W_{max8} = 10,9197804 kg/s

6 Determining the additional fluid mass for release hole size starting for the small release hole size until the rupture release hole size.

$Mass_{add1}$ = 1,91729446 kgs

$Mass_{add2}$ = 30,6767113 kgs

$Mass_{add3}$ = 490,827381 kgs

$Mass_{add4}$ = 1965,56048 kgs

7 Determining the available mass for each release hole size

$Mass_{avail1}$ = 17534,00 kgs

$Mass_{avail2}$ = 17534,00 kgs

$Mass_{avail3}$ = 17534,00 kgs

$Mass_{avail4}$ = 17534,00 kgs

5.1 RELEASE TYPE

The release is modeled as one of these two followinng types:

A). INSTANTANEOUS RELEASE

An instataneous or puff release is one that occurs so rapidly that the fluid disperses as a single large cloud or pool.

B). CONTINOUS RELEASE

A continous or plume release is one that occurs over a longer period of time, allowing the fluid to disperse in the shape of elongated ellipse (depending in the weather conditions).

The process for determining the appropriate type for release to model requires to determine the time required to release 4536 kgs (10000 lbs) of fluid, tn, through each release hole size.

STEP 5.1 Calculate the time required to release 4536 kgs (10000 lbs) of fluid for each hole size.
To determine the time required to release 4536 kgs (10000 lbs) of fluid for each hole size can be adopted from the equation (4.13):

$$t_n = \frac{C3}{W_n} \qquad (4.13)$$

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 n^{th} release hole size, kg/s

W_{n1} = 0,01065164 kg/s

W_{n2} = 0,17042617 kg/s

W_{n3} = 2,72681878 kg/s

W_{n4} = 43,6291005 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_1 = \frac{4536}{0,010651636}$$

= 425850,081 s

2). MEDIUM RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_2 = \frac{4536}{0{,}170426174}$$

$= 26615{,}6301$ s

3). LARGE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_3 = \frac{4536}{2{,}726818784}$$

$= 1663{,}47688$ s

4). RUPTURE RELEASE HOLE SIZE AREA

$$t_n = \frac{C3}{W_n}$$

$$t_4 = \frac{4536}{43{,}62910055}$$

$= 103{,}967305$ 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 = 425850 s (Continous)

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 26616 s (Continous)

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 1663,5 s (Continous)

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 103,97 s (Instantaneous)

SUMMARY:

1 Calculating the time required to release 4536 kgs (10000 lbs) of fluid for each hole size, starting for the small until the rupture release hole size.

t_{n1} = 425850,081 s

t_{n2} = 26615,6301 s

t_{n3} = 1663,47688 s

t_{n4} = 103,967305 s

2 Based on the characteristic that if the release hole size is 0.25 inch or less, then, automatically including into the continuous release type. And the other hand, if t_n<180 sec and the release mass is gretaer than 4356 kgs (10000 lbs), it is including into instantaneous release type.

	CONSEQUENCE OF FAILURE	Doc. No:	4
	PART 6 : ESTIMATE THE IMPACT OF DETECTION AND ISOLATION SYSTEMS ON RELEASE MAGNITUDE	Page:	19

STEP 6.1 Determine the detection and isolation systems present in the unit using Table 4.8 and 4.9

Table 4.8 Detection and Isolation System Rating Guide

Type of Detection System	Det. Classification
Instrumentation designed specifically to detect material losses by changes in operating conditions (i.e. loss of pressure or flow) in the system	A
Suitably 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 System	**Iso. Classification**
Isolation or shutdown systems activated directly from process instrumentation or detectors, with no operator intervention	A
Isolation or shutdown systems activated by operators in the control room or other suitable location remote from the leak	B
Isolation dependent on manually operated valves	C

Table 4.9 Adjustment to Release Based on Detection and Isolation Systems

System Classification		Release Magnitude Adjustment	Reduction Factor, $fact_{di}$
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	0,00

STEP 6.2 Type of detection system = Instrumentation designed specifically to detect material losses by changes in operating conditions (i.e. loss of pressure or flow) in the system *

Detection Classification = A

STEP 6.3 Type of isolation system = Isolation or shutdown systems activated directly from process instrumentation or detectors, with no oprator intervention *

Isolation Classification = A

STEP 6.4 Determine the release reduction factor $fact_{di}$ using Table 4.6 of API 581

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 4.10

Table 4.10 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 = 425850 s (Continous)

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

2). MEDIUM RELEASE HOLE SIZE AREA

d_2 = 1 inch

t_2 = 26616 s (Continous)

$ld_{max,2}$ = 10 minutes for 1 inch leaks

3). LARGE RELEASE HOLE SIZE AREA

d_3 = 4 inch

t_3 = 1663,5 s (Continous)

$ld_{max,3}$ = 5 minutes for 4 inch leaks

4). RUPTURE RELEASE HOLE SIZE AREA

d_4 = 16 inch

t_4 = 103,97 s (Instantaneous)

$ld_{max,4}$ = 5 minutes for 4 inch leaks

SUMMARY:

1 Detection and isolation system is refered to the "X" oil and gas company which one of the following option provided by the API RP 581 suits them better.

2 Choosing the best category of detection system that suits the Production

3 Choosing the best category of isolation system that suits the Production Separator.

4 Based on the category both of detection and isolation system, then we could determine the percentage of the release factor magnitude ($fact_{di}$) of the whole production separator safety plan. From the result above, the release factor magnitude ($fact_{di}$) is 0,25 % because of both detection and isolation system are including into Category A

5 Based on the Category A of both detection and isolation systems, the maximum leaks duration can be known.

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks

$ld_{max,2}$ = 10 minutes for 1 inch leaks

$ld_{max,3}$ = 5 minutes for 4 inch leaks

$ld_{max,4}$ = 5 minutes for 4 inch leaks

7.1 CONTINOUS RELEASE RATE

For continous releases, the release is modeled as a steady state plume: therefore, the release rate is used as an input to the consequence analysis. The release rate that is used in the analysis is the theoretical release adjusted for the presence of unit detection and isolations as formulated in the equation below:

$$Rate_n = W_n\,(1 - fact_{di}) \tag{4.14}$$

7.2 INSTANTANEOUS RELEASE RATE

For transient instataneous puff releases, the release mass is required to perform the analysis. The available release mass for each hole size, $mass_{avail,n}$, is used ass an upper bound for the release mass, $mass_n$, as shown in the equation below:

$$Mass_n = min\,.\,[\{Rate_n\,.\,ld_n\},Mass_{avail,n}] \tag{4.15}$$

STEP 7.1 Calculate the adjusted release rate, $rate_n$ for each release hole size

For each release hole size, determine the adjusted release rate, $rate_n$, using equation (4.14) where the theoreical release rate, W_n, and also note that the release reduction factor, $fact_{di}$, account for any detection and isolation systems that are present.

Reduction Factor, $fact_{di}$ = 0,25

W_{n1} = 0,01065164 kg/s

W_{n2} = 0,17042617 kg/s

W_{n3} = 2,72681878 kg/s

W_{n4} = 43,6291005 kg/s

1). SMALL RELEASE HOLE SIZE AREA

$$Rate_1 = W_n\,(1 - fact_{di})$$

$$Rate_1 = 0{,}0010651636\,(1 - 0{,}25)$$

= 0,008 kg/s

2). MEDIUM RELEASE HOLE SIZE AREA

$$Rate_2 = W_n\,(1 - fact_{di})$$

$$Rate_2 = 0{,}170426174\,(1 - 0{,}25)$$

= 0,1278 kg/s

3). LARGE RELEASE HOLE SIZE AREA

$$Rate_3 = W_n\,(1 - fact_{di})$$

$$Rate_3 = 2{,}726818784\,(1 - 0{,}25)$$

= 2,0451 kg/s

4). RUPTURE RELEASE HOLE SIZE AREA

$$Rate_4 = W_n\,(1 - fact_{di})$$

$$Rate_4 = 43{,}62910055\,(1 - 0{,}25)$$

$$= 32{,}722 \text{ kg/s}$$

STEP 7.2 Calculate the leak duration, ld_n, for each release hole size

For each release hole size, calculate the leak duration, ld_n, of the release using this equation (4.16). Note that the leak duration cannot exceed the maximum duration $ld_{max,n}$.

$$ld_n = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_n}\},\{60\,.\,ld_{max,n}\,] \quad (4.16)$$

$ld_{max,1}$	=	20 minutes for 1/4 inch leaks	20	$Mass_{avail,1}$	=	17534,00	kgs
$ld_{max,2}$	=	10 minutes for 1 inch leaks	10	$Mass_{avail,2}$	=	17534,00	kgs
$ld_{max,3}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,3}$	=	17534,00	kgs
$ld_{max,4}$	=	5 minutes for 4 inch leaks	5	$Mass_{avail,4}$	=	17534,00	kgs

1). SMALL RELEASE HOLE SIZE AREA

$$ld_1 = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_1}\},\{60\,.\,ld_{max,1}\,]$$

$$ld_1 = min\,.\,[\{\frac{17534}{0{,}007988727}\},\{60\,.\,20\}]$$

$$= 1200 \text{ s}$$

2). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2 = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_2}\},\{60\,.\,ld_{max,2}\,]$$

$$ld_2 = min\,.\,[\{\frac{17534}{0{,}127819631}\},\{60\,.\,10\}]$$

$$= 600 \text{ s}$$

3). LARGE RELEASE HOLE SIZE AREA

$$ld_3 = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_3}\},\{60\,.\,ld_{max,3}\,]$$

$$ld_3 = min\,.\,[\{\frac{17534}{2{,}045114088}\},\{60\,.\,5\}]$$

$$= 300 \text{ s}$$

4). RUPTURE RELEASE HOLE SIZE AREA

$$Id_4 = min\,.\,[\{\frac{Mass_{avail,n}}{Rate_4}\},\{60\,.\,Id_{max,4}\}]$$

$$Id_4 = min\,.\,[\{\frac{17534}{32{,}72182541}\},\{60\,.\,5\}]$$

$= 300$ s

STEP 7.3 Calculate the release mass, $mass_n$, for each release hole size

For each release hole size, calculate the release mass, $mass_n$, using equation (4.15) above based on the release rate, $rate_n$, the leak duration, Id_n, and the available mass, $mass_{avail,n}$.

1). SMALL RELEASE HOLE SIZE AREA

$$Mass_1 = min\,.\,[\{Rate_1\,.\,Id_1\},Mass_{avail,1}]$$

$$Mass_1 = min\,.\,[\{0{,}007988727\,.\,1200\};17534]$$

$= 9{,}58647229$ kgs

2). MEDIUM RELEASE HOLE SIZE AREA

$$Mass_2 = min\,.\,[\{Rate_2\,.\,Id_2\},Mass_{avail,n}]$$

$$Mass_2 = min\,.\,[\{0{,}127819631\,.\,600\};17534]$$

$= 76{,}6917783$ kgs

3). LARGE RELEASE HOLE SIZE AREA

$$Mass_3 = min\,.\,[\{Rate_3\,.\,Id_3\},Mass_{avail,n}]$$

$$Mass_3 = min\,.\,[\{2{,}045114088.\,300\};17534]$$

$= 613{,}534226$ kgs

4). RUPTURE RELEASE HOLE SIZE AREA

$$Mass_4 = min\,.\,[\{Rate_4\,.\,Id_4\},Mass_{avail,n}]$$

$$Mass_4 = min\,.\,[\{32{,}72182541\,.\,300\};17534]$$

$= 9816{,}54762$ kgs

SUMMARY:

1. Determining the adjusted release rate, $rate_n$, for each release hole size. This adjusted release rate is quite different with the theoretical release rate, W_n because the adjusted release rate is based on the real condition with the theoretical release rate referrence. Otherwise, the theoretical release rate, $W_{n,}$ is purely based on the theory and approching equationg provided by API RP 581.

$Rate_1$	=	0,00798873	kg/s
$Rate_2$	=	0,12781963	kg/s
$Rate_3$	=	2,04511409	kg/s
$Rate_4$	=	32,7218254	kg/s

2. Determining the leak duration, ld_n, for each release hole size.

ld_1	=	1200	s
ld_2	=	600	s
ld_3	=	300	s
ld_4	=	300	s

3. Determining the release mass for each release hole size based on the release rate, leak duration, and available mass for each release hole size.

$Mass_1$	=	9,58647229	kgs
$Mass_2$	=	76,6917783	kgs
$Mass_3$	=	613,534226	kgs
$Mass_4$	=	9816,54762	kgs

8.1 CONSEQUENCE AREA EQUATIONS

The following equations are used to determine the flammable consequence areas for comoponent damage and personnel injury. There are two kind of equantions explained based on its type of release, either continous release or instataneous release as mentioned below:

1). CONTINOUS RELEASE

$$CA_n^{CONT} = \alpha(rate_n)^b \quad (4.17)$$

2). INSTATANEOUS RELEASE

$$CA_n^{CONT} = \alpha(mass_n)^b \quad (4.18)$$

The coefficients for those equations for component damage areas and personel injury are provided in Table 4.13 and 4.14.

STEP 8.1 Select the consequence area mitigation reduction factor, factmit, from Table 4.11

Table 4.11 Adjustments to Flammable Consequence for Mitigation Systems

Mitigation System	Consequence Area Adjustment	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.

$$eneff_n = 4.\, log_{10}[C_{4A}\, .mass_n] - 15 \quad (4.19)$$

This correction is made for instantaneous events exceeding a release mass of 4,536 kgs (10,000 Ibs). Comparison of calculated consequence with those of actual historical releases indicates that there is need to correct large instantaneous releases for energy efficiency.

C_{4A} = 2205 1/kg

A) SMALL RELEASE HOLE SIZE AREA

$eneff_1 = 4.\, log_{10}[C_{4A}\, .mass_1] - 15$

$eneff_1$ = 0 (because it continous release)

B) MEDIUM RELEASE HOLE SIZE AREA

$eneff_2 = 4.\, log_{10}[C_{4A}\, .mass_2] - 15$

$eneff_2$ = 0 (because it continous release)

C) LARGE RELEASE HOLE SIZE AREA

$eneff_3 = 4.\, log_{10}[C_{4A}\, .mass_3] - 15$

$eneff_3$ = 0 (because it continous release)

D) RUPTURE RELEASE HOLE SIZE AREA

$eneff_4 = 4.\, log_{10}[C_{4A}\, .mass_4] - 15$

$eneff_4$ = 14,341

STEP 8.3 Determine the fluid type

Determine the fluid type, either TYPE 0 or TYPE 1 based on Table 4.12.

Table 4.12 List of Representative Fluids Available for Level 1 Consequence Analysis

Representative Fluide	Fluid Type	Examples of Applicable Materials
C1 – C2	TYPE 0	Methane, Ethane, Ethylene, LNG, Fuel Gas
C3 – C4	TYPE 0	Propane, Butane, Isobutane, LPG
C5	TYPE 0	Pentane
C6 – C8	TYPE 0	Gasoline, Naphtha, Light Straight Run, Heptane
C9 – C12	TYPE 0	Diesel, Kerosene

C1-C2	=	TYPE 0		T	=	48,8	(^{o}C)
MW	=	23,00	(kg/kg-mol)	T	=	120	(^{o}F)
AIT	=	1036	(^{o}F)	T	=	322,04	(K)
AIT	=	830,93	(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 4.13

Table 4.13 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	###			55,13	###			6,5	###			163,7	###		

$\alpha = \alpha_{cmd,n}^{AINL-CONT} =$ 8,669 $\qquad$ $b = b_{cmd}^{AINL-CONT} =$ 0,98

2). Calculate the consequence of area using equation (4.20)

$Rate_1$	=	0,0080	kg/s
$Rate_2$	=	0,1278	kg/s
$Rate_3$	=	2,0451	kg/s
$Rate_4$	=	32,7218	kg/s

$$CA_{cmd,n}^{AINL-CONT} = \alpha(rate_n)^b \,.\, (1 - fact_{mit}) \tag{4.20}$$

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-CONT} = \alpha(rate_1)^b \,.\, (1 - fact_{mit})$$

$= 0,0572 \ m^2$

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-CONT} = \alpha(rate_2)^b \,.\, (1 - fact_{mit})$$

$= 0,866 \ m^2$

C) LARGE RELEASE HOLE SIZE AREA

$CA^{AINL-CONT}_{cmd,3} = \alpha(rate_3)^b \,.\,(1 - fact_{mit})$

$= 13{,}108 \text{ m}^2$

D) RUPTURE RELEASE HOLE SIZE AREA

$CA^{AINL-CONT}_{cmd,4} = \alpha(rate_4)^b \,.\,(1 - fact_{mit})$

$= 0 \text{ m}^2$ (because it instataneous release)

STEP 8.5 For each 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 4.13

$\alpha = \alpha^{AIL-CONT}_{cmd,n} = 55{,}1$ $\quad b = b^{AIL-CONT}_{cmd} = 0{,}95$

2). Calculate the consequence of area using equation (4.21)

$$CA^{AINL-CONT}_{cmd,n} = \alpha(rate_n)^b \,.\,(1 - fact_{mit}) \quad (4.21)$$

A) SMALL RELEASE HOLE SIZE AREA

$CA^{AINL-CONT}_{cmd,1} = \alpha(rate_1)^b \,.\,(1 - fact_{mit})$

$= 0{,}4205 \text{ m}^2$

B) MEDIUM RELEASE HOLE SIZE AREA

$CA^{AINL-CONT}_{cmd,2} = \alpha(rate_2)^b \,.\,(1 - fact_{mit})$

$= 5{,}8576 \text{ m}^2$

C) LARGE RELEASE HOLE SIZE AREA

$CA^{AINL-CONT}_{cmd,3} = \alpha(rate_3)^b \,.\,(1 - fact_{mit})$

$= 81{,}589 \text{ m}^2$

D) RUPTURE RELEASE HOLE SIZE AREA

$CA^{AINL-CONT}_{cmd,4} = \alpha(rate_4)^b \,.\,(1 - fact_{mit})$

$= 0 \text{ m}^2$ (because it instataneous release)

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 4.13

α = $\alpha_{cmd,n}^{AINL-INST}$ = 6,5 b = $b_{cmd}^{AINL-INST}$ = 0,67

2). Calculate the consequence of area using equation (4.22).

$$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (4.22)$$

From step 7, known that:

Mass1	=	9,58647229 kgs	Mass3	=	613,534226 kgs
Mass2	=	76,69177830 kgs	Mass4	=	9816,547623 kgs

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha(mass_1)^b \cdot \left(\frac{1-fact_{mit}}{eneff_1}\right)$$

= 0 m^2 (because it continous release)

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha(mass_2)^b \cdot \left(\frac{1-fact_{mit}}{eneff_2}\right)$$

= 0 m^2 (because it continous release)

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha(mass_3)^b \cdot \left(\frac{1-fact_{mit}}{eneff_3}\right)$$

= 0 m^2 (because it continous release)

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-INST} = \alpha(mass_4)^b \cdot \left(\frac{1-fact_{mit}}{eneff_4}\right)$$

= 159,93 m^2

STEP 8.7 For ech release hole size, calculate the component damage consequence areas for Auto-Ignition Likely, Instataneous Release (AIL-INST), $CA^{AIL\text{-}INST}$

1). Determine the appropriate constant a and b from the Table 4.13

α = $\alpha_{cmd,n}^{AIL-INST}$ = 163,7 b = $b_{cmd}^{AIL-INST}$ = 0,62

2). Calculate the consequence of area using equation (4.23).

$$CA_{cmd,n}^{AINL-INST} = \alpha(mass_n)^b \cdot \left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (4.23)$$

From step 7, known that:

Mass1	=	9,58647229 kgs	Mass3	=	613,534226 kgs
Mass2	=	76,69177830 kgs	Mass4	=	9816,547623 kgs

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{cmd,1}^{AINL-INST} = \alpha(mass_1)^b \cdot \left(\frac{1-fact_{mit}}{eneff_1}\right)$$

= 0 m^2 (because it continous release)

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{cmd,2}^{AINL-INST} = \alpha(mass_2)^b \cdot \left(\frac{1-fact_{mit}}{eneff_2}\right)$$

= 0 m^2 (because it continous release)

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{cmd,3}^{AINL-INST} = \alpha(mass_3)^b \cdot \left(\frac{1-fact_{mit}}{eneff_3}\right)$$

= 0 m^2 (because it continous release)

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA_{cmd,4}^{AINL-INST} = \alpha(mass_4)^b \cdot \left(\frac{1-fact_{mit}}{eneff_4}\right)$$

= 2555,8 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 4.14 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 4.14 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	22	###			143,2	###			###	###			473,9	###		

α = $\alpha_{inj,n}^{AINL-CONT}$ = 21,83 b = $b_{inj,n}^{AINL-CONT}$ = 0,96

2). Calculate the consequence of area using equation (4.24)

$$CA_{inj,n}^{AINL-CONT} = [\alpha.(rate_n^{AINL-CONT})^b].(1 - fact_{mit}) \quad (4.24)$$

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-CONT} = \left[\alpha.\left(rate_1^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 0,1587 m^2

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-CONT} = \left[\alpha.\left(rate_2^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 2,2722 m^2

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-CONT} = \left[\alpha.\left(rate_3^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 32,539 m^2

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-CONT} = \left[\alpha.\left(rate_4^{AINL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 0 m^2 (because it instataneous release)

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 4.14 from API RP 581 Part 3. The release phase as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

α = $\alpha_{inj,n}^{AIL-CONT}$ = 143,2 b = $b_{inj,n}^{AIL-CONT}$ = 0,92

2). Calculate the consequence of area using equation (4.25)

$$CA_{inj,n}^{AIL-CONT} = [\alpha.(rate_n^{AIL-CONT})^b].(1 - fact_{mit}) \quad (4.25)$$

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-CONT} = \left[\alpha.\left(rate_1^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 1,2627 m^2

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-CONT} = \left[\alpha.\left(rate_2^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 16,184 m^2

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-CONT} = \left[\alpha.\left(rate_3^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 207,43 m^2

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-CONT} = \left[\alpha.\left(rate_4^{AIL-CONT}\right)^b\right].(1 - fact_{mit})$$

= 0 m^2 (because it instataneous release)

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 phase as determined in STEP 1.4 willl be needed to assure selection of the correct constant.

α = $\alpha_{inj,n}^{AINL-INST}$ = 12,46 b = $b_{inj,n}^{AINL-INST}$ = 0,67

2). Calculate the consequence of area using equation (4.26)

$$CA_{inj,n}^{AINL-INST} = [\alpha.(mass_n^{AINL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (4.26)$$

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AINL-INST} = \left[\alpha.\left(mass_1^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

= 0 m^2 (because it continous release)

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AINL-INST} = \left[\alpha.\left(mass_2^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

= 0 m^2 (because it continous release)

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AINL-INST} = \left[\alpha.\left(mass_3^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

= 0 m^2 (because it continous release)

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AINL-INST} = \left[\alpha.\left(mass_4^{AINL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

= 308,033559 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 = $\alpha_{inj,n}^{AIL-INST}$ = 473,9 b = $b_{inj,n}^{AIL-INST}$ = 0,63

2). Calculate the consequence of area using equation (4.27)

$$CA_{inj,n}^{AIL-INST} = [\alpha.(mass_n^{AIL-INST})^b].\left(\frac{1-fact_{mit}}{eneff_n}\right) \quad (4.27)$$

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{AIL-INST} = \left[\alpha.\left(mass_1^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_1}\right)$$

= 0 m^2 (because it continous release)

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{AIL-INST} = \left[\alpha.\left(mass_2^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_2}\right)$$

= 0 m^2 (because it continous release)

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{AIL-INST} = \left[\alpha.\left(mass_3^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_3}\right)$$

= 0 m^2 (because it continous release)

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{AIL-INST} = \left[\alpha.\left(mass_4^{AIL-INST}\right)^b\right].\left(\frac{1-fact_{mit}}{eneff_4}\right)$$

= 8111,26049 m^2

STEP 8.12 For each release hole size, calculate the instataneous/continous blending factor, $fact_n^{IC}$.

1). FOR CONTINOUS RELEASE

C_5 = 25 kg/s

$$fact_n^{IC} = \min\left[\left\{\frac{rate_n}{C_5}\right\}, 1.0\right] \quad (4.28)$$

A) SMALL RELEASE HOLE SIZE AREA

$$fact_1^{IC} = \min\left[\left\{\frac{rate_1}{C_5}\right\}, 1.0\right]$$

= 0,000317013

B) MEDIUM RELEASE HOLE SIZE AREA

$$fact_2^{IC} = \min\left[\left\{\frac{rate_2}{C_5}\right\}, 1.0\right]$$

= 0,005072208

C) LARGE RELEASE HOLE SIZE AREA

$$fact_3^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$

= 0,081155321

2). FOR INSTATANEOUS RELEASE

$$fact_n^{IC} = 1 \qquad (4.29)$$

A) **RUPTURE RELEASE HOLE SIZE AREA**

$$fact_4^{IC} = \min\left[\left\{\frac{rate_3}{C_5}\right\}, 1.0\right]$$

= 1

STEP 8.13 Calculate the AIT blending factor, $fact^{AIT}$, using these optional equation below.

$fact^{AIT}$	=	0	for, $T_S + C_6 \leq AIT$	(4.30)
$fact^{AIT}$	=	$\frac{(T_s - AIT + C_6)}{2 . C_6}$	for, $T_S + C_6 > AIT > T_S - C_6$	(4.31)
$fact^{AIT}$	=	1	for, $T_S - C_6 \geq AIT$	(4.32)

Ts	=	48,8	(^oC)	AIT	=	1036	(^oF)
Ts	=	120	(^oF)	AIT	=	830,93	(K)
Ts	=	322,04	(K)	C_6	=	55,6	(K)

$T_s + C_6$ = 377,64 (K)

$T_s - C_6$ = 266,44 (K)

$$\frac{(T_s - AIT + C_6)}{2 . C_6} = -4,0763389 \text{ (K)}$$

So, $fact^{AIT}$ = 0

STEP 8.14 Calculate the continuous/instantaneous blended consequence area for the component using equation (4.33) through (4.36) based on the consequence areas calculated in

1 **Calculate the continuous/instantaneous blended consequence area for the Auto-ignition Likely for component damage.**

$$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} . fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} . (1 - fact_n^{IC}) \qquad (4.33)$$

A) SMALL RELEASE

$CA_{cmd,1}^{AIL-INST}$ = 0,00 m^2

$fact_1^{IC}$ = 3,17E-04

C) LARGE RELEASE

$CA_{cmd,3}^{AIL-INST}$ = 0,00 m^2

$fact_3^{IC}$ = 8,1E-02

$CA^{AIL-CONT}_{cmd,1}$ = 0,42 m²

$CA^{AIL}_{cmd,1}$ = 0,420402465 m²

$CA^{AIL-CONT}_{cmd,3}$ = 81,59 m²

$CA^{AIL}_{cmd,3}$ = 74,967 m²

B) MEDIUM RELEASE

$CA^{AIL-INST}_{cmd,2}$ = 0,00 m²

$fact^{IC}_{2}$ = 0,005072

$CA^{AIL-CONT}_{cmd,2}$ = 5,86 m²

$CA^{AIL}_{cmd,2}$ = 5,827851788 m²

D) RUPTURE RELEASE

$CA^{AIL-INST}_{cmd,4}$ = 2555,82 m²

$fact^{IC}_{4}$ = 1,0000

$CA^{AIL-CONT}_{cmd,4}$ = 0,00 m²

$CA^{AIL}_{cmd,4}$ = 2555,8 m²

2 Calculate the continuous/instantaneous blended consequence area for the Auto-ignition Likely for personnel injury.

$$CA^{AIL}_{inj,n} = CA^{AIL-INST}_{inj,n} . fact^{IC}_{n} + CA^{AIL-CONT}_{inj,n} . (1 - fact^{IC}_{n}) \quad (4.34)$$

A) SMALL RELEASE

$CA^{AIL-INST}_{inj,1}$ = 0 m²

$fact^{IC}_{1}$ = 3,17E-04

$CA^{AIL-CONT}_{inj,1}$ = 1,26265194 m²

$CA^{AIL}_{inj,1}$ = 1,262251663 m²

C) LARGE RELEASE

$CA^{AIL-INST}_{inj,3}$ = 0 m²

$fact^{IC}_{3}$ = 0,0812 m²

$CA^{AIL-CONT}_{inj,3}$ = 207,43 m²

$CA^{AIL}_{inj,3}$ = 190,59 m²

B) MEDIUM RELEASE

$CA^{AIL-INST}_{inj,2}$ = 0 m²

$fact^{IC}_{2}$ = 0,005072

$CA^{AIL-CONT}_{inj,2}$ = 16,18355897 m²

$CA^{AIL}_{inj,2}$ = 16,1014726 m²

D) RUPTURE RELEASE

$CA^{AIL-INST}_{inj,4}$ = 8111,3 m²

$fact^{IC}_{4}$ = 1,0000 m²

$CA^{AIL-CONT}_{inj,4}$ = 0 m²

$CA^{AIL}_{inj,4}$ = 8111,3 m²

3 **Calculate the continuous/instantaneous blended consequence area for the Auto-ignition Not Likely for component damage.**

$$CA^{AINL}_{cmd,n} = CA^{AINL-INST}_{cmd,n} \cdot fact^{IC}_{n} + CA^{AINL-CONT}_{cmd,n} \cdot (1 - fact^{IC}_{n}) \quad (4.35)$$

A) SMALL RELEASE

$CA^{AINL-INST}_{cmd,n}$ = 0 m²

$fact^{IC}_{1}$ = 3,17E-04

$CA^{AINL-CONT}_{cmd,1}$ = 0,057208201 m²

$CA^{AINL}_{cmd,1}$ = 0,057190065 m²

B) MEDIUM RELEASE

$CA^{AINL-INST}_{cmd,n}$ = 0 m²

$fact^{IC}_{2}$ = 0,005072

$CA^{AINL-CONT}_{cmd,2}$ = 0,865956094 m²

$CA^{AINL}_{cmd,2}$ = 0,861563785 m²

C) LARGE RELEASE

$CA^{AINL-INST}_{cmd,n}$ = 0 m²

$fact^{IC}_{3}$ = 0,0812

$CA^{AINL-CONT}_{cmd,3}$ = 13,108 m²

$CA^{AINL}_{cmd,3}$ = 12,044 m²

D) RUPTURE RELEASE

$CA^{AINL-INST}_{cmd,4}$ = 2555,8 m²

$fact^{IC}_{4}$ = 1,0000

$CA^{AINL-CONT}_{cmd,4}$ = 0 m²

$CA^{AINL}_{cmd,4}$ = 2555,8 m²

4 **Calculate the continuous/instantaneous blended consequence area for the Auto-ignition Not Likely for personnel injury.**

$$CA^{AINL}_{inj,n} = CA^{AINL-INST}_{inj,n} \cdot fact^{IC}_{n} + CA^{AINL-CONT}_{inj,n} \cdot (1 - fact^{IC}_{n}) \quad (4.36)$$

A) SMALL RELEASE

$CA^{AINL-INST}_{inj,n}$ = 0 m²

$fact^{IC}_{1}$ = 0,0003

$CA^{AINL-CONT}_{inj,1}$ = 0,158669507 m²

$CA^{AINL}_{inj,1}$ = 0,158619206 m²

C) LARGE RELEASE

$CA^{AINL-INST}_{inj,n}$ = 0 m²

$fact^{IC}_{3}$ = 0,0812

$CA^{AINL-CONT}_{inj,3}$ = 32,539 m²

$CA^{AINL}_{inj,3}$ = 29,898 m²

B) MEDIUM RELEASE

$CA_{inj,n}^{AINL-INST}$ = 0 m²

$fact_2^{IC}$ = 0,005072

$CA_{inj,2}^{AINL-CONT}$ = 2,272210982 m²

$CA_{inj,2}^{AINL}$ = 2,260685856 m²

D) RUPTURE RELEASE

$CA_{inj,4}^{AINL-INST}$ = 308,03 m²

$fact_4^{IC}$ = 1,0000

$CA_{inj,4}^{AINL-CONT}$ = 0 m²

$CA_{inj,4}^{AINL}$ = 308,03 m²

STEP 8.15 Calculate the AIT blended consequence areas for the component using equations (4.37) and (4.38) based on the consequence areas determined in step 8.14 and the AIT blending factors, $fact_{AIT}$ calculate in step 8.13. the resulting consequence areas are the component damage and personnel injury flammable consequence areas, $CA_{icmd,n}^{flam}$ and $CA_{inj,n}^{flam}$ for each release hole size selected in step 2.2

1 Calculate the AIT blended consequence areas for damage component.

$$CA_{cmd,n}^{flam} = CA_{smd,n}^{AIL} \cdot fact^{AIT} + CA_{cmd,n}^{AINL} \cdot (1 - fact^{AIT}) \quad (4.37)$$

A) SMALL RELEASE

$CA_{cmd,1}^{AIL}$ = 0,42040246 m²

$fact^{AIT}$ = 0

$CA_{cmd,1}^{AINL}$ = 0,05719007 m²

$CA_{cmd,1}^{flam}$ = 0,05719007 m²

C) LARGE RELEASE

$CA_{cmd,3}^{AIL}$ = 74,9674993 m²

$fact^{AIT}$ = 0

$CA_{cmd,3}^{AINL}$ = 12,0441335 m²

$CA_{cmd,3}^{flam}$ = 12,0441335 m²

B) MEDIUM RELEASE

$CA_{cmd,2}^{AIL}$ = 5,82785179 m²

$fact^{AIT}$ = 0

$CA_{cmd,2}^{AINL}$ = 0,86156379 m²

$CA_{cmd,2}^{flam}$ = 0,86156379 m²

D) RUPTURE RELEASE

$CA_{cmd,4}^{AIL}$ = 2555,822751 m²

$fact^{AIT}$ = 0

$CA_{cmd,4}^{AINL}$ = 0 m²

$CA_{cmd,4}^{flam}$ = 0 m²

2 Calculate the AIT blended consequence areas for personnel injury.

$$CA_{inj,n}^{flam} = CA_{inj,n}^{flam-AIL} . fact^{AIT} + CA_{inj,n}^{AINL} . (1 - fact^{AIT}) \quad (4.38)$$

A) SMALL RELEASE

$CA_{inj,1}^{flam-AIL}$ = 1,26225166 m²

$fact^{AIT}$ = 0

$CA_{inj,1}^{AINL}$ = 0,15861921 m²

$CA_{inj,1}^{flam}$ = 0,15861921 m2

B) MEDIUM RELEASE

$CA_{inj,2}^{flam-AIL}$ = 16,1014726 m²

$fact^{AIT}$ = 0

$CA_{inj,2}^{AINL}$ = 2,26068586 m²

$CA_{inj,2}^{flam}$ = 2,26068586 m2

C) LARGE RELEASE

$CA_{inj,3}^{flam-AIL}$ = 190,5928145 m²

$fact^{AIT}$ = 0

$CA_{inj,3}^{AINL}$ = 29,89826195 m²

CA_{inj3}^{flam} = 29,89826195 m²

D) RUPTURE RELEASE

$CA_{inj,4}^{flam-AIL}$ = 8111,260491 m²

$fact^{AIT}$ = 0

$CA_{inj,4}^{AINL}$ = 308,033559 m²

$CA_{inj,4}^{flam}$ = 308,033559 m²

STEP 8.16 Determine the consequence areas (probability weighted on release hole size) for component damage and personnel injury using equations (4.39) and (4.40) based on the consequence ara from step 8.15

Table 4.15 Suggested Component Generic Failure Frequency

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		Small	Medium	Large	Rupture	
Vessel/ FinFan	KODRUM COLBTM FINFAN FILTER DRUM REACTOR COLTOP COLMID	8,0E-06	2,0E-05	2,0E-06	6,0E-07	3,1E-05

1 CONSEQUENCE AREA FOR COMPONENT DAMAGE

$$CA_{cmd}^{flam} = \left(\frac{\sum gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right) \quad (4.39)$$

$$CA_{cmd}^{flam} = \left(\frac{(gff_{1} \cdot CA_{cmd,1}^{flam}) + (gff_{2} \cdot CA_{cmd,2}^{flam}) + (gff_{3} \cdot CA_{cmd,3}^{flam}) + (gff_{4} \cdot CA_{cmd,4}^{flam})}{gff_{total}} \right)$$

$= 1,37 \; m^2$

2 CONSEQUENCE AREA FOR PERSONNEL INJURY

$$CA_{inj}^{flam} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{flam}}{gff_{total}} \right) \quad (4.40)$$

$$CA_{inj}^{flam} = \left(\frac{\left(gff_1 \cdot CA_{inj,1}^{flam}\right) + \left(gff_2 \cdot CA_{inj,2}^{flam}\right) + \left(gff_3 \cdot CA_{inj,3}^{flam}\right) + \left(gff_4 \cdot CA_{inj,4}^{flam}\right)}{gff_{total}} \right)$$

$= 9,513 \; m^2$

STEP 9.1 For each release hole size selected in STEP 2.2, calculate the effective duration of the toxic release using this equation (4.41).

$$ld_n^{tox} = \min\left(3600\,,\left\{\frac{mass_n}{W_n}\right\},\{60.\,ld_{max,n}\}\right) \quad (4.41)$$

W_{n1} = 0,01065164 kg/s $Mass_1$ = 9,586472 kgs
W_{n2} = 0,17042617 kg/s $Mass_2$ = 76,691778 kgs
W_{n3} = 2,72681878 kg/s $Mass_3$ = 613,534226 kgs
W_{n4} = 43,6291005 kg/s $Mass_4$ = 9816,54762 kgs

$ld_{max,1}$ = 20 minutes for 1/4 inch leaks
$ld_{max,2}$ = 10 minutes for 1 inch leaks
$ld_{max,3}$ = 5 minutes for 4 inch leaks
$ld_{max,4}$ = 5 minutes for 4 inch leaks

A). SMALL RELEASE HOLE SIZE AREA

$$ld_1^{tox} = \min\left(3600\,,\left\{\frac{mass_1}{W_1}\right\},\{60.\,ld_{max,1}\}\right)$$

= 900 s

B). MEDIUM RELEASE HOLE SIZE AREA

$$ld_2^{tox} = \min\left(3600\,,\left\{\frac{mass_2}{W_2}\right\},\{60.\,ld_{max,2}\}\right)$$

= 450 s

C). LARGE RELEASE HOLE SIZE AREA

$$ld_n^{tox} = \min\left(3600\,,\left\{\frac{mass_n}{W_n}\right\},\{60.\,ld_{max,n}\}\right)$$

= 225 s

D). RUPTURE RELEASE HOLE SIZE AREA

$$ld_n^{tox} = \min\left(3600\,,\left\{\frac{mass_n}{W_n}\right\},\{60.\,ld_{max,n}\}\right)$$

= 225 s

STEP 9.2 Determine the toxic percentage of the toxic component, $mfrac^{tox}$, in the release material. The release fluid is a pure fluid, $mfrac^{tox}$ = 1.0. note that if there is more than one toxic component in the release fluid mixture, this procedure can be repeated for each toxic component

H_2S = 0,1%
$mfrac^{tox}$ = 0,0010

Cl = 0,0015%
$mfrac^{tox}$ = 0,000015

STEP 9.3 For each release hole size, calculate the release the release rate, $rate_n^{tox}$, and release mass, $mass_n^{tox}$,to be used in the toxic analysis

$$rate_n^{tox} = mfrac^{tox}.W_n \quad (4.42)$$

$$mass_n^{tox} = mfrac^{tox}.mass_n \quad (4.43)$$

For H_2S

A) SMALL RELEASE HOLE SIZE AREA

$rate_1^{tox} = mfrac^{tox}.W_1$ = 1,07E-05 kg/s

$mass_1^{tox} = mfrac^{tox}.mass_1$ = 0,00958647 kgs

B) MEDIUM RELEASE HOLE SIZE AREA

$rate_2^{tox} = mfrac^{tox}.W_2$ = 1,70E-04 kg/s

$mass_2^{tox} = mfrac^{tox}.mass_2$ = 0,07669178 kgs

C) LARGE RELEASE HOLE SIZE AREA

$rate_3^{tox} = mfrac^{tox}.W_3$ = 2,73E-03 kg/s

$mass_3^{tox} = mfrac^{tox}.mass_3$ = 0,61353423 kgs

D) RUPTURE RELEASE HOLE SIZE AREA

$rate_4^{tox} = mfrac^{tox}.W_4$ = 4,36E-02 kg/s

$mass_4^{tox} = mfrac^{tox}.mass_4$ = 9,81654762 kgs

For Cl

A) SMALL RELEASE HOLE SIZE AREA

$rate_1^{tox} = mfrac^{tox}.W_1$ = 1,64E-07 kg/s

$mass_1^{tox} = mfrac^{tox}.mass_1$ = 0,00014745 kgs

B) MEDIUM RELEASE HOLE SIZE AREA

$rate_2^{tox} = mfrac^{tox}.W_2$ = 2,62E-06 kg/s

$mass_2^{tox} = mfrac^{tox}.mass_2$ = 0,0011796 kgs

C) LARGE RELEASE HOLE SIZE AREA

$rate_3^{tox} = mfrac^{tox}.W_3$ = 4,19E-05 kg/s

$mass_3^{tox} = mfrac^{tox}.mass_3$ = 0,00943677 kgs

D) RUPTURE RELEASE HOLE SIZE AREA

$rate_4^{tox} = mfrac^{tox}.W_4$ = 6,71E-04 kg/s

$mass_4^{tox} = mfrac^{tox}.mass_4$ = 0,15098832 kgs

STEP 9.4 For each release hole size, calculate the toxic consequence area for each of the release hole size.

1) Calculate $CA_{inj,n}^{toxCONT}$ for HF acid and H_2S

Table 4.16 as Release Toxic Consequence Equation Constants for HF Acid and H2S

Continous Release Duration (minutes)	HF Acid		H_2S	
	c	d	c	d
5	1,1401	3,5683	1,2411	3,9686
10	1,1031	3,8431	1,241	4,0948
20	1,0816	4,104	1,237	4,238
40	1,0942	4,3295	1,2297	4,3626
60	1,4056	4,4576	1,2266	4,4365
Instantaneous	1,4056	33606	0,9674	2,784

$$CA_{inj,n}^{toxCONT} = C_8.10^{(c.log_{10}[C_{4B}.rate_n^{tox}]+d)} \quad (4.44)$$

$$CA_{inj,n}^{toxINST} = C_8.10^{(c.log_{10}[C_{4B}.mass_n^{tox}]+d)} \quad (4.45)$$

C_8 = 0,0929 m^2.sec

C_{4B} = 2,25 sec/kg

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{toxCONT} = C_8.10^{(c.log_{10}[C_{4B}.rate_1^{tox}]+d)}$$

$CA_{inj,1}^{toxCONT}$ = 0,00309 m^2

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{toxCONT} = C_8 . 10^{(c.log_{10}[C_{4B}.rate_2^{tox}]+d)}$$

$CA_{inj,2}^{toxCONT}$ = 0,067 m^2

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{toxCONT} = C_8 . 10^{(c.log_{10}[C_{4B}.rate_3^{tox}]+d)}$$

$CA_{inj,3}^{toxCONT}$ = 1,55 m^2

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA_{inj,4}^{toxCONT} = C_8 . 10^{(c.log_{10}[C_{4B}.mass_4^{tox}]+d)}$$

$CA_{inj,4}^{toxCONT}$ = 1128,08 m^2

2) Calculate $CA_{inj,n}^{toxCONT}$ for Ammonia and Chlorine

Table 4.17 Gas Release Toxic Consequence Equation Constants for Ammonia and Chlorine

Continous Release Duration (minutes)	Ammonia		Chlorine	
	e	f	e	f
5	636,7	1,183	3350	1,089
10	846,3	1,181	3518	1,095
20	1256	1,178	4191	1,089
Instantaneous	2,684	0,9011	3,528	1,177

$$CA_{inj,n}^{toxCONT} = e(Rate_n^{tox})^f \quad (4.46)$$

$$CA_{inj,n}^{toxINST} = e(Mass_n^{tox})^f \quad (4.47)$$

For Cl

A) SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{toxCONT} = e(Rate_1^{tox})^f$$

$CA_{inj,1}^{toxCONT}$ = 0,00017092 m^2

B) MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{toxCONT} = e(Rate_2^{tox})^f$$

$CA_{inj,2}^{toxCONT}$ = 0,00272005 m^2

C) LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{toxCONT} = e(Rate_3^{tox})^f$$

$CA_{inj,3}^{toxCONT}$ = 0,05729288 m^2

D) RUPTURE RELEASE HOLE SIZE AREA

$$CA^{toxINST}_{inj,4} = e(Mass^{tox}_{4})^{f}$$

$$CA^{toxINST}_{inj,4} = 0,3811930 \ m^2$$

STEP 9.5 If there are additional toxic component in the released fluid mixture, the STEP 9.2 througt 9.4 should be repeated for each toxic component.

There are no additional toxic components.

STEP 9.6 Determine the final toxic consequence areas for personnel injury in accordance with equation (4.48).

$$CA^{tox}_{inj} = \left(\frac{\sum gff_n \cdot CA^{tox}_{inj,n}}{gff_{total}}\right) \quad (4.48)$$

Table 4.18 Suggested Component Generic Failure Frequency

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		Small	Medium	Large	Rupture	
Vessel/ FinFan	KODRUM COLBTM FINFAN FILTER DRUM REACTOR COLTOP COLMID	8,0E-06	2,00E-05	2,0E-06	6,00E-07	3,06E-05

$$CA^{tox}_{inj} = \left(\frac{\sum gff_n \cdot CA^{tox}_{inj,n}}{gff_{total}}\right)$$

$$CA^{tox}_{inj} = \left(\frac{(gff_1 \cdot CA^{tox}_{inj,1})+(gff_2 \cdot CA^{tox}_{inj,2})+(gff_3 \cdot CA^{tox}_{inj,3})+(gff_4 \cdot CA^{tox}_{inj,4})}{gff_{total}}\right)$$

$$= 22,28 \ m^2$$

SUMMARY:

1 Calculating the effectice duration of leaks because of toxic composition for each release hole size. As a reminder that the toxic consequence area doesn't affect the component damage, only affects the personnel injury consequence area.

$ldtox_1$ = 900 s

$ldtox_2$ = 450 s

$ldtox_3$ = 225 s

$ldtox_4$ = 225 s

The leak duration of leak consequence area will be got from the minimum value of 45,32s, $Mass_n$ divided by theoretical release rate (W_n), or 60 sec multiplied by maximum leak duration (ld_{max}).

2 Identified from the chemical composition data wether there is one or more toxic content(s) which have been listed in API RP 581. In this case, the fluid contains mixture of H_2S and chlorine which defined as toxic fluid and flammable content.

3 To determine the consequence area, so, the first step define the release rate or flow rate the mass for each release hole size. For toxic consequence release rate will be gotten by multiplying the $mfract^{toxic}$ with the flow W_n and $Mass_n$.

4 Calculate the consequence area of toxic content both for continuous and instantaneous release type. When calculating the continuous release type, the parameter is commonly using release rate ($Rate^{toxic}$), otherwise, when conductinng the instantaneous release type the common parameter is using the mass [illegible]^{tooxic})

5 If there is another toxic content in the fluid stream, then, the previous steps must be calculated. If not, then, it can be continued to define the final toxic consequence area.

6 Calculating the final toxic consequennce area by combining the value between generic failure frequency with the toxic consequence area for each release hole size.

Step 10.1 For each release hole size, calculate the non-flammable , non-toxic consequence

For steam-calculate using equation (3.69) of Part 3 API RP 581 for continous release or equation (3.70) of Part 3 API RP 581 for instantaneous release.

1). FOR STEAM

Steam represents a hazard to personnel who are exposed to it at high temperatures. In general, steam is at 100°C (212°F) 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 60°C (140°F). In this case of Production Separator, the temperatur inside the presssure vessel is working around 120°F. So, steam leaks is not potentially occur at this situation.

So, the value is 0

2). FOR ACIDS AND CAUSTIC

For Acids or caustics- compute, $CA_{inj,N}^{CONT}$ using equation (4.49), (4.50), (4.51). Note that the data is not provided for an instantaneous release

For caustics/acids that have splash type consequences. Acid or caustic leaks do not result in a component damage consequence. The consequence area was defined at the 180° semi-circular area covered by the liquid spray or rainout. Modeling was performed at three pressures; 103.4 kPa, 206.8 kPa, and 413.7 kPa (15 psig, 30 psig, and 60 psig) for four release hole sizes (see Table 4.4). The results were analyzed to obtain a correlation between release rate and consequence area, and were divided by 5 since it is believed that serious injuries to personnel are only likely to occur within about 20% of the total splash area as calculated by the above method

The resulting consequence area for non-flammable releases of acids and caustics is calculated using Equations below

$$CA_{inj,n}^{CONT} = 0.2 \cdot C_8 \cdot g(C_4 \cdot rate_n)^h \quad (4.49)$$

$$CA_{inj,n}^{INST} = 0 \quad (4.50)$$

The constants g and h shown in Equation above ,are functions of pressure and can be calculated using Equations below, respectively.

$$g = 2696 - 21.9 \cdot C_{11}\,(P_S - P_{atm}) + 1.474\,[C_{11}(P_S - P_{atm})]^2 \quad (4.51)$$

$$h = 0.31 - 0.00032\,[C_{11}(P_S - P_{atm}) - 40]^2 \quad (4.52)$$

$Rate_1$	=	0,007989	kg/s	C_8	=	0,0929	$m^2.s$
$Rate_2$	=	0,127820	kg/s	C_4	=	2,205	s/kg
$Rate_3$	=	2,045114	kg/s	C_{11}	=	0,145	1/kPa
$Rate_4$	=	32,721825	kg/s			0,00145	1/bar
				P_S	=	6240	kPa
						62	bar
				P_{atm}	=	101,33	kPa
						1,01	bar

$$g = 2696 - 21.9 \cdot C_{11}\,(P_S - P_{atm}) + 1.474\,[C_{11}(P_S - P_{atm})]^2$$
$$g = 2696 - 21.9 \cdot 0{,}145\,(62 - 101{,}33) + 1.474\,[0{,}00145(6240 - 1{,}01)]^2$$
$$g = 2694{,}06242$$

$$h = 0.31 - 0.00032\,[C_{11}(P_S - P_{atm}) - 40]^2$$
$$h = 0.31 - 0.00032\,[0{,}00145(62 - 1{,}01) - 40]^2$$
$$h = \text{-}0{,}2$$

A. SMALL RELEASE HOLE SIZE AREA

$$CA_{inj,1}^{CONT} = 0.2 \cdot C_8 \cdot g(C_4 \cdot rate_1)^h$$
$$CA_{inj,1}^{CONT} = 0.2 \cdot 0{,}0929 \cdot 2694{,}6092(2{,}205 \cdot 7301{,}75)^{-0,2}$$
$$CA_{inj,1}^{CONT} = 112{,}1481 \quad m^2$$

B. MEDIUM RELEASE HOLE SIZE AREA

$$CA_{inj,2}^{CONT} = 0.2 \cdot C_8 \cdot g(C_4 \cdot rate_2)^h$$
$$CA_{inj,2}^{CONT} = 0.2 \cdot 0{,}0929 \cdot 2694{,}6092(2{,}205 \cdot 116827{,}96)^{-0,2}$$
$$CA_{inj,2}^{CONT} = 64 \quad m^2$$

C. LARGE RELEASE HOLE SIZE AREA

$$CA_{inj,3}^{CONT} = 0.2 \cdot C_8 \cdot g(C_4 \cdot rate_3)^h$$
$$CA_{inj,3}^{CONT} = 0.2 \cdot 0{,}0929 \cdot 2694{,}6092(2{,}205 \cdot 1869247{,}38)^{-0,2}$$
$$CA_{inj,3}^{CONT} = 64 \quad m^2$$

D. RUPTURE RELEASE HOLE SIZE AREA

Because it instataneous release so,

$$CA_{inj,n}^{INST} = 0 \quad m^2$$

Step 10.2 For each release hole size, calculate the instantaneous/continuous blending factor .
For acids or caustics, $fact_n^{IC} = 0$

Because its acid, so : $fact_n^{IC} = 0$ (4.53)

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 (4.55) 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) :

$CA_{cmd,n}^{leak} = 0 \text{ m}^2$ (4.54)

$CA_{inj,n}^{leak} = CA_{inj,n}^{INST} . fact_n^{IC} + CA_{inj,n}^{CONT} . (1 - fact_n^{IC})$ (4.55)

$fact_1^{IC} = 0$
$fact_2^{IC} = 0$
$fact_3^{IC} = 0$
$fact_4^{IC} = 0$

A). SMALL RELEASE HOLE SIZE AREA

$CA_{inj,1}^{leak} = CA_{inj,1}^{INST} . fact_1^{IC} + CA_{inj,1}^{CONT} . (1 - fact_1^{IC})$

$= 112,148096 \text{ m}^2$

B). MEDIUM RELEASE HOLE SIZE AREA

$CA_{inj,2}^{leak} = CA_{inj,2}^{INST} . fact_2^{IC} + CA_{inj,2}^{CONT} . (1 - fact_2^{IC})$

$= 64,4614851 \text{ m}^2$

C). LARGE RELEASE HOLE SIZE AREA

$CA_{inj,3}^{leak} = CA_{inj,3}^{INST} . fact_3^{IC} + CA_{inj,3}^{CONT} . (1 - fact_3^{IC})$

$= 64,4614851 \text{ m}^2$

D). RUPTURE RELEASE HOLE SIZE AREA

$CA_{inj,4}^{leak} = CA_{inj,4}^{INST} . fact_4^{IC} + CA_{inj,4}^{CONT} . (1 - fact_4^{IC})$

$= 0 \text{ m}^2$

Step 10.4 Determine the final non-flammable, non toxic consequence areas for personnil injury, CA_{inj}^{nfnt} using equation (4.57) 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 :

$$CA_{cmd,n}^{lnfnt} = 0 \text{ m}^2 \tag{4.56}$$

$$CA_{inj}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{inj,n}^{leak}}{gff_{total}} \right) \tag{4.57}$$

$$CA_{inj}^{nfnt} = \left(\frac{(gff_1 \cdot CA_{inj,1}^{leak}) + (gff_2 \cdot CA_{inj,2}^{leak}) + (gff_3 \cdot CA_{inj,3}^{leak}) + (gff_4 \cdot CA_{inj,4}^{leak})}{gff_{total}} \right)$$

$$= 75{,}66 \text{ m}^2$$

Table 4.19 Suggested Component Generic Failure Frequency

Equipment Type	Component Type	gff as a function of hole size (failure/yr)				gff total (failure/yr)
		Small	Medium	Large	Rupture	
Vessel/ FinFan	KODRUM	8,0E-06	2,00E-05	2,0E-06	6,00E-07	3,06E-05
	COLBTM					
	FINFAN					
	FILTER					
	DRUM					
	REACTOR					
	COLTOP					
	COLMID					

SUMMARY:

1. In this case, the operating temperature is approximately 120^{o}F. So, that is why, it NO need to be consider although there is no consequence of steam leaks. Then the is 5,85 which is PH < 7, so it consider to be acid consequence.

2. Calculating the blending factor ($fact^{IC}$) both for continuous and instantaneous release type. The $fact^{IC}$ has been determined by using previous STEPs

3. Calculate the consequence area of non-flammable non-toxic content both for continuous and instantaneous release type. When calculating the continuous release type, the parameter is commonly using release rate ($Rate^{toxic}$), otherwise, when conductinng the instantaneous release the value is 0 for acid.

4. Calculating the final non-flammable non-toxic consequennce area by combining the value between generic failure frequency with the non-flammable non-toxic consequence area for each release hole size.

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, $CAcmd^{flam}$.

$$CA_{cmd} = CA_{cmd}^{flam} \quad (4.58)$$

$= 1{,}3653 \text{ m}^2$

Step 11.2 Calculate the final personnel injury consequence area, CA_{inj}

$$CA_{inj} = \max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right] \quad (4.59)$$

$CA_{inj}^{flam} = 9{,}5131 \text{ m}^2$

$CA_{inj}^{tox} = 22{,}2780 \text{ m}^2$

$CA_{inj}^{nfnt} = 75{,}6646 \text{ m}^2$

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

$= 75{,}6646 \text{ m}^2$

Step 11.3 Calculate the final consequence area, CA, using equation (4.60):

$$CA = \max\left[CA_{cmd}, CA_{inj}\right] \quad (4.60)$$

$= 75{,}6646 \text{ m}^2$

$= 814{,}4472 \text{ ft}^2$

SUMMARY:

1. Calculating the final consequence area for component damage. As reminder the the toxic consequence area and non-flammable non-toxic consequence area do not have any affect to the component damage. So, the final consequence area for the component damage is equal to the component damage of flammabe and explosive consequence area.
2. The final personnel injury consequence area is the maximum value from the consequence area of flammable, toxic, and non-flammable non-toxic consequence area.
3. The final consequence area is the maximum value of consequence area for the component damage and personnel innjury

PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

DOC. NO. 05

DETERMINING THE RISK

Rev	Date	Remark	Prepared by		Approved by	
			Name	Sign	Name	Sign
			Ni Luh Triska Adelia		Ir. Dwi Priyanta, M.SE	
					Nurhadi Siswantoro, S.T., M.T	

1 Last Inspection Date

Last known ispection date is June 1th 2014.

2 RBI Date

RBI date is the date when the Risk-Based Inspection is conducted. In this case, the RBI date is set on default date January 1st 2020.

$$R_{RBI} = POF_{RBI}\ x\ COF_{RBI}$$

	POF	COF (m2)	RISK
Shell	1,04607,E-04	7,56646,E+01	7,91502,E-03
Head	1,04607,E-04	7,56646,E+01	7,91502,E-03

3 Plan Date

Based on API 510 standard internal inspections shall be performed at least every 10 years or one-half remaining corrosion rate life, whichever is less. So, the plan date is 10 years after the last inspection.

Plan Date = 10 years

$$R_{PD} = POF_{PD}\ x\ COF_{PD}$$

	POF	COF (m2)	RISK
Shell	1,86953,E-04	7,56646,E+01	1,41457,E-02
Head	1,86953,E-04	7,56646,E+01	1,41458,E-02

PERENCANAAN INSPEKSI PADA PRODUCTION SEPARATOR DENGAN METODE RISK BASED INSPECTION API 581

DOC. NO. 06

INSPECTION PLANNING

Rev	Date	Remark	Prepared by		Approved by	
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Risk Plotting

	Date	Time since last inspection	Risk (m^2/year)
RBI date	01/01/2020	6	0,00791502
Target date		x	3,71
Plan date	01/01/2024	10	0,01414574

Interpolation

X_1	=	6	Y_1	=	0,01
X	=	x	Y	=	3,7100
X_2	=	10	Y_2	=	0,01

$$X = X_1 + \left(\frac{Y - Y_1}{Y_2 - Y_1}\right)(X_2 - X_1)$$

$$X = 2 + \left(\frac{3{,}71 - 0{,}007}{0{,}01 - 0{,}007}\right)(10 - 6)$$

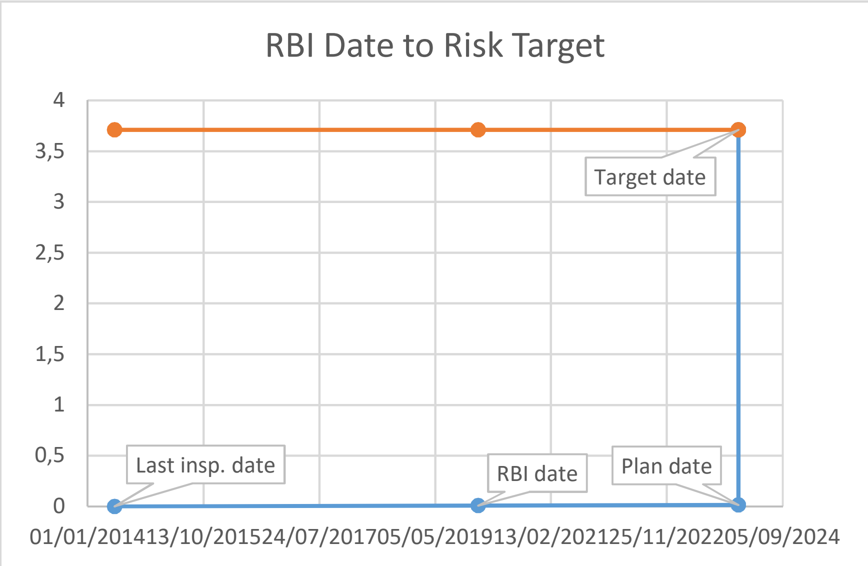
= 2382,7 Year

Because the equipment Risk at the Plan Date does not exceed the Risk Target, the target date is very far from the estimate. In this case, the inspection due date for inspection scheduling purposes may be set to the plan date so that re-analysis of risk will be performed by the end of the plan period. So that the target date for the production separator is on January 1, 2024, coinciding with the plan date that is in accordance with API 510 recommendation, which is 10 years after the last inspection.

So, time to risk target is on 01/01/2024

	Time	Risk (m^2/year)	Risk target (m^2/year)
Last inspection date	01/06/2014	0	3,7
RBI date	01/01/2020	0,00791502	3,7
Plan date	01/01/2024	0,01414574	3,7
Target date	01/01/2024	3,71	3,7

Graphic 6.1 RBI Date to Risk Target



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1 VESSEL SPECIFICATION

Tag Number = ABC-V-0007
Dimension (mm) = 2591 ID x 6706 T-T
Material = SA 516 Gr. 70
Min. Wall Thickness Design (mm)= 72,058
Fluid Handle = C1 - C2
Operating Pressure (psi) = 905
Operating Temperature (^{O}F) = 120

B. RBI SUMMARY

Determine the probability and consequence category based on table 6.1.

Table 6.1 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 (m2)
1	Pf(t,Ie) ≤ 3,06E-05	Df total ≤ 1	A	CA ≤ 9,29
2	3,06E-05 < Pf(t,Ie) ≤ 3,06E-04	1 < Df total ≤ 10	B	9,29 < CA ≤ 92,9
3	3,06E-04 < Pf(t,Ie) ≤ 3,06E-03	10 < Df total ≤ 100	C	92,9 < CA ≤ 929
4	3,06E-03 < Pf(t,Ie) ≤ 3,06E-02	100 < Df total ≤ 1000	D	929 < CA ≤ 9290
5	Pf(t,Ie) > 3,06E-02	Df total > 1000	E	CA > 9290

RBI Date

a. Probability Assessment

Total Damage Factor of Shell = 3,418516705
Probability of Shell = 1,0460661,E-04
Probability Category = 2
Total Damage Factor of Head = 3,418518605
Probability of Head = 1,0460667,E-04
Probability Category = 2
Active Damage Mechanism = Thinning Damage Factor, Component Lining Damage Factor, SCC Sulfide, SCC HIC/SOHIC, External Corrosion Damage Factor

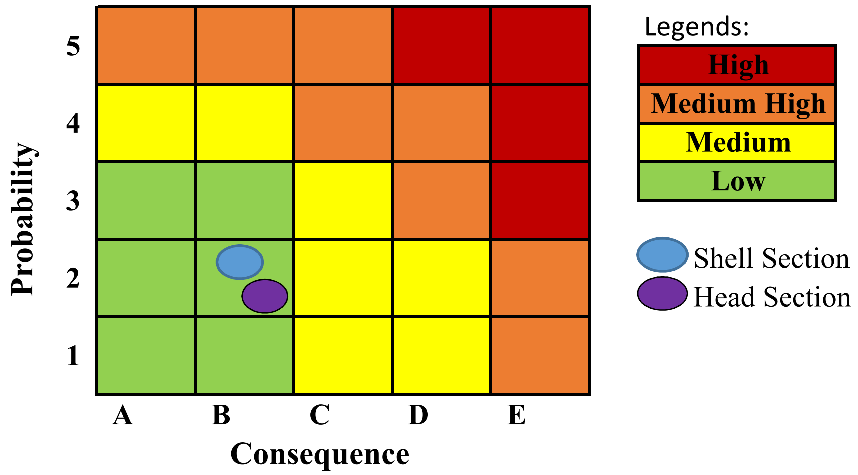
b. Consequence Assessment

Fluid Representative = C1 - C2
Fluid Phase = Gas

Consequence Area (m^2) = 75,664622
Consequence Category = B

c. Risk Ranking

Probability Category Shell = 2
Probability Category Head 2
Consequence Category = B
Risk Ranking Shell = Low
Risk Ranking Head = Low
Area Risk (m^2/year) = 0,00791502
Risk Category = Acceptable



Plan Date

a. Probability Assessment

Total Damage Factor Shell = 6,109580274
Probability = 1,8695316,E-04
Probability Category = 2
Total Damage Factor Head = 6,109587501
Probability = 1,8695338,E-04
Probability Category = 2
Active Damage Mechanism = Thinning Damage Factor, Component Lining Damage Factor, SCC Sulfide, SCC HIC/SOHIC, External Corrosion Damage Factor

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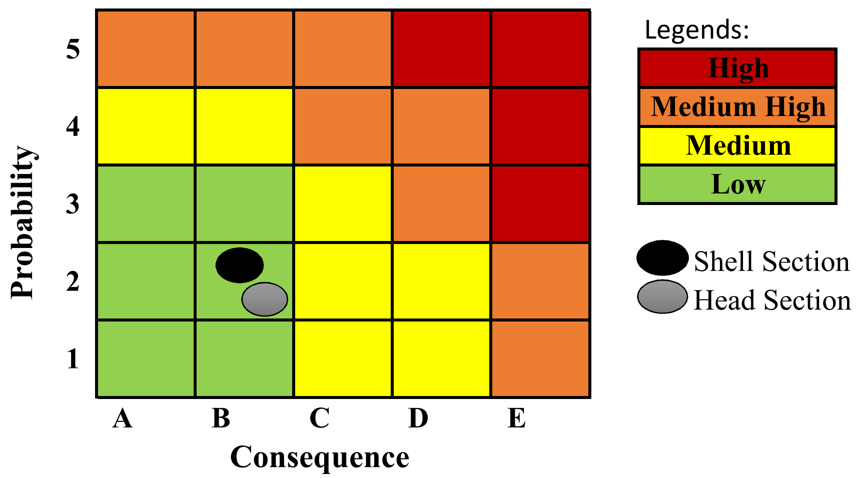
b. Consequence Assessment

Fluid Representative	= C1 - C2
Fluid Phase	= Gas
Consequence Area (m^2)	= 75,664622
Consequence Category	= B

c. Risk Ranking

Probability Category Shell	= 2
Probability Category Head	2
Consequence Category	= B
Risk Ranking Shell	= Low
Risk Ranking Head	Low
Area Risk (m^2/year)	= 1,4145740E-02
Risk Category	= Acceptable



d. Recommendation

Based on the screening tool in Attachment 2, there are some damage factor that can be occur on the Production Separator. Damage Factor(s) provides the screening tool to determine inspection priorities and optimize inspection. The following are the inspection plannings for each damage factor.

1) Local Thinning and Component Lining Damage Factor

Inspection Planning Category of Local Thinning Damage Factor

Based on Annex 2.C Part 2 API RP 581, the recommendation of inspection planning category for local thinning damage factor is as written in the following table.

Damage Factor	Effectiveness	Description		Due Date	
				Shell	Head
Local Thinning Damage Factor	C	For the total suspect area:		01/01/2024	01/01/2024
		1	**>50%** coverage of the CML's using ultrasonic scanning or profile		

Inspection Planning Category of Component Lining Damage Factor

Based on Annex 2.C Part 2 API RP 581, the recommendation of inspection planning category for local thinning damage factor is as written in the following table.

Damage Factor	Effectiveness	Description		Due Date	
				Shell	Head
Linning Damage Factor	C	For the total surface area:		01/01/2024	01/01/2024
		1	**>65%** automated or manual ultrasonic scanning.		

Inspection Planning Methods of Local Thinning and Component Lining Damage Factor

The following are the recommendation of inspection planning methods for local thinning damage factor based on API 571 and ASME Section V Code.

a) Visual Testing (VT) Inspection

Visual testing, often abbreviated as VT, is an optical or visual non-destructive material testing. Visual inspection can be used for internal and external surface inspection of a variety of equipment types, including storage tanks, pressure vessels, piping, and other equipment. There are some types of visual testing, such as:

- Direct Visual Examination
  Direct visual examination may usually be made when access is sufficient to place the eye within 24 in. (600 mm) of the surface to be examined and at an angle not less than 30 deg to the surface to be examined.
- Remote Visual Examination
  Remote visual examination may use visual aids such as mirrors, telescopes, borescopes, fiber optics, cameras, or other suitable instruments. Such systems shall have a resolution capability at least equivalent to that obtainable by direct visual
- Translucent Visual Examination
  Translucent visual examination is a supplement of direct visual examination. The method of translucent visual examination uses the aid of artificial lighting, which can be contained in an illuminator that produces directional

b) Ultrasonic Test (UT) Inspection
Ultrasonic testing (UT) is a non-destructive test method that utilizes high frequency sound waves to detect cracks and defects in parts and materials. It can also be used to determine a material's thickness, such as measuring the wall thickness of a pipe. There are some types of ultrasonic testing, such as:

- Automated Ultrasonic Backscatter Technique (AUBT)
  Advanced Ultrasonic Backscatter Technique (AUBT) is a UT technique developed for detecting damage from High-Temperature Hydrogen Attack (HTHA). The technique is for use in pressure vessels and piping. The technique makes use of high frequency, broadband UT probes and a digital oscilloscope. These allow it to provide both an A-Scan display and frequency analysis.
- Phased Array Ultrasonic Testing (PAUT)
  Phased Array Ultrasonic Testing (PAUT) is a UT technique that utilizes a set of UT probes made up of numerous (anywhere from 16 to over 250) small elements. Each of the elements in a PAUT system is able to pulse individually. This is done with computer calculated timing, through a process known as phasing. This allows the system to steer focused beam through various angles and focal distances.

- Long Range Ultrasonic Testing (LRUT)
  Long Range Ultrasonic Testing (LRUT) is a UT method developed to allow for testing large volumes of material from a single test point. This method works by fixing transducer rings uniformly around a pipe. These rings then generate a series of low frequency guided waves. The waves can then propagate symmetrically along the pipe axis. This provides complete coverage of the pipe wall.
- Internal Rotating Inspection Systems (IRIS)
  An Internal Rotating Inspection System (IRIS) is an ultrasonic technique used to detect corrosion in piping and tubing. using an internally inserted probe that generates sound waves. The system works by inserting a probe into a flooded pipe. The probe them move through the pipe, scanning as it goes.
- Time of Flight Diffraction (TOFD)
  Time of Flight Diffraction (TOFD) is a method used to look for flaws in welds. It uses the time of flight of an ultrasonic pulse to find the location of a reflector. To find the TOF, the method uses a pair of ultrasonic transducers. The transmitter emits low frequency waves that propagate at an angle. They only diffract back to the receiver if they hit a defect.
- Dry-Coupled Ultrasonic Testing (DCUT)
  Dry-Coupled Ultrasonic Testing (DCUT) is an alternative, low-cost method that does not require a liquid couplant to inspect metallic and nonmetallic material. Additionally, DCUT transducers are capable of withstanding high voltages. DCUT is a versatile method that can be performed using flexible, contact, wheel, or remote transducers.
  - Flexible transducers can be applied on an external or internal surface of a component to detect flaws.
  - Contact transducers are also used to detect flaws as well as thickness measurements.
  - Wheel transducers allow inspectors to inspect long piping systems in a short amount of time.
  - Remote transducers are advantageous because they can take thickness measurements at non-conventional angles (i.e., at angles that are not 90° to the surface). This eliminates the need to build supports or remove components in order to perform inspection.

- Rapid Ultrasonic Gridding (RUG)
  Rapid Ultrasonic Gridding (RUG) is an NDE method of performing ultrasonic thickness in which multiple ultrasonic thickness probes are utilized, simultaneously, to rapidly gather thickness measurements in a predefined or ad hoc space. Like other UT methods, RUG captures raw A-Scan data, which can be presented in B-Scan or C-Scan modes — or used to create visual representation as 3-D models. However, RUG is capable of capturing multiple A-Scan data points at a much faster rate than traditional thickness measuring techniques.

2) Stress Corrosion Cracking (SCC)

Inspection Planning Category of SCC- Sulfide Stress Cracking

Based on Annex 2.C Part 2 API RP 581, the recommendation of inspection planning category for local thinning damage factor is as written in the following table.

Damage Factor	Effectiveness	Description		Due Date	
				Shell	Head
Sulfide Stress Cracking	C	For selected welds / weld		01/01/2024	01/01/2024
		1	**>35%** automated or manual ultrasonic scanning		
		OR			
		2	**>35%** radiographic testing.		

Inspection Planning Category SCC- HIC/SOHIC-H2S Stress Cracking

Based on Annex 2.C Part 2 API RP 581, the recommendation of inspection planning category for local thinning damage factor is as written in the following table.

<table>
<tr><th rowspan="2">Damage Factor</th><th rowspan="2">Effectiveness</th><th rowspan="2" colspan="2">Description</th><th colspan="2">Due Date</th></tr>
<tr><th>Shell</th><th>Head</th></tr>
<tr><td rowspan="4">HIC/SOHIC – H2S Stress Cracking</td><td rowspan="4">C</td><td colspan="2">For the total surface area:</td><td rowspan="4">01/01/2024</td><td rowspan="4">01/01/2024</td></tr>
<tr><td>1</td><td>>5% C scan of the base metal using advanced UT</td></tr>
<tr><td colspan="2">AND</td></tr>
<tr><td>2</td><td>HIC: One 0.5-ft2 area, C scan of the base metal using advanced UT on each plate and the heads.</td></tr>
</table>

Inspection Planning Methods of Stress Corrosion Cracking (SCC)

The following are the recommendation of inspection planning methods for local thinning damage factor based on API 571.

a) Inspection for wet H2S damage generally focuses on weld seams and nozzles. Although cracks may be seen visually, crack detection is best performed with,

- Wet Fluorescent Magnetic Test (WFMT)

  Wet suspension magnetic particle inspection, more commonly known as wet magnetic particle inspection, involves applying the particles while they are suspended in a liquid carrier. Wet magnetic particle inspection is most commonly performed using a stationary, wet, horizontal inspection unit but suspensions are also available in spray cans for use with an electromagnetic yoke.

- Edy Current (EC)

  In general, eddy current inspections are a method of non-destructive testing that use the principle of electromagnetic induction. When alternating current is applied to a conductor, in the case of an eddy current probe, a magnetic field develops around it which changes in intensity as the current alternates. If another conductor, in this case the material being tested, is brought close to the first field, a current will be induced in it as well. If there are any flaws in this material then the eddy current emanating from it will be distorted.

- Radiography Test (RT) Inspection
  Radiographic Testing (RT) is a nondestructive examination (NDE) technique that involves the use of either x-rays or gamma rays to view the internal structure of a component. In the petrochemical industry, RT is often used to inspect machinery, such as pressure vessels and valves, to detect for flaws. There are some types of radiography testing, such as:
  - Conventional or Film Radiography
    Conventional radiography uses a sensitive film which reacts to the emitted radiation to capture an image of the part being tested. This image can then be examined for evidence of damage or flaws. The biggest limitation to this technique is that films can only be used once and they take a long time to process and interpret.
  - Digital Radiography
    Digital radiography uses a digital detector to display radiographic images on a computer screen almost instantaneously. It allows for a much shorter exposure time so that the images can be interpreted more quickly. With the ability to capture highly quality images, the technology can be utilized to identify flaws in a material, foreign objects in a system, examine weld repairs, and inspect for corrosion under insulation. The four most commonly utilized digital radiography techniques in the oil & gas and chemical processing industries such as:
    - Computed Tomography (CT)
      Computed tomography (CT) is a technique that takes hundreds to thousands (depending on the size of the component) of 2D radiography scans and superimposes them to create a 3D radiographic image.

      In an industrial setting, CT can be achieved in two ways. In one method, the component to be inspected remains stationary while the radiation source and x-ray detector rotate around the component. This technique is more likely to be utilized for large components. The second method consists of the radiation source and x-ray detector remaining stationary while the component is rotated 360 degrees. This second technique is more useful when the component is small or has complex geometry.

- Real Time Radiography (RTR)
  RTR works by emitting radiation through an object. These rays then interact with either a special phosphor screen or flat panel detector containing micro-electronic sensors. The interaction between the panel and the radiation creates a digital image that can be viewed and analyzed in real time.
- Computed Radiography (CR)
  Computed radiography (CR) uses a phosphor imaging plate that replaces film in conventional radiography techniques. This technique is much quicker than film radiography but slower than direct radiography. CR requires several extra steps compared to direct radiography. First, it indirectly captures the image of a component on a phosphor plate, then converts the image into a digital signal that can be visualized on a computer monitor.
- Direct Radiography (DR)
  Direct Radiography (DR) is also a form of digital radiography and very similar to computed radiography. The key difference lies in how the image is captured. In DR, a flat panel detector is used to directly capture an image and display that image on a computer screen. Although this technique is fast and produce higher quality images, it is more costly than computed

- Alternating Current Field Measurement (ACFM)
  Alternating Current Field Measurement uses electromagnetic fields to identify and size cracks (length and depth). This non-destructive non-contact examination method uses a uniform electric current which is induced into the material under test; the magnetic field generated is

b) UT techniques including external SWUT can be used. SWUT is especially useful for volumetric inspection and crack sizing. Electrical resistance instruments are not effective for measuring crack depth.

- Shear Wave Ultrasonic Testing (SWUT)
  SWUT utilize digital ultrasonic instruments to detect, size, and map out flaws in various welded components. Shear wave testing, or angle beam inspection, is most useful in weld inspections. A probe consisting of an ultrasonic transducer sends an ultrasonic beam at an angle into the test area. As the probe is moved, it detects flaws in a weld based on the refraction of the ultrasonic beam.

c) Acoustic emission testing (AET) can be used for monitoring crack growth. Acoustic Emission Testing (AET) is a nondestructive testing (NDT) method that is based on the generation of waves produced by a sudden redistribution of stress in a material. When a piece of equipment is subjected to an external stimulus, such as a change in pressure, load, or temperature, this triggers the release of energy in the form of stress waves, which propagate to the surface and are recorded by sensors. Acoustic emissions can come from natural sources, such as earthquakes or rockbursts, or from the equipment itself such as melting, twinning, and phase transformations in metals. Detection and analysis of AE signals can provide information on the origin and importance of discontinuities in a material.

3) External Corrosion Damage Factor

Inspection Planning Category

Based on Annex 2.C Part 2 API RP 581, the recommendation of inspection planning category for local thinning damage factor is as written in the following table.

Damage Factor	Effectiveness	Description	Due Date	
			Shell	Head
External Corrosion Damage Factor	C	Visual inspection of **>30%** of the exposed surface area with follow-up by UT, RT or pit gauge as required.	01/01/2024	01/01/2024

Inspection Planning Methods

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