TUGAS AKHIR
(KS 1702)

IDENTIFIKASI KERUSAKAN SECONDARY SUPERHEATER UNIT IV PLTU GRESIK

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JURUSAN TEKNIK SISTEM PERKAPALAN
FAKULTAS TEKNOLOGI KELAUTAN
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SURABAYA
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IDENTIFIKASI KERUSAKAN SECONDARY SUPERHEATER UNIT IV PLTU GRESIK

TUGAS AKHIR

Diajukan Guna Memenuhi Salah Satu Syarat
Untuk Memperoleh Gelar Sarjana Teknik
Pada
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Mengetahui / Menyetujui

Dosen Pembimbing I	Dosen Pembimbing II
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YA Allah....

Ampunilah aku dan kedua orang tuaku

Sayangilah mereka...

Sebagaimana mereka menyayangiku di waktu kecil

Sak kathahipun atur mboten cekap

makili raos pangabekti kawulo.

Bapak... Ibu... Matur Sembah Nuwun...

ABSTRAK

Di dalam pengoperasiannya, boiler kadang mengalami berbagai masalah, ini dimungkinkan sekali karena boiler bekerja pada temperatur dan tekanan yang tinggi. Misalnya yang terjadi di Unit Pembangkit IV PLTU Gresik yang mengalami kerusakan boiler berupa retak bahkan pecahnya secondary superheater. Untuk memprediksi penyebab kegagalan dari secondary superheater digunakan analisa keandalan menggunakan analisa kualitatif dengan metode Fault Tree Analysis (FTA). Sistem yang dianalisa terdiri dari sistem Flow Steam and Water System yang difokuskan pada Boiler feed pump system, Plant Water Supply System, Burner System. Pada akhir analisa dapat disimpulkan bahwa penyebab utama kerusakan secondary superheater Unit IV PLTU Gresik adalah oleh dua faktor utama yaitu penurunan kekuatan material dan over pressure. Penurunan kekuatan material disebabkan oleh proses penipisan material dan overheating. Gagalnya komponen Steam pressure control, Dearator dan Bocornya Condenser serta tidak adanya fungsi inhibitor skid bahan bakar adalah penyebab kerusakan yang paling kritis.

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I.1. Latar Belakang

Boiler merupakan bagian yang penting dari suatu sistem *steam power plant*, karena *boiler* adalah penghasil uap bertekanan yang digunakan untuk menggerakkan turbin, sehingga daya dapat dihasilkan untuk berbagai keperluan, diantaranya sebagai pembangkit daya pada sistem *power plant*, pemilihan *steam power plant* sebagai pembangkit daya karena sistem tenaga uap mampu menghasilkan daya yang relatif besar.

Di dalam pengoperasiannya, *boiler* kadang mengalami berbagai masalah, ini dimungkinkan sekali karena *boiler* bekerja pada temperatur dan tekanan yang tinggi. Misalnya yang terjadi di Unit Pembangkit IV PLTU Gresik yang mengalami kerusakan *boiler* berupa retak bahkan pecahnya *secondary superheater*.

Kerusakan terhadap suatu sistem yang lebih kecil akan mempengaruhi kinerja dari sistem lain yang lebih besar atau dengan kata lain kinerja tiap subsistem akan mempengaruhi kerja sistem. Untuk mengetahui keandalan suatu sistem dan penyebab kegagalan suatu komponen pada sistem *power plant* tersebut maka dibutuhkan suatu analisa keandalan (*Reliability Analysis*).

Kemampuan *power plant* untuk melaksanakan fungsinya dengan baik amatlah diperlukan karena semakin besar keandalan dari *power plant* akan semakin besar pula kemampuannya untuk menghasilkan atau memasok daya sesuai dengan yang diinginkan. Untuk meningkatkan ketersediaan dari *boiler* dapat dicapai dengan meningkatkan *MTTF (main time to failure)* dan mempersingkat *MTTR*

(main time to repair) dengan cara mengoperasikan *boiler* sesuai dengan petunjuk pengoperasian dan dalam perawatannya hendaknya dilakukan sesuai dengan petunjuk dari *manual book*.

Data-data perawatan *boiler* tercatat di bagian Unit Bisnis dan Pemeliharaan PJB Gresik. Data perawatan tersebut menjadi acuan bagi PT PJB Gresik untuk kebijaksanaan perawatan berikutnya. Sedangkan data diagram sistem dan data spesifikasi tercatat pada *manual book* dan prosedur operasi *boiler*.

Dalam pelaksanaan operasi dilapangan Pembangkit Unit IV PLTU Gresik yang berkapasitas 200 MW sering mengalami variasi beban sesuai dengan yang diinginkan. Proses pembangkitan dituntut untuk dapat berjalan dengan sebagai mana mestinya namun kadang-kadang terdapat berbagai masalah yaitu dengan adanya sistem-sistem yang tidak berjalan dengan baik sehingga akan mempengaruhi kinerja seluruh sistem. Pada kasus yang terjadi di Pembangkit Unit IV PLTU Gresik telah terjadi kegagalan pada bagian *superheater* berupa pecah dan bocornya komponen tersebut, ini dapat terjadi dimungkinkan karena faktor waktu operasional, variasi daya yang berpengaruh juga pada variasi kapasitas dan kecepatan fluida serta tekanan dan temperatur, hal tersebut juga dapat dipengaruhi oleh kwalitas *feed water* ataupun dari kualitas *operator boiler*.

Untuk mengetahui penyebab kerusakan dari komponen *secondary superheater* tersebut maka perlu dilakukan identifikasi kerusakan yang terjadi pada *boiler*. Identifikasi tesebut menggunakan metode FTA *(Fault Tree Analysis)*.

Tujuan identifikasi adalah mengidentifikasi kerusakan sistem dengan metode *Fault Tree Analysis* yaitu dengan *Top – down approach* sehingga dapat diketahui komponen penyebab kegagalan, *minimum cut sets* dan juga kekritisan dari masing-masing penyebab kegagalan tersebut sehingga dapat diketahui pada bagian –bagian mana yang perlu diberikan perhatian khusus agar kerusakan yang sama tidak akan terjadi. Identifikasi tersebut diharapkan mampu memberikan rekomendasi teknis guna untuk mengurangi dan mengatasi kegagalan dalam *boiler* sistem sehingga sistem dapat berjalan dengan baik dan lancar.

I.2 PERUMUSAN MASALAH

Untuk memprediksi kegagalan dapat dilakukan dengan analisa keandalan yang dapat dirumuskan dengan permasalahan sebagai berikut :

- Bagaimana mendapatkan data – data yang diperlukan untuk memprediksi penyebab kegagalan.
- Bagaimana menentukan komponen-komponen yang dapat menyebabkan kegagalan sistem.
- Bagaimana menentukan *minimum cut sets.*

I.3 Batasan Masalah

Batasan masalah yang digunakan dalam pembahasan adalah

- Identifikasi yang digunakan adalah dengan Fault Tree Analysis
- Pembahasan difokuskan pada faktor penyebab kegagalan sistem peralatan.

I.4 Tujuan

Tujuan penulisan tugas akhir ini adalah untuk memprediksikan kegagalan sistem dengan menggunakan analisa kualitatif . Analisa keandalan ini digunakan untuk mengidentifikasi :

- Komponen – komponen sistem yang dapat menyebabkan kegagalan .
- *Minimum Cuts sets* sehingga dapat diketahui komponen penyebab yang paling kritis.

I.5 Manfaat Hasil Tugas Akhir

Dengan melakukan analisa keandalan untuk mengetahui penyebab kerusakan maka dapat memberikan manfaat – manfaat yaitu :

- Dapat digunakan sebagai acuan teknis kepada pihak PLTU Gresik khususnya bidang perawatan untuk memberikan perhatian yang khusus pada komponen kritis
- Menjaga agar kerusakan yang sama tidak terjadi kembali.

BAB II
DASAR TEORI

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II.1 Konsep Keandalan

Keandalan didefinisikan sebagai probabilitas dari suatu item untuk dapat melaksanakan fungsi yang telah ditetapkan, pada kondisi pengoperasian tertentu dan dalam lingkungan tertentu untuk peride waktu yang telah ditentukan. Terminologi item yang dipakai dalam definisi keandalan diatas dapat mewakili sembarang komponen, subsistem atau sistem yang dapat dianggap satu kesatuan.

Definisi diatas dapat disarikan menjadi empat komponen pokok yaitu :

- Probabilitas
- Kerja (performance) yang memadai.
- Waktu
- Kondisi pengoperasian

Probabilitas yang merupakan komponen pertama merupakan *input numeric* bagi kajian kendalan suatu sistem. Pada beberapa kajian yang melibatkan beberapa disiplin ilmu probabilitas bukan merupakan satu – satunya indek, ada beberapa indek yang lain yang dapat dipakai untuk menilai keandalan suatu sistem yang sedang dikaji. Tiga komponen lain yaitu kerja, waktu dan kondisi pengoperasian semuanya merupakan parameter – parameter *engineering* dan teori probabilitas tidak banyak membantu dalam untuk kajian *engineering* ini.

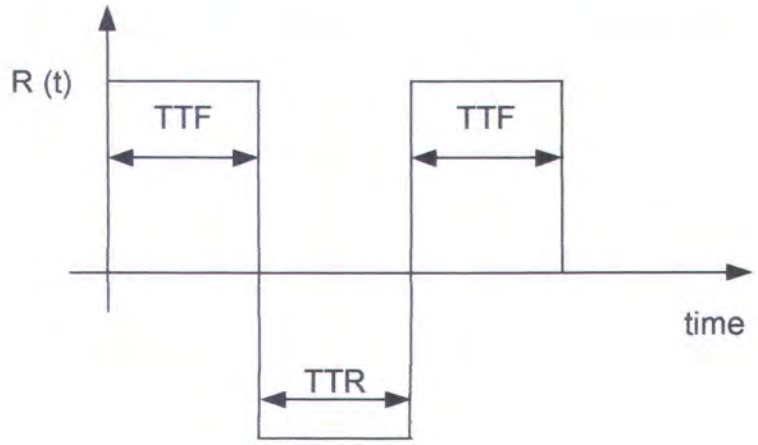
Kriteria tentang kinerja yang memadai dari sebuah sistem merupakan masalah yang melibatkan masalah manajerial. Kegagalan dari suatu sistem dapat

didefinisikan secara beragam mulai dari kegagalan katrotospik atau gangguan terhadap fungsi suatu sistem. Waktu yang telah ditetapkan untuk pengoperasian sistem bisa secara kontinu maupun sporadic, sedangkan kondisi pengoperasian bisa secara *uniform* atau variabel.

Ada suatu nilai atau parameter yang akan diukur di dalam pengolahan data. Agar teori probabilitas dapat diterapkan maka kejadian atau nilai – nilai tersebut harusalah random terhadap waktu. Parameter kejadian yang akan diukur yaitu misalnya laju kegagalan komponen, lama waktu untuk mereparasi, kekuatan mekanis komponen, variable yang bervariasi secara random terhadap waktu dan atau ruang. Variable random ini dapat didefinisikan secara diskrit maupun secara kontinyu.

Konsep waktu dalam hal ini adalah *Time to Failure (TTF)* dan *Time to Repair (TTR).* TTF didefinisikan sebagai waktu yang dilalui komponen saat mulai beroperasi sampai mengalami kegagalan. TTR adalah waktu perbaikan yang diperlukan oleh komponen agar dapat berfungsi kembali.

Model kegagalan diperoleh dari TTF dan TTR komponen yang dianalisa. TTF dan TTR komponen mengikuti beberapa distribusi kegagalan yang kita kenal seperti distribusi exponensial, poison, weibull, normal, dan sebagainya. Gambar 2.1 dibawah ini menunjukan hubungan antara TTF dan TTR.



Gambar II.1.1
Waktu Kegagalan
Komponen

Ketersedian *(availability)* adalah probabilitas system/peralatan/komponen untuk berdaya guna pada waktu t . Dalam beberapa situasi, ketersediaan system lebih penting dibandingkan dengan keandalan itu sendiri. Ketersedian di simbolkan dengan A(t). Dengan kata lain ketersedian adalah rasio antara sejumlah waktu bekerja sistem *(up – time)* dengan total waktu *(down – time)*.

$$A(t) = \frac{MTBF}{MTBF + MTTR} \quad \text{.....(II.1.1)}$$

Dari formula di atas, secara implisit menyatakan bahwa tingginya ketersediaan dapat dicapai dengan menaikan MTBF. Dalam hal ini keandalan atau melakukan improvisasai pada kemampurawatan dengan menurunkan MTTR. MTBF adalah nilai waktu rata – rata antara kegagalan berurut sebagai ratio antara waktu observasi komulatif dengan jumlah kegagalan dalam kondisi tertentu.

II.2 Analisa Kualitatif

Salah satu metode untuk mengetahui keandalan suatu sistem adalah dengan melakukan analisa kualitatif sebuah sistem tersebut dapat dilakukan beberapa pendekatan untuk mengilustrasikan bagaimana sistem tersebut bekerja dan kemungkinan sistem tersebut mengalami kegagalan.

Analisa kualitatif sering digunakan untuk menganalisa keandalan suatu sistem berdasarkan analisa kegagalan komponen atau sistem. Analisa kualitatif merupakan analisa alternatif jika situasi tertentu data yang diperlukan untuk analisa kuantitatif tidak memadai ataupun mungkin tidak ada, sehingga kita dapat melakukan penilaian keandalan berdasarkan data kualitatif serta pengalaman yang sudah ada. Dalam analisa kualitatif untuk menganalisa keandalan suatu sistem dengan menggunakan metode FMEA (*Failure Mode and Effect Analysis*) dan FTA (*Fault Tree Analysis*).

II.2.1 Fault Tree Analysis (FTA)

FTA *(Fault Tree Analysis)* lebih menekankan pada ***"top – down approach"*** yaitu karena analisa ini barawal dari system *top level* dan meneruskannya ke bawah. Titik awal analisa ini adalah pengidentifikasian *mode* kegagalan pada *top level* suatu sistem.

FTA adalah teknik yang banyak digunakan untuk studi yang berkaitan dengan resiko dan keandalan dari suatu sistem *engineering*. Event potensial yang dapat menyebabkan kegagalan suatu sistem *engineering* dan probabilitas terjadinya eventtersebut dapat ditentukan dengan FTA. Sebuah *Top Event* yang

merupakan definisi kegagalan suatu sistem,harus ditentukan terlebih dahulu dalam mengkonstruksi FTA. Sistem kemudian dianalisa untuk menemukan semua kemungkinan yang telah didefinisikan oleh *Top Event*. *Fault Tree* adalah pemodelan grafis yang terdiri dari beberapa kombinasi kesalahan (*Fault*) secara parallel dan secara berurutan yang mungkin menyebabkan awal dari f*ailure event* yang sudah ditetapkan.

Setelah mengidentifikasi *Top Event*, *event – event* yang memberi kontribusi secara langsung terjadinya *top event* diidentifikasi dan dihubungkan ke *top event* dengan memakai hubungan logika (*Logical link*) sampai dicapai yang independen dan seragam (*Mutually Independent basic event*).

Sebuah *Fault Tree Analysis* secara umum dilakukan dengan tahapan sebagai berikut :

- Mendefinisikan problem dan kondisi batas dari sistem
- Pengkonstruksian *Fault Tree*
- Mengidentifikasian *Minimal cuts sets* atau *Minimal path set*
- Analisa kualitatif *Fault Tree*
- Analisa kuantitatif *Fault Tree*

II. 2.1.1 Definisi Problem dan Kondisi Batas

Aktifitas pertama dari *Fault Tree analysis* terdiri dari dua *step*, yaitu :

- Mendefinisikan *Critical event* yang akan dianalisa
- Mendefinisikan *boundary condition* untuk analisa

Critical event secara normal disebut *top event*. Penting kiranya bahwa *top event* didefinisikan secara jelas dan tidak kabur (*unambiguous*). Diskripsi *Top event* harus dapat menjawab pertanyaan apa, dimana, kapan.

Agar analisa dapat dilakukan secara konsisten, hal yang penting bahwa kondisi batas harus didefinisikan secara hati – hati. Dari kondisi batas akan diperoleh pengertian – pengertian sebagai berikut :

- Batas fisik sistem

  Bagian mana dari sistem yang akan dianalisa dan bagian mana yang tidak.

- Kondisi awal

  Kondisi pengoperasian yangb bagaimana saat *Top event* terjadi. Apakah pada saaat pengoperasian beban penuh atau sebagian.

- Kondisi batas yang berhubungan dengan stress eksternal

  Apakah tipe *stress* eksternal yangyang harus diikutsertakan dalam analisa.

- Level resolusi

  Seberapa detail kita akan mengidentifikasikan berbagaialasan potensial yang menyebabkan kegagalan.

II.2.1.2 Pengkonstruksian Fault Tree

Pengkonstruksian fault tree selalu bermula dari *Top event*. Oleh Karena itu tiap-tiap *fault event* yang secara langsung, penting dan berbagai penyebab terjadinya *Top event* harus secara teliti diidentifikasi. Berbagai penyebab tersebut

dikoneksikan ke *Top event* oleh gerbang logika. Penting kiranya bahwa penyebab *level* pertama dibawah *Top event* harus disusun secara struktural. Level pertama ini sering disebut dengan *Top structure* dalam *Fault Tree*. *Top structure* ini diambil dari kegagalan modul – modul utama sistem atau fungsi sistem utama. Analisa dilanjutkan level demi level sampai semua *fault event* telah dikembangkan pada batas resolusi tertentu yang telah ditentukan.

Ada beberapa aturan yang harus dipenuhi dalam pengkonstruksian *fault tree*, aturan –aturan tesebut yaitu:

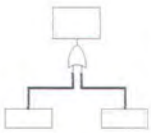
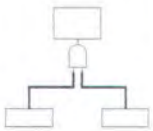
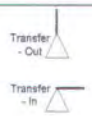
1. Deskripsikan *Fault event*

   Masing – masing fault event harus didefinisikan secara teliti dalam sebuah kotak.

2. Evaluasi *Fault event*

   Kegagalan komponen dikelompokkan dalam tiga kelompok yaitu *Primary failures, Secondary failures* dan *Command fault.*

Tabel II.2.1.2 Simbol fault tree.

Nama Simbol	Simbol	Deskripsi
OR – gate		Kejadian output akan terjadi hanya jika beberapa input terjadi.
AND – gate		Kejadian output akan terjadi hanya jika beberapa input terjadi.
Basic events		Kegagalan sebuah basic equipment yang tidak memerlukan penelitian lebih lanjut dari penyebab kegagalan.
Undeveloped events		Event yang tidak dianalisa lebih jauh karena keterbatasan informasi atau alasan lain.
Coment Retangale		Digunakan untuk informasi tambahan
Transfer Symbols		Simbol transfer out menunjukkan bafaw fault tree dikembangkan lebih jauhdan berkaitan dengan symbol Transfer In

Sebuah normal *basic event* dalam pengkonstrusian *fault tree* merupakan sebuah *primary failures* yang menunjukkan bahwa komponen merupakan penyebab dri kegagalan. *Secondary failure* dan *command fault* merupakan *intermediate event* yang membutuhkan investigasi lebih mendalam untuk mengidentifikasi alasan utama.

3. Melengkapi semua gerbang logika

Semua *input* ke *gate* tertentu harus didefinisikan sebelum melakukan penelaahan *gate* selanjutnya. *Fault tree* harus diselesaikan pada masing – masing *level* sebelum memulai *level* berikutnya.

II. 2.1.3 Pengidentifikasian Minimal Cut Set

Sebuah *fault tree* memberikan keterangan berharga tentang berbagai kombinasi *fault event* yang mengarah pada *critical failures* sistem. Pada *terminology fault tree, cut set* didefinisikan sebagai *basic event* yang apabila terjadi secara simultan akan menyebabkan terjadinya *Top event*. Sebuah *cut sets* dikatakan *minimal cut set* apabila *cut set* tersebut tidak dapat direduksi tanpa menghilangkan statusnya sebagai *cut set.*

Jumlah *basic event* yang berbeda dalam sebuah *minimal cut set* disebut *orde cut set*. Untuk *fault tree* yang sederhana sangat mungkin untuk mendapatkan *cut set* dengan menggunakan prosedur yang tidak formal / Algoritma. Untuk *fault tree* yang komplek maka diperlukan algoritma untuk mendapatkan *cut set*. MOCUS (*Method for Obtaining Cut Set*) merupakan sebuah algoritma yang dapat digunakan untuk menetukan minimal *cut set.*

II.2.1.4 Evaluasi Kualitatif Fault Tree

Evaluasi kualitatif *fault tree* dapat dilakukan berdasarkan minimal *cut set*. Kekritisan dari sebuah *cut set* tergantung pada jumlah *basic events* di dalam *cut sets (orde cut sets)*. Sebuah *cut set* dengan orde satu umumya lebih kritis daripada

sebuah *cut sets* dengan orde dua atau lebih. Jika sebuah *fault tree* memiliki *cut set* dengan orde satu, maka *top events* akan terjadi sesaat setelah *basic events* yang bersangkutan terjadi. Jika *cut sets* memiliki dua *basic event*, kedua *event* ini harus terjadi secara serentak agar *top events* dapat terjadi.

Faktor lain yang penting juga adalah jenis *basic event* dari sebuah *cut set*. Kekritisan dari berbagai *cut set* dapat di rangking berdasarkan dari *basic event* sebagai berikut ;

- *Human error*
- Kegagalan komponen / peralatan yang aktif
- Kegagalan komponen / peralatan yang pasif

Peringkat ini disusun berdasarkan asumsi bahwa human error lebih sering terjadi dari peraltan yang aktif dan peralatan yang aktif lebih rentan daripada peralatan yang pasif.

II.2.1.5 Evaluasi Kuantitatif Fault Tree

Secara umum ada dua macam metode yang digunakan untuk menganlisa kuantitatif yaitu metode dengan pendekatan aljabar Boolean (*Boolean algebra approach*) dan metode perhitungan langsung *(Direct numerical approach)*

II.3 Permasalahan operasional dan penyebab kerusakan Boiler

Keamanan operasional boiler membutuhkan komitmen managerial keselamatan, efisiensi operasional, kekontinuan untuk menjaga operasional tersebut. dan juga membutuhkan manajemen untuk mendukung operator dan

maintenance personel dalam menaggulangi masalah *power plant* ketika masalah tersebut timbul. Banyak peralatan otomatis yang digunakan untuk mengontrol operasional membuat *boiler* semakin mudah untuk dikontrol, lebih aman dan lebih efisien. tetapi dengan semakin komplek perangkat otomatis tersebut apabila terjadi kegagalan *operating engineer* harus dapat menggunakan *manual control* untuk melangsungkan proses operasional.

Pecahnya beberapa komponen dapat terjadi, ini dapat disebabkan oleh beberapa hal sebagai berikut :

- Banyak peralatan operasional otomatis yang diabaikan, dengan hanya menggantungkan peralatan otomatis padahal peralatan otomatis juga mempunyai kemungkinan untuk *fail.*
- Karena otomatisasi *boiler* yang semakin komplek sehingga kerusakan pada peralatan *control* menjadi sumber penyebab kerusakan
- Pemeliharaan *boiler* dan paralatan pembantu yang tidak bagus, termasuk *boiler feed water* pada *water treatment* dan pembersihan.

Pada banyak kasus pecah dan meledaknya *boiler* masalah penyebab terdapat pada masalah *water treatment* dan *overheating.*

Beberapa hal yang dapat ditimbulkan dengan buruknya *water treatment* adalah sebagai berikut :

II.3.1 Scalling

Scalling yang terjadi disebabkan oleh kontak - kotoran pada *water boiler* dengan permukaan panas. Campuran kotoran dapat berupa Kalsium (Ca), Magnesium (Mg) dan Silica (SiO_2). Magnesium atau Kalsium tergabung dengan

Sulfat (SO_4) membentuk Magnesium Sulfat ($MgSO_4$).*Scalling* lebih banyak terjadi pada *watertube boiler* daripada *firetube boiler.*

Mekanisme terbentuknya *scales bicarbonate* terurai menjadi *carbonate scales.*

$Ca(HCO_3)_2$ + Heat = $CaCO_3$ + H_2O + CO_2 (Calcium bicarbonate scales)

$Mg(HCO_3)_2$ + Heat = $MgCO_3$ + H_2O + CO_2 (Magnesium bicarbonatescales)

.....(II.3.1.1)

Scalle mempunyai sifat buruk sebagai penghantar panas sehingga penyerapan panas menjadi tidak merata, sehingga pada sisi yang lainnya dapat terjadi reaksi pada suhu tinggi yang dapat menyebabkan pecahnya boiler. *Scalling* juga dapat menimbulkan penyumbatan pada katup – katup sehingga katup tidak dapat berfungsi secara sempurna karena aliran menjadi terhanbat. *Scalling* dapat diminimalisir dengan penanganan *water treatment* yang bagus.

II.3.2 Korosi

Internal corrosion adalah proses *electrochemical* antara permukaan dengan *water line.* Ukuran asam basa (pH) memberikan ukuran properties korosifitas. Efek kerusakan korosi tergantung dari laju penetrasi, penetrasi pada korosi dengan luasan yang lebar berbeda dengan penetrasi korosi pada area yang lebih kecil. Korosi yang terlokalisir dapat berupa *pitting* atau *grooving. Pitting* disebabkan karena proses yang berulang – ulang pada titik yang sama. *Grooving* terbentuk dengan adanya kombinasi antara korosi yang terlokalisasi dengan konsentrasi stress.

Oksidasi merupakan faktor penyebab korosi pada temperatur tinggi adapun contoh raksi yang sederhana dari oksidasi adalah sebagai berikut :

$$M + \tfrac{1}{2}O_2 \longrightarrow MO$$
$$M \longrightarrow M^{2+} + 2e^- \,(Anodicreaction)$$
$$\tfrac{1}{2}O_2 + 2e^- \longrightarrow O^{2-} \,(Cathodicreaction)$$

.....(II.3.1.2)

Kombinasi korosi suhu tinggi menyebabkan penurunan material ketika bercampur dengan Sulfur, Chlorine, Vanadium dan kontaminan lainnya.

Korosi yang mungkin dapat ditimbulkan dari reaksi Hidrogen klorida pada dinding pipa adalah sebagai berikut :

$$Fe + 2HCl = FeCl_2 + H_2$$
$$FeO + 2HCl = FeCl_2 + H_2O$$
$$Fe_2O_3 + 2HCl + CO = FeO + FeCl_2 + H_2O + CO_2$$

.....(II.3.1.3)

Pada reaksi pembakaran Sulfur dioksida bereaksi dengan oksigen pada temperatur tinggi membentuk Sulfur trioksida

$$SO_2 + [O] = SO_3$$

.....(II.3.1.4)

Ketika flue gas melintasi permuakan konveksi SO_2 dirubah menjadi Sulfur tioksida oleh katalis V_2O_5 dan Fe_2O_5 yang terdapat pada kotoran. Adapun reaksi kimianya sebagai berikut :

$$V_2O_5 + SO_2 = V_2O_4 + SO_3$$
$$2S0_3 + 0_2 + V_2O_4 = 2VOSO_4 \quad \text{.....(II.3.1.5)}$$
$$2VOSO_4 = V_2O_5 + SO_3 + SO_2$$

Jumlah Vanadium dan Sodium yang terdapat pada deposit memiliki peran yang sangat menunjang terjadinya korosi.

Faktor lain yng menjadi permasalahan dalam operasional boiler adalah sebagai berikut :

II.3.3 Erosi

Erosi hampir sama dengan *external corrosion* tetapi erosi murni karena masalah mechanical, erosi terjadi karena penipisan material yang disebabkan oleh kotoran dengan kecepatan tinggi dan berlansung secara lama. Pada *boiler* yang menggunakan batubara sebagai bahan bakar akan menimbulkan kotoran yang banyak dari sisa pembaran dan ini dapat menimbulkan kemungkinan erosi yang tinggi. Erosi dapat dikurangi dengan proses *soot blow* yang berkala sehingga ktoran – kotoran yang ada dapat dihilangkan.

II.3.4 Flame impingement

Flame impingement adalah terjadinya kontak langsung lidah api dengan pipa- pipa pada *watertube boiler*. Apabila pada tube telah terjadi korosi maka kan terjadi menyebabkan konsentrasi pemanasan local yang dapat menyebabkan overheating. *Flame impingement* dapat terjadi karena ketidak sempurnaan kerja burner. Dapat terjadi pula variasi lidah api yang terjadi akibat dari variasi pembebanan.

II.4 Boiler Water Treatment

Tujuan utama dari *Boiler water treatment* adalah untuk menghilangkan masalah yang dapat ditimbulkan dari *scalling*, korosi, *embrittlement* dan hal – hal yang menyangkut masalah kualitas *feedwater*.

Boiler water treatment merupakan proses yang periodik dilakukan, yang memiliki langkah – langkah *pretreatment* pada *raw water*, *treatment* pada *make up water*, *Internal treatment water*, *treatment condensate return to boiler*, *blowdown control* untuk menghilangkan kotoran.

Kebanyakan kotoran terdapat atau terlarut dalam air. Yang akan mengendap dan akan membentuk kerak dan sebagainya. Calsium sulfate dan Calsium Hydroxide adalah contoh kotoran. *Pretreatment* pada *raw water* penting dilakukan karena banyak kotoran yang terkandung di dalam air agar proses *water treatment* selanjutnya lebih ringan.

Deaerator digunakan untuk memisahkan oksigen pada air dengan menggunakan panas. Oksigen dapat terlarut dalam air dan dapat dipisahkan dengan peningkatan temperature. Oksigen yang direduksi sampai 0.005 sentimeter kubik per liter.

Internal treatment digunakan untuk menghindari masalah yang dapat disebabkan karena korosi, scalling dan penurunan material seperti material *embrittlement*. Scalle dapat disebabkan karena adanya Kalsium dan Magnesium. Korosi dapat dihindari dengan pengontrolan pH, kadang- kadang penambahan

Amonia atau *neutralizing amines* disuplai ke air untuk menetralkan karbon dioksida.

Condensate yang kembali ke boiler banyak mengandung kotoran, perlakuan pada uap yang kembali ke *boiler* sangat penting untuk membatasi kotoran yang terkandung di dalamnya.

BAB III
METODOLOGI

BAB III
METODOLOGI

III.1 Umum

Metodologi merupakan suatu kerangka dasar yang digunakan sebagai acuan untuk menyelesaikan permasalahan yang akan dipecahkan atau dianalisa. Metodologi penulisan ini mencakup semua tindakan ataupun langkah – langkah yang akan dilakukan untuk penulisan tugas akhir.

Penulisan Tugas Akhir ini bertujuan untuk memprediksi penyebab kegagalan dari *secondary superheater*. Dalam memprediksi penyebab kegagalan ini digunakan analisa keandalan. Analisa keandalan yang digunakan yaitu analisa kualitatif. Analisa secara kualitatif dalam penganalisaan keandalan sistem menggunakan metode FTA. Tahap – tahap yang digunakan untuk memprediksi penyebab kegagalan *secondary superheater* dapat dilihat pada gambar III.1

III.2 Pengumpulan Data

Dalam melakukan analisa kegagalan dengan analisa keandalan tidak terlepas akan tersedianya data yang akan diolah. Tujuan pengumpulan data yaitu agar kita dapat memprediksi kegagalan sistem *boiler*. Data–data yang diperlukan yaitu data diagram sistem-sistem, komponen penyusun sistem, dan juga riwayat dari komponen sebelum kegagalan terjadi . Data – data tersebut akan digunakan untuk penganalisaan secara kualitatif dengan metode FTA. Data yang didapat berasal dari Unit Bisnis dan Pemeliharaan PT PJB Gresik. Pengumpulan data

diagram sistem diambil dari *manual book boiler*. Data lain yang dikumpulkan adalah data riwayat komponen sebelum terjadinya kerusakan pada tiap – tiap komponen.

III.3 Pengolahan data mentah menjadi data matang

Data yang didapat pada tahap pengumpulan data tidak dapat langsung diolah karena data yang diperoleh masih berupa data mentah sehingga perlu pengolahan untuk menjadi data matang.

Agar nantinya penganalisaan dengan metode FTA dapat dilakukan maka data diagram sistem tersebut perlu dipelajari dan diketahui cara kerjanya dan hal-hal yang dapat menyebabkan kerusakan dari masing-masing komponen.

III.4 Analisa Data

Analisa data dilakukan secara kualitatif, penggunaan metode tersebut mengacu pada pertimbangan bahwa output dari metode tersebut memiliki kaitan yang dapat digunakan sebagai kontribusi untuk mengetahui penyebab kegagalan *secondary superheater*. Penggunaan metode FTA dilakukan untuk mengetahui titik-titik lemah dari sistem yang kemudian mengetahui komponen mana yang dapat menyebabkan kegagalan. Untuk analisa secara kualitatif sebuah sistem tersebut dapat dilakukan beberapa pendekatan untuk mengilustrasikan bagaimana sistem tersebut bekerja dan kemungkinan sistem tersebut mengalami kegagalan.

Penggunaan metode FTA *(Fault Tree Analysis)* bertujuan untuk mengetahui komponen - komponen yang dapat menyebabkan kegagalan pada

secondary superheater. Adapun tahapan-tahapan yang dilakukan dalam analisa FTA adalah sebagai berikut :

- Langkah pertama dalam metode FTA mendefinisikan kegagalan (*top event*) yang diprediksi akan terjadi pada sistem ke tingkat yang lebih rendah (*top down approach*) dari suatu sistem yaitu dengan menelusuri ke komponen – komponen yang diprediksi dapat menyebabkan terjadinya kegagalan pada sistem sehingga akan diketahui titik – titik lemah sistem yang menyebabkan kegagalan *secondary superheater*. Dalam langkah ini juga diikuti penentuan batasan analisa agar dapat terfokus dan konsisten.
- Langkah kedua adalah pengkonsturksian *fault tree*, dari berbagai penyebab kegagalan ini dikoneksikan ke *top event* oleh sebuah gerbang logika.
- Langkah yang ketiga adalah identifikasi *cut set* dan *minimal cut sets*, tahapan ini dapat ilakuakn dengan dengan metode MOCUS *(Method for obtaining cut set)*.

III.5 Hasil Prediksi Kegagalan

Pada tahap ini diambil suatu hasil prediksi kegagalan sistem dari hasil analisa kualitatif. Adapun hasil prediksi kegagalan tersebut adalah komponen – komponen penyebab kegagalan , *Minimal Cuts sets*.

III.6 Kesimpulan dan Rekomendasi.

Pada tahapan ini akan diambil suatu langkah penyimpulan dengan menggunakan acuan rekomendasi dari langkah yang telah dilakukan dalam bab-

bab sebelumnya untuk mengetahui prediksi penyebab kerusakan *secondary superheater* pada Pembangkit Unit IV PLTU Gresik.

Gambar III.1 Diagram penyelesaian Tugas Akhir

BAB IV
HASIL ANALISA

BAB IV
HASIL ANALISA

IV.1 Umum

Suatu *power plant* yang telah beroperasi dalam waktu yang lama mempunyai kemungkinan kegagalan sistem yang lebih besar. Kerusakan atau kegagalan pada suatu komponen atau sistem akan berpengaruh pada sistem yang lebih besar lagi. Akibatnya akan dapat menimbulkan kerusakan *power plant* dan membahayakan kehidupan manusia di sekitar *power plant*.

Seperti yang telah terjadi pada Pembangkit Unit IV PLTU Gresik telah terjadi kerusakan pada *Secondary Superheater* berupa cacat pecah, hal tersebut dapat terjadi berkaitan erat dengan sistem – sistem lain yang bekerja pada *power plant* tersebut. Sehubungan dengan hal tersebut maka perlu dilakukan analisa untuk mencari penyebab kerusakan tersebut.

Sebelum dilakukan analisa kerusakan terlebih dahulu dilakukan pendeskripsian kerusakan yang terjadi, setelah itu dilakukan analisa sistem yang memungkinkan kerusakan tersebut terjadi, namun sebelum analisa sistem – sistem dilakukan terlebih dahulu dilakukan pendeskripsian sistem – sistem tersebut terlebih dahulu. Dalam hal ini terdapat tiga sistem yaitu *Steam and Water System, Plant Water Supply System, Burner.*

IV.2 Deskripsi Kerusakan dan Kondisi Batas

Di dalam pengoperasiannya *power plant* kadang mengalami berbagai masalah, ini dimungkinkan sekali karena *power plant* bekerja pada temperatur dan

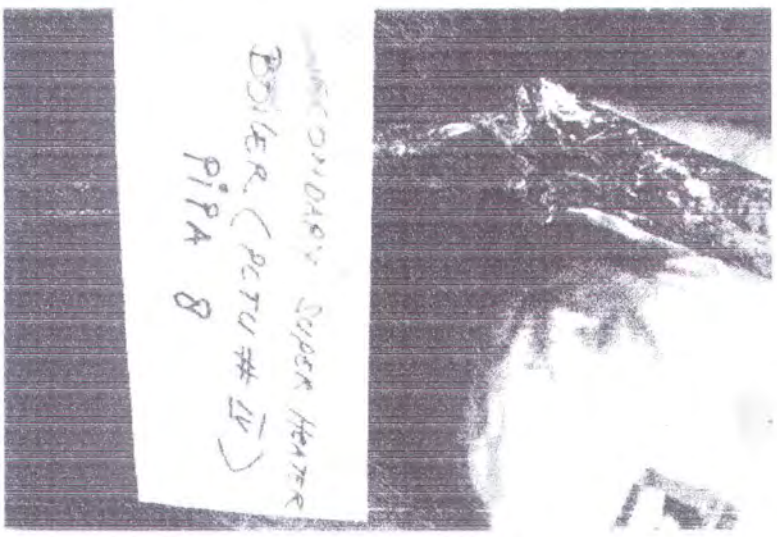
tekanan yang tinggi. Misalnya yang terjadi di Unit Pembangkit IV PLTU Gresik yang mengalami kerusakan boiler pada *secondary superheater*.

Kasus yang terjadi pada tahun 1993 telah terjadi kerusakan berupa :

1. Cacat pecah diikuti dengan hilangnya sebagian material.

Gambar IV.2.1 Cacat pecah dengan hilangnya sebagian material

2. Cacat pecah tanpa kehilangan material.

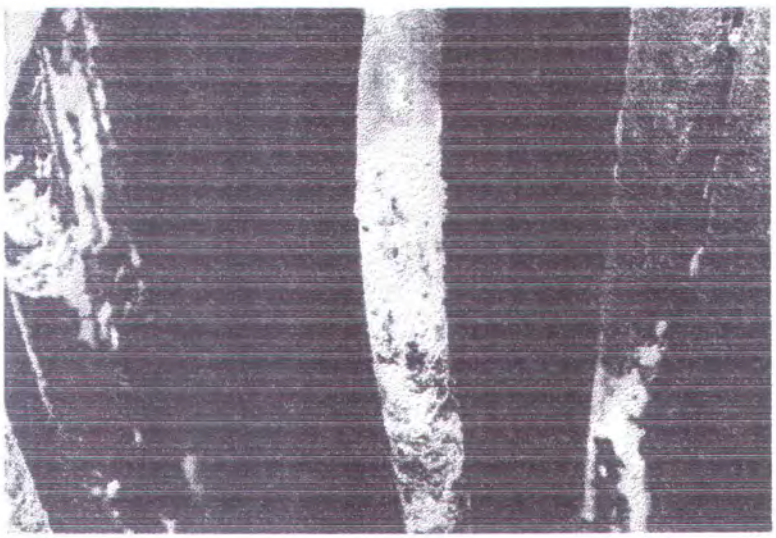


Gambar IV 2.2 Cacat pecah tanpa kehilangan material

3. Cacat retak berbentuk garis gores dengan kedalaman 3 mm dan panjang 25 – 30 mm.

Gambar IV.2.3 Cacat retak

4. Cacat gelembung berbentuk seperti bisul (bengkak).



Gambar IV.2.4 Cacat gelembung

Dari hasil pengamatan kerusakan dapat ditemukan lokasi kerusakan, yaitu sebagai berikut :

Tabel IV.2.1 Lokasi kerusakan *Secondary Superheater* tahun 1993

NO	JENIS KERUSAKAN	KODE PERALATAN	JUMLAH (Point)	Keterangan
1	Pecah	Loop D03	2 2	Row 3
2	Retak	D01	4	Row 8,9
3	Retak & Rembes	Loop D03	15 10	
4	Gelembung	D02	22	

Kasus yang hampir sama terjadi lagi pada tanggal 16 Januari 2002 yaitu telah terjadi kerusakan berupa kebocoran *secondary superheater* sejumlah 2 (dua) buah yaitu pada Row 9 No 2 dan Row 11 No 3, Kerusakan tersebut diketahui ditandai sebelumnya dengan terjadinya *boiler metal temperatur high* dan setelah dicek dengan tes hidrostatik pada tanggal 21 Januari 2002 diketahui kerusakan tersebut.

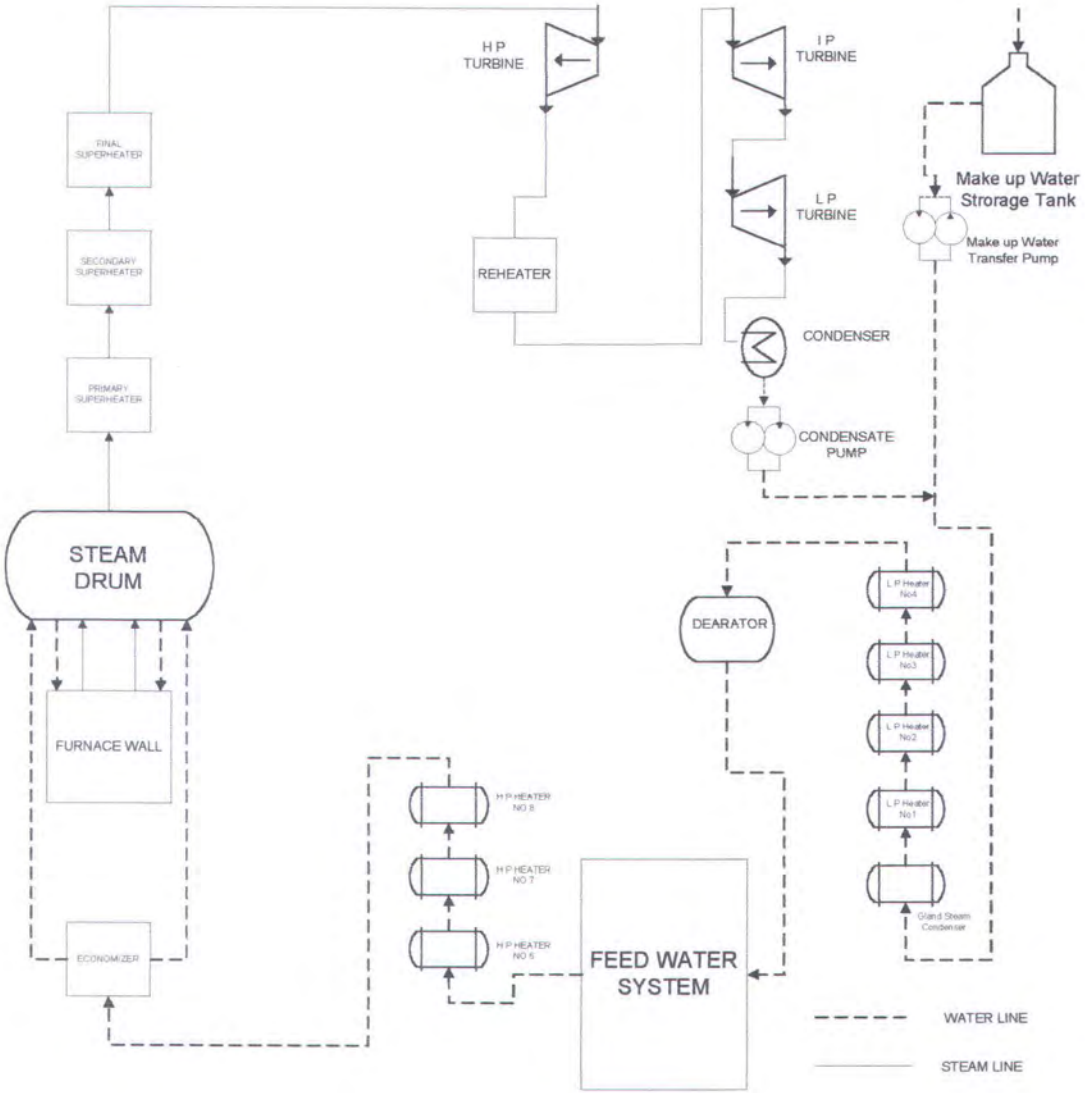
Agar analisa dapat dilakukan secara konsisten dalam hal ini boundary yang yang dipakai adalah sistem yang dianalisa adalah sistem *Flow Steam and Water System* yang difokuskan pada *Boiler feed pump system, Plant Water Supply System, Furnace.*

IV.3 Deskripsi Flow Steam And Water System

Untuk dapat mengetahui penyebab kerusakan yang terjadi pada *Secondary Superheater* maka harus dijelaskan bagaimana urutan – urutan fluida kerja yang bekerja pada Pembangkit Unit IV PLTU Gresik. Fluida kerja terdiri dari air dan uap.

Untuk sistem aliran air dan uap, dimulai dari S*upply make up water* dialirkan dari *make up water storage tank* 1,2,3,4 oleh *make up water transfer pump* 1,2,3,4 ke *Low Pressure Heater* yang terdiri dari *Low pressure Heater* 1,2,3,4. Sebelum memasuki ke *Low Pressure Heater* uap – uap yang tercampur akan dikondensasikan oleh *Gland steam condenser*. Setelah itu air memasuki *Dearator* untuk dilakukan *treatment* pemisahan Oksigen, kemudian air dialirkan ke *Feed Water System*, *Boiler Feed pump* terdiri dari *Boiler Feed Pump* System 4A, 4B, 4C. Air melalui *High Pressure Heater* yang terdiri dari *High Pressure Heater* No 6, 7, 8, yang kemudian dialirkan ke Ekonomiser untuk dilakukan proses pemanasan awal sebelum masuk *Steam Drum*. Di dalam *Steam Drum* fluida kerja yang berupa air dialirkan ke *Furnace* wall untuk dilakukan pemanasan sehingga berubah menjadi uap yang dialirkan kembali ke *Steam Drum*. Fluida yang telah berupa uap jenuh dari *Steam Drum* dipanaskan lanjut di *Primary Superheater* kemudian berlanjut ke *Secondary Superheater* dan *Final Superheater*. Setelah itu uap yang telah menjadi uap super panas dialirkan ke *High Pressure Turbine*, dilakukan pemanas ulang oleh *Reheater* sebelum diguakan untuk menggerakkan *Intermediate Pressure Turbine* dan berlanjut ke *Low Pressure Turbine*. Uap yang telah digunakan untuk menggerakkan turbine

dikondensasikan menjadi air oleh *Condenser* dan dialirkan dengan *Condensate Pump* kembali ke awal sistem.



Gambar IV.3.1 Aliran sistem air dan uap

Adapun fungsi komponen-komponen tersebut adalah sebagai berikut :

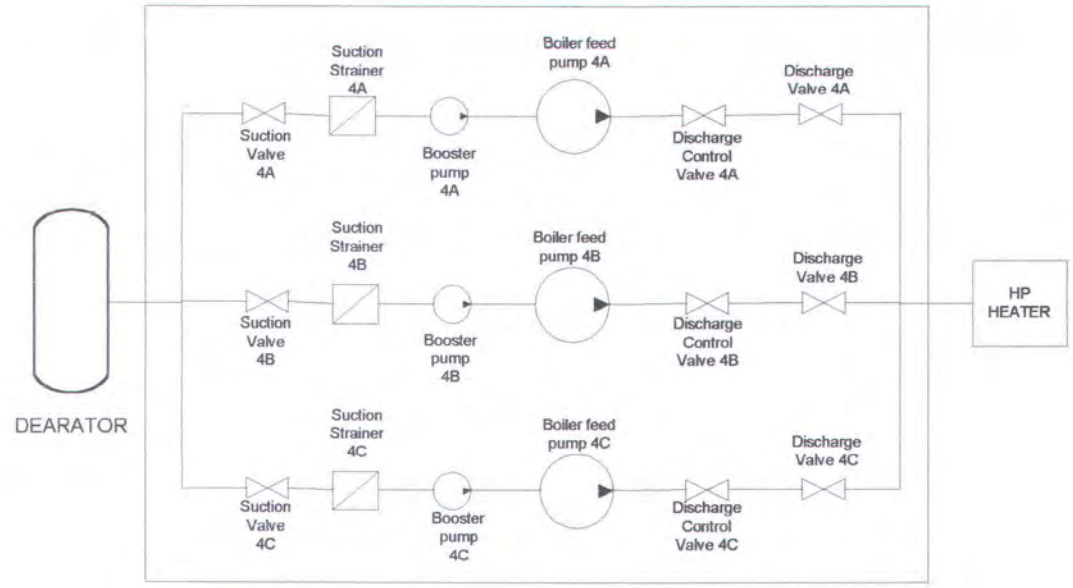
Tabel IV.3.1 Peralatan dan Fungsi water and steam sistem

Peralatan	Fungsi
Make up water storage tank	Sebagai tempat untuk penampung make up water
Make up water transfer pump	Digunakan untuk mengalirkan make up water
Gland steam condenser	Kelenjar uap yang digunakan untuk mengembunkan steam untuk digunakan siklus selanjutnya.
Low Pressure Heater	Digunakan untuk memanaskan feed water mendekati temperature boiler water, terdiri dari LP 1 Heater Temp : 85 ^0C , Press :-30 mmHg LP 2 Heater Temp : 104 ^0C , Press : 0,2 mmHg LP 3 Heater Temp : 129 ^0C , Press : 1.9 Kg/cm^2 LP 4 Heater Temp : 147 ^0C , Press : 3,9 Kg/cm^2
Dearator	Digunakan untuk memisahkan oksigen, kadar 0,005 cc/L,proses ini bertujuan untuk menghindari korosi dan kerusakan lainya, outlet water temperature 177 ^0C dan tekanan 8 Kg/cm^2
Boiler Feed pump	Mensuplai kebutuhan feed water secara kontinyu 600 T/H, terdiri dari BFP 4A, BFP 4B, BFP 4C.
High Pressure heater	Digunakan untuk pemanas feed water agar mendekati temperature water boiler juga untuk memisahkan oksigen, terdiri dari : HP 6 Heater Temp : 203 ^0C , Press : 16 Kg/cm^2 HP 7 Heater Temp : 238 ^0C , Press : 33 Kg/cm^2 HP 8 Heater Temp : 278 ^0C , Press : 62 Kg/cm^2
Economizer	Sebagai pemanas awal sebelum memasuki boiler dengan heating surface 2 210 m^2, inlet Temp 278 ^0C dan inlet press 188 Kg/cm^2
Steam Drum	Sebagai tempat penampung baik air maupun uap jenuh, dengan tekanan 180 Kg/cm^2, leve 1 mm
Furnace wall	Dinding tubes untuk merubah air menjadi uap jenuh, dengan

Superheater	heating surface 1,203 m^2 Untuk merubah uap jenuh menjadi uap super panas dengan heating surface 3 550 m^2 dengan superheated outlet 173,9 Kg/cm^2 Temp 541 ^0C
Turbine	Sebagai sumber gerak untuk generator
Reheater	Sebagai pemanas ulang dengan heating surface 6200 m^2 dan reheat outlet 32,3 Kg/cm^2 Temp 541 ^0C
Condenser	Untuk kondensasi uap yang telah digunakan agar dapat digunakan siklus selanjutnya, dengan condenser surface 10590 m^2
Condensate pump	Untuk mengalirkan air hasil kondensasi dengan Condensate pump A 49 AMP dan Condensate pump B 50 AMP

IV.4 Deskripsi Boiler Feed Pump

Proses Kerja *Boiler Feed Pump System* adalah menyuplai secara terus – menerus *preheated feed water* kwalitas tinggi dari *storage tank* yang sudah melalui *Dearator* menuju Ekonomiser. *Boiler Feed Pump (BFP) System* terdiri dari BFP System 4A, 4B, 4C yang masing – masing mempunyai saluran utama BFP yaitu tediri dari *Suction Valve, Suction Strainer, Booster Pump, Boiler Feed Pump, Discharge Valve, Discharge Control Valve.* BFP *System* ini terpasang secara parallel yaitu dua buah pompa running masing – masing 50 % dari kapasitas dan satu *stand by.* Apabila dua buah pompa ini gaagl maka operasi akan terjadi *derating.*



Gambar IV.4.1 Boiler Feed Pump System

Adapun fungsi komponen utama adalah sebagai berikut :

- *Boiler feed pump* : untuk memompakan kebutuhan feed water secara kontinu, kapasitas 365 T/H, kecepatn 7250 rpm, model 6X 10 ¼ - stg HDB, shaft power 2627,9 kW
- *Booster pump* : sebagai pompa penguat dalam *line suction* , tipe 200 UCW Kecepatan 2480 rpm
- *Strainer* : sebagai penyaring feed water

IV.5 Deskripsi Plant Water Supply System

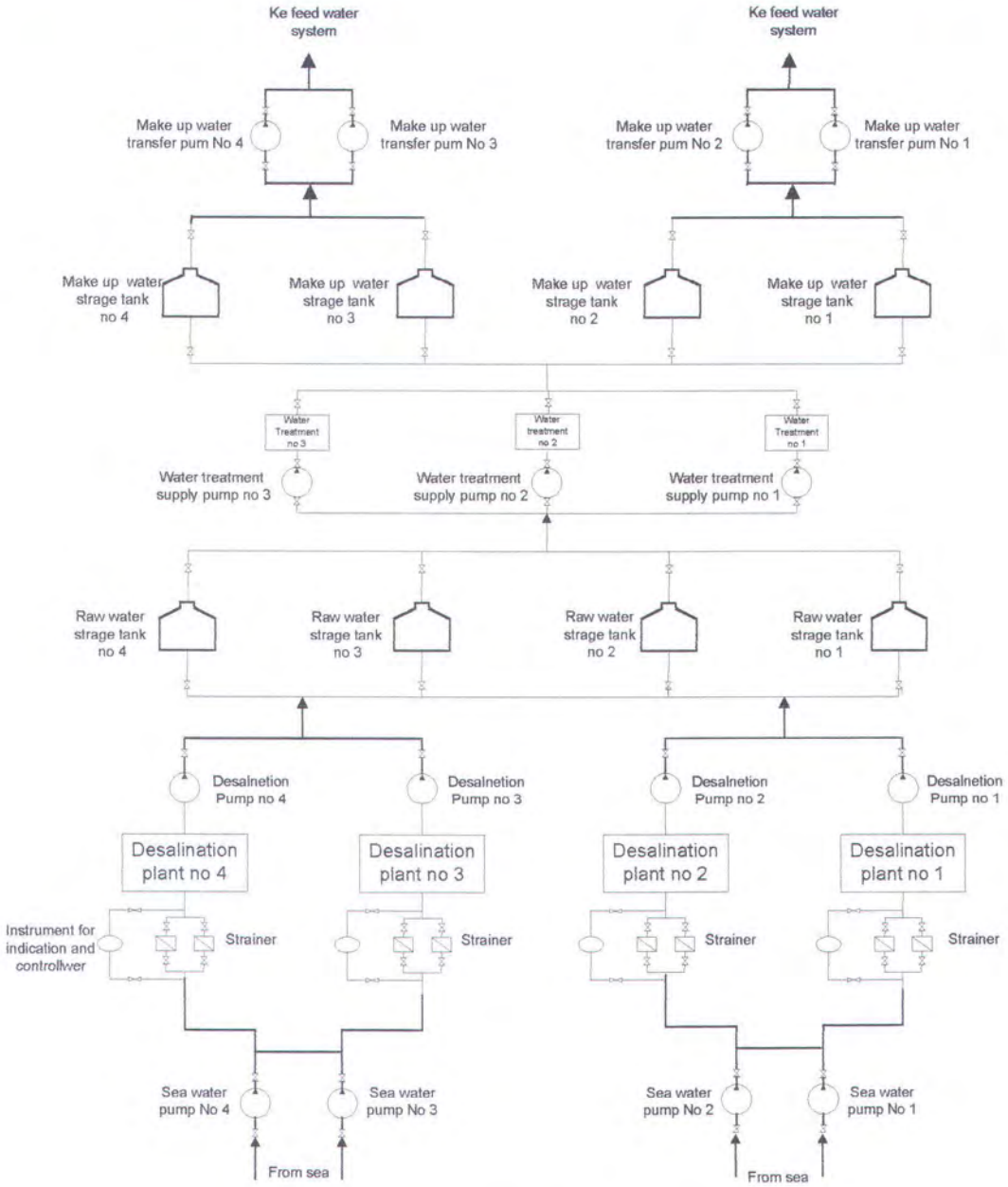
Air laut dipompa oleh *Sea water booster pump* A,B,C,D sebagai sumber *feed water*. Dilakukan *treatment* untuk memperoleh kualitas air yang memenuhi standar. Adapun urutan prosesnya adalah sebagai berikut air laut menuju *Desalination Plant* melalui *strainer*. Terdapat empat buah *Desalination plant* yaitu *Desalination Plant* No 1,2,3,4. Setelah melalui proses desalinasi, air

dipompakan oleh *Desalination Pump* menuju *Raw water storage tank* yang berjumlah empat buah yaitu *Raw water Sorage tank* 1, 2, 3, 4. Dari *Raw water strorage tank* air dialirkan ke *Water treatment* oleh tiga buah pompa yaitu *Water treatment supply pump* 1, 2, 3. Terdapat tiga buah *Water treatment* yaitu *Water treatment* No 1, 2, 3. Dari *Water treatment* air yang telah memenuhi kwalitas standar akan dialirkan ke *Make up water storage tank* dan siap dialirkan untuk digunakan sebagai fluida kerja.

Fungsi masing masing komponen penyusun sistem adalah sebaagi berikut :

Tabel IV.5.1 Peralatan dan Fungsi Water Supply System

Sistem/ Peralatan	Fungsi
Desalination plant	Proses untuk pemurnian air laut dengan kapasitas 500 m^3 / day, batas pH 25 ^0C 6,5 – 8, *conductivity* 20 µs/cm, *total iron* 0,2 ppm,total dissolved solid 10 ppm, temperature < 40 ^0C
Strainer	Penyaring air laut sebelum memasuki *desalination plant*
Sea Water Booster Pump	Untuk memompakan air laut dengan kapasitas 321.3 m^3 /H dengan total head 53 m
Desalination pump	Untuk mengalirkan air hasil desalinasi ke raw water tank
Raw water storage tank	Tempat penyimpan *raw water*
Water treatment supply pump	Untuk mengalirkan *raw water* ke *water treatment* instalasi, kapasitas 30 m^3 /H
Water treatment	Tempat pemrosesan secara kimiawi raw water untuk mendapatkan kwalitas *feed water* yang sesuai:, mencegah tejadinya korosi, scalling. batas ph 25 ^0C 6,8 – 7, *conductivity* <10 µs/cm, *total iron* 50 ppb, silica 20 ppb, Cl 29 ppb
Make up water storage tank	Tempat penyimpan *make up water*



Gambar I.V.5.1 Aliran *Plant water supply system*

IV.6 Deskipsi Burner

Burner berfungsi sebagai sumber nyala api dalam ruang bakar/ *furnace*. Kerja *burner* dipengaruhi dari target pembebanan yang akan dicapai, untuk mendapatkan target keluaran daya yang lebih besar pasokan bahan bakar menjadi lebih banyak demikian juga nyala api yang ditimbulkan akan semakin besar pula, dari perubahan pembebanan tersebut akan menyebabkan variasi nyala api dan juga memungkinkan terjadinya kontak langsung antara api dengan *secondary superheater* yang secara posisi letaknya paling dekat dengan furnace. Susunan burner terbagi menjadi dua yaitu *burner* pada *furnace front wall* dan *burner* pada *furnace rear wall*. Pada *furnace front wall* terdapat tiga susunan *burner* yaitu *burner* A, B, C yang masing – masing susunan tediri dari empat *burner*, jadi secara lengkap pada *furnace front wall* tersusun oleh dua belas *burner* yaitu *burner* A-1, A-2, A-3, A-4, B-1, B-2, B-3, B-4, C-1, C-2, C-3, C-4. Pada *furnace rear wall* terdiri dari dua susunan burner A dan B yang tiap susunannya juga terdiri dari empat *burner*, secara lengkap pada *furnace rear wall* terdiri dari delapan burner yaitu burner A-5, A-6, A-7, A-8, B-5, B-6, B-7, B-8.

Di dalam operasionalnya dapat digunakan dua macam bahan bakar yaitu Natural gas dan minyak, *penggunaan residual oil* sebagai bahan bakar utama dan HSD *oil* untuk penyalaan dan *warm up*.

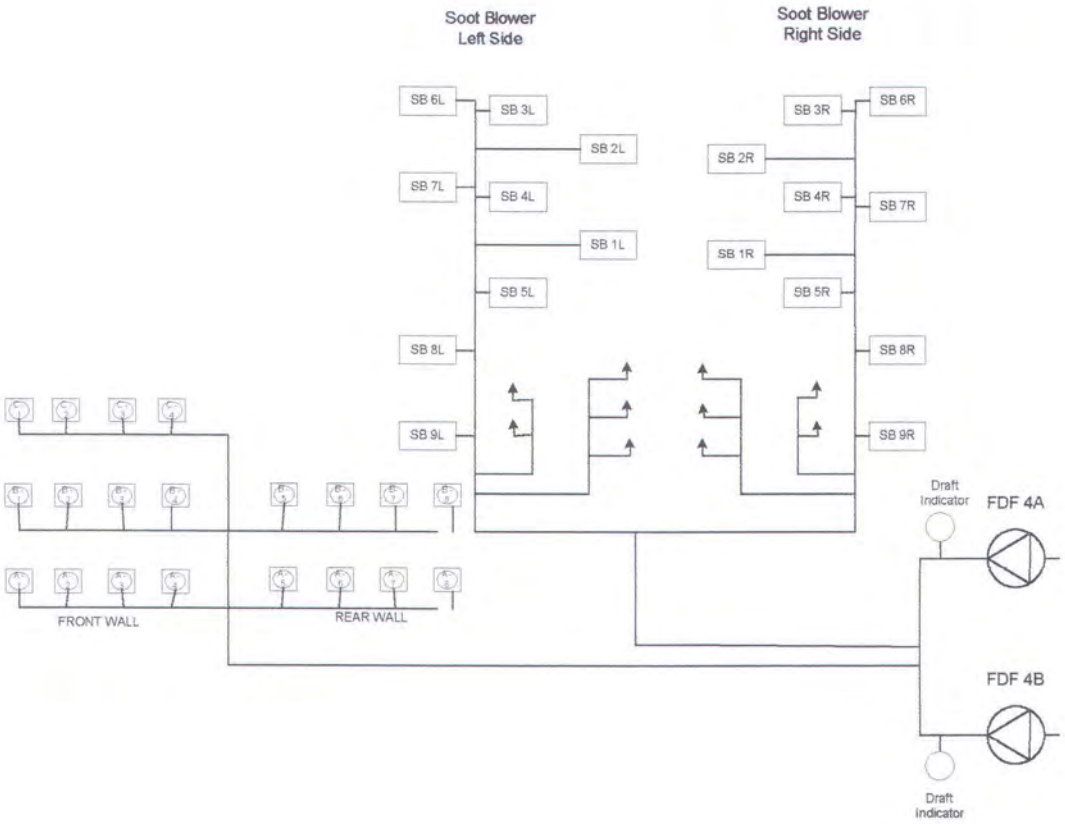
Udara pembakaran menggunakan *Forced Draft* sistem yang disuplai dari *Force Draft Fan* (FDF) A,B dengan menggunakan Draft indicator sebagai fungsi control draft. FDF A dan B bekerja secara parallel. Untuk menghilangkan kotoran yang bisa menempel pada dinding maupun pipa digunakan *Soot Blower*, yang

terdiri dari *Soot Blower left side* dan *Soot Blower right side*, yang setiap *side*-nya terdiri dari sembilan *soot blower*. *Soot blower* menggunakan dua buah motor dengan flow rate 3660 kg/H yang dikontrol menggunakan *automatic control remote*.

Adapun spesifikasi dari burner adalah sebagai berikut :

Tabel IV.6.1 Spesifikasi burner dan peralatan lainnya

Main oil Burner	Type : Kapasitas Fuel Oil press Steam press	Intermediate mixing steam atomizing 2400 kg/h Residual oil 21 $kg/cm^2 g$ 10.5 $kg/cm^2 g$
Warm up Burner	Type : Kapasitas Fuel Oil press Steam press	Intermediate mixing air atomizing 800 kg/h H S D oil 6.5 $kg/cm^2 g$ 6 $kg/cm^2 g$
Ignation Burner	Type : Kapasitas Fuel Oil press Steam press	Electric spark ignation 200 kg/h H SD oil 3.5 $kg/cm^2 g$ 4 $kg/cm^2 g$
Main Gas Burner	Type : Kapasitas Fuel Gas press	Multi spud 2030 kg/h Natural gas 2.3 $kg/cm^2 g$
Force Draft Fan	Sebagai penyuplai udara pembakaran dengan kapasitas 5560 m^3/min (31^0C), power 1116 kW	
Soot Blower Electric motor	Dengan model BLR 503 – 65-S . Flow rate 3660 kg/H	



Gambar IV.6.1 Burner,Soot blower dan Force Draft Fan

Untuk lebih mempermudah analisa maka tiap komponen dari sistem-sistem tersebut yang menyebabkan kerusakan dilakukan pengkodean secara lengkap sebagai berikut :

Tabel IV.6.2 Daftar nama komponen

Kode	Nama Kompnen
1100 1L,2L,3L,4L,5L,6L,7L,8L,9L 1R,2R,3R,4R,5R,6R,7R,8R,9R	SootBlower 1L,2L,3L,4L,5L,6L,7L,8L,9L 1R,2R,3R,4R,5R,6R,7R,8R,9R
1200 1,2	Soot Blower Control 1,2
1300 1,2	Soot Blower electric motor 1,2
2000	Dearator
3000	Condenser
3100 A,B	Condensate pump A,B
4000	Inhitor sistem bahan bakar

5100 A,B,C,D	Sea water Feed pump A,B,C,D
5110 A,B,C,D	Suction valve sea water A,B,C,D
5120 A,B,C,D	Discharge valve sea water A,B,C,D
5130-1 A,B,C,D	Strainer 1 sea water A,B,C,D
5130-2 A,B,C,D	Strainer 2 sea water A,B,C,D
5141-1 A,B,C,D	Gate valve 1 sea water strainer 1 sea water A,B,C,D
5142-1 A,B,C,D	Gate valve 2 sea water strainer 1 sea water A,B,C,D
5141-2 A,B,C,D	Gate valve 1 sea water strainer 2 sea water A,B,C,D
5142-2 A,B,C,D	Gate valve 2 sea water strainer 2 sea water A,B,C,D
5310 -1, -2, -3	Water Treatment Supply Pump No1,2,3
5320 -1, -2, -3	Suction valve WT Supply Pump No1,2,3
5330 -1, -2, -3	Discharge valve WT Supply Pump No1,2,3
5300 –1, -2, -3	Water Treatment No 1, 2, 3
5200–1, -2, -3, -4	Desalination Plant 1, 2, 3, 4
5210 –1, -2, -3, -4	Desalination Pump 1, 2, 3, 4
5220 –1,-2,-3,-4	Desalination Valve 1,2,3,4
5400 1,2,3,4	Make up water transfer pump 1,2,3,4
5410 1,2,3,4	Suction valve M U transfer pump 1,2,3,4
5420 1,2,3,4	Disc valve M U transfer pump 1,2,3,4
6100 1,2	Condensate pump 1,2
7000 4A, 4B, 4C	Boiler Feed Pump 4A, 4B, 4C
7100 4A, 4B, 4C	Suction Pipe 4A, 4B, 4C
7200 4A, 4B, 4C	Suction Strainer 4A, 4B, 4C
7300 4A, 4B, 4C	Booster Pump 4A, 4B, 4C
7400 4A, 4B, 4C	Suction Valve 4A, 4B, 4C
7500 4A, 4B, 4C	Discharge Pipe 4A, 4B, 4C
7600 4A, 4B, 4C	Discharge Valve 4A, 4B, 4C
7700 4A, 4B, 4C	Discharge Control Valve 4A, 4B, 4C
8000 A1, A2, A3, A4, A5, A6, A7,A8 B1, B2, B3, B4, B5, B6, B7, B8 C1, C2, C3, C4	Burner A1,A2, A3, A4, A5, A6, A7,A8, B1,B2,B3,B4,B5,B6,B7,B,C1,C2,C3,C4
9100	Steam pressure control
9200 A,B	Force Draft Fan A,B
9300 A,B	Draft Indicator A,B

IV.7 Fault Tree Analysis (FTA)

Tujuan penggunaan FTA yaitu untuk mengetahui komponen – komponen yang dapat menyebabkan pecahnya *secondary superheater*. FTA lebih menekankan pada *"top down" approach* yaitu karena analisa ini berawal dari *system top level* dan meneruskan ke bawah. Titik awal dari analisa ini adalah pengidentifikasian *mode* kegagalan pada *top level* suatu sistem.

Sebuah *top – event* yang merupakan definisi kegagalan suatu system, harus ditentukan terlebih dahulu dalam pengkonstruksian FTA. Sistem kemudian dianalisa untuk menemukan semua kemungkinan kegagalan yang didefinisikan pada top event. Setelah mengidentifikasi *top event*, *event-event* yang memberikan kontribusi secara langsung terjadinya *top event* dengan memakai hubungan logika dengan menggunakan gerbang AND (*And gate*) dan gerbang OR (*OR gate*) sampai dicapai *event* dasar. Setelah diagram FTA terbentuk maka selanjutnya mencari *minimum cut set* yaitu serangkaian komponen yang dapat menyebabkan kegagalan system dengan menggunakan metode MOCUS *(Methode for obtaining cut sets).*

Berdasarkan lampiran konstruksi FTA dan hasil *Minimal cut set* yang diperoleh dari algoritma MOCUS, terlihat bahwa *top – event*-nya adalah *Secondary superheater* pecah, kerusakan tersebut terjadi jika kejadian dibawah gerbang G0, yaitu penurunan kekuatan material atau over pressure terjadi

Penurunan kekuatan material dapat disebabkan oleh dua faktor pada gerbang G1 yaitu penipisan material atau temperatur material o*verheating*

Pada *basic event Soot blower, Soot blower electric motor* atau *Soot blower control* tidak berfungsi maka akan menimbulkan banyaknya kotoran yang berada di ruang bakar, dengan kecepatan yang tinggi dan secara terus - menerus akan menyebakan erosi pada permukaan luar pipa. Dari timbulnya erosi inilah akan terjadi penipisan material yang menyebabkan penurunan kekuatan material.

Penyebab lain adalah gagalnya fungsi *Deaerator* untuk memisahkan oksigen sesuai dengan batas sebesar 0,005 cc/L untuk *feed water.* sehingga

kandungan oksigen berlebih, dari kandungan oksigen yang berlebih ini akan menyebabkan terjadinya korosi sisi dalam yang berlanjut pada penipisan material yang akan berakibat kekuatan material menurun.

Bocornya *condenser* akan menyebabkan kandungan Chlor melebihi batas sebesar 100 ppb *feed water*, ini dapat menjadikan kwalitas *feed water* tidak sesuai standar, yang dapat menimbulkan korosi pada sisi dalam tube dan berlanjut pada penipisan material yang mengakibatkan penurunan kekuatan material.

Kadar Sodium sulfat dan Vanadium attack yang berasal dari bahan bakar dan keberadaannya selama pembakaran akan dapat menimbulkan terjadinya korosi pada permukaan luar pipa ini disebabkan tidak adanya fungsi dari inhibitor skid pada bahan bakar. Batas kandungan Sulfur dalam bahan bakar adalah sebesar 3,5 % sedangkan untuk Vanadium adalah sebesar 0,04 %. Dari korosi pada permukaan luar akan menimbulkan penipisan material yang berakibat pada penurunan kekuatan material.

Batas maksimum temperature pipa *secondary superheater* adalah 573 ^{0}C. Pada event temperatur material *overheating* dapat disebabkan oleh dua faktor yang terdapat di bawah gerbang G4 yaitu kurangnya suplai air atau kontak langsung dan variasi bunga api.

Kegagalan *Desalination plant* 1, *Desalintion Plant* 2, *Desalination Plant* 3, *Desalination Plant* 4 di bawah gerbang G20 untuk menyediakan *raw water* dengan batas kualitas yaitu pH 25 ^{0}C sebesar 6,5 – 8, *conductivity* 20 µs/cm, *total iron* 200 ppb akan menyebabkan terjadinya penurunan kualitas air yang akan menimbulkan terjadinya scalling. Penyempitan sisi dalam pada *orifice hanger* dan

inlet header akibat dar scalling menyebabkan berkurangnya luasan aliran fluida sehingga suplai air berkurang dan apabila suplai air di dalam pipa kurang dari 640 T/H maka akan terjadi *overheating* yang berlanjut menyebabkan penurunan kekuatan material, karena air selain sebagai fluida kerja juga sebagai media pendingin.

Kegagalan *Water treatment* 1, *Water treatment* 2, *Water treatment* 3 di bawah gerbang G 21 untuk mendapatkan hasil kualitas air sesuai dengan standar yaitu pH 25 ^{0}C sebesar 6,8 – 7, *conductivity* ,<10 µs/cm, *total iron* 50 ppb, Silica 20 ppb, Cl 100 ppb akan menimbulkan terjadinya scalling yang berakibat penyempitan sisi dalam pada *orifice hanger* dan *inlet header* sehingga suplai air berkurang dan apabila suplai air di dalam pipa kurang dari 640 T/H maka akan terjadi *overheating* yang berlanjut menyebabkan penurunan kekuatan material.

Terjadinya *overheating* karena kekurangan suplai air juga dapat disebabkan dari gagalnya kombinasi sistem pompa distribusi seperti yang terkonstruksi di bawah gerbang G11, mulai dari kombinasi *Sea water Feed pump* A,B,C,D, kombinasi *Desalination pump* 1,2,3,4 , kombinasi *Water Treatment Supply pump* 1,2,3, kombinasi *water make up transfer pump 1,2,3,4 and condensate supply pump A,B,* dan *Boiler feed pump 4A, 4B, 4C.*

Pressure pada *secondary superheater* pada kondisi MCR adalah sebesar 173,9 kg/cm^{2}. *Over pressure* terjadi jika komponen di bawah gerbang G2 yaitu *Steam pressure control, Draft indicator* yang terdiri dari *Draft indicator A,B* dan *Force Draft Fan* yang terdiri dari *force draft fan* A, B mengalami kegagalan.

DISKUSI

Dari hasil Minimal cut sets yang tebentuk dari algoritma MOCUS dapat diketahui beberapa kekritisan setiap komponen dalam menunjang terjadinya kerusakan *secondary superhe*ater, semakin sedikit jumlah komponen dalam tiap *minimal cut set* maka semakin kritis pula peran komponen tesebut menimbulkan kerusakan. Dari hasil analisa terdapat beberapa *minimal cut set* yang mempunyai komponen penyebab kerusakan berjumlah satu, yaitu *Dearator, Condenser, Steam Pressure Control*, dan tidak adanya fungsi *Inhibitor Skid* bahan bakar. Jadi komponen - komponen tersebut merupakan komponen penyebab kerusakan yang paling kritis.

Tabel IV.7.1 Satu komponen Minimal Cut Sets

CUT SET	Event
{4000}	Tidak adanya Fungsi Inhibitor Bahan Bakar
{2000}	Deaerator
{3000}	Condenser Bocor
{9100}	Steam Pressure Control

Tabel IV.7.2 Dua Komponen Minimal Cut Sets

CUT SET				
1200-1,1200-2	7000-4A, 7200-4B	7200-4A, 7000-4C	7500-4A, 7700-4C	7000-4B, 7300-4C
1300 1,13002	7000-4A, 7300-4B	7200-4A, 7500-4C	7600-4A, 7100-4C	7000-4B, 7400-4C
7100-4A, 7100-4B	7000-4A, 7400-4B	7200-4A, 7600-4C	7600-4A, 7200-4C	7000-4B, 7000-4C
7100-4A, 7200-4B	7000-4A, 7000-4B	7200-4A, 7700-4C	7600-4A, 7300-4C	7000-4B, 7500-4C
7100-4A, 7300-4B	7000-4A, 7500-4B	7300-4A, 7100-4C	7600-4A, 7400-4C	7000-4B, 7600-4C
7100-4A, 7400-4B	7000-4A, 7600-4B	7300-4A, 7200-4C	7600-4A, 7000-4C	7000-4B, 7700-4C
7100-4A, 7000-4B	7000-4A, 7700-4B	7300-4A, 7300-4C	7600-4A, 7500-4C	7500-4B, 7100-4C
7100-4A, 7500-4B	7500-4A, 7100-4B	7300-4A, 7400-4C	7600-4A, 7600-4C	7500-4B, 7200-4C
7100-4A, 7600-4B	7500-4A, 7200-4B	7300-4A, 7000-4C	7600-4A, 7700-4C	7500-4B, 7300-4C
7100-4A, 7700-4B	7500-4A, 7300-4B	7300-4A, 7500-4C	7700-4A, 7100-4C	7500-4B, 7400-4C
7200-4A, 7100-4B	7500-4A, 7400-4B	7300-4A, 7600-4C	7700-4A, 7200-4C	7500-4B, 7000-4C
7200-4A, 7200-4B	7500-4A, 7000-4B	7300-4A, 7700-4C	7700-4A, 7300-4C	7500-4B, 7500-4C
7200-4A, 7300-4B	7500-4A, 7500-4B	7400-4A, 7100-4C	7700-4A, 7400-4C	7500-4B, 7600-4C
7200-4A, 7400-4B	7500-4A, 7600-4B	7400-4A, 7200-4C	7700-4A, 7000-4C	7500-4B, 7700-4C

7200-4A, 7000-4B	7500-4A, 7700-4B	7400-4A, 7300-4C	7700-4A, 7500-4C	7600-4B, 7100-4C
7200-4A, 7500-4B	7600-4A, 7100-4B	7400-4A, 7400-4C	7700-4A, 7600-4C	7600-4B, 7200-4C
7200-4A, 7600-4B	7600-4A, 7200-4B	7400-4A, 7000-4C	7700-4A, 7700-4C	7600-4B, 7300-4C
7200-4A, 7700-4B	7600-4A, 7300-4B	7400-4A, 7500-4C	7100-4B, 7100-4C	7600-4B, 7400-4C
7300-4A, 7100-4B	7600-4A, 7400-4B	7400-4A, 7600-4C	7100-4B, 7200-4C	7600-4B, 7000-4C
7300-4A, 7200-4B	7600-4A, 7000-4B	7400-4A, 7700-4C	7100-4B, 7300-4C	7600-4B, 7500-4C
7300-4A, 7300-4B	7600-4A, 7500-4B	7000-4A, 7100-4C	7100-4B, 7400-4C	7600-4B, 7600-4C
7300-4A, 7400-4B	7600-4A, 7600-4B	7000-4A, 7200-4C	7100-4B, 7000-4C	7600-4B, 7700-4C
7300-4A, 7000-4B	7600-4A, 7700-4B	7000-4A, 7300-4C	7100-4B, 7500-4C	9300 A,9300B
7300-4A, 7500-4B	7700-4A, 7100-4B	7000-4A, 7400-4C	7100-4B, 7600-4C	9200 A,9200B
7300-4A, 7600-4B	7700-4A, 7200-4B	7000-4A, 7000-4C	7100-4B, 7700-4C	
7300-4A, 7700-4B	7700-4A, 7300-4B	7000-4A, 7500-4C	7200-4B, 7100-4C	
7400-4A, 7100-4B	7700-4A, 7400-4B	7000-4A, 7600-4C	7200-4B, 7200-4C	
7400-4A, 7200-4B	7700-4A, 7000-4B	7000-4A, 7700-4C	7200-4B, 7300-4C	
7400-4A, 7300-4B	7700-4A, 7500-4B	7700-4B, 7100-4C	7200-4B, 7400-4C	
7400-4A, 7400-4B	7700-4A, 7600-4B	7700-4B, 7200-4C	7200-4B, 7000-4C	
7400-4A, 7000-4B	7700-4A, 7700-4B	7700-4B, 7300-4C	7200-4B, 7500-4C	
7400-4A, 7500-4B	7100-4A, 7100-4C	7700-4B, 7400-4C	7200-4B, 7600-4C	
7400-4A, 7600-4B	7100-4A, 7200-4C	7700-4B, 7000-4C	7200-4B, 7700-4C	
7400-4A, 7700-4B	7100-4A, 7300-4C	7700-4B, 7500-4C	7400-4B, 7100-4C	
7300-4B, 7100-4C	7100-4A, 7400-4C	7700-4B, 7600-4C	7400-4B, 7200-4C	
7300-4B, 7200-4C	7100-4A, 7000-4C	7700-4B, 7700-4C	7400-4B, 7300-4C	
7300-4B, 7300-4C	7100-4A, 7500-4C	7500-4A, 7100-4C	7400-4B, 7400-4C	
7300-4B, 7400-4C	7100-4A, 7600-4C	7500-4A, 7200-4C	7400-4B, 7000-4C	
7300-4B, 7000-4C	7100-4A, 7700-4C	7500-4A, 7300-4C	7400-4B, 7500-4C	
7300-4B, 7500-4C	7200-4A, 7100-4C	7500-4A, 7400-4C	7400-4B, 7600-4C	
7300-4B, 7600-4C	7200-4A, 7200-4C	7500-4A, 7000-4C	7400-4B, 7700-4C	
7300-4B, 7700-4C	7200-4A, 7300-4C	7500-4A, 7500-4C	7000-4B, 7100-4C	
	7200-4A, 7400-4C	7500-4A, 7600-4C	7000-4B, 7200-4C	

Tabel IV.7.3 Tiga Komponen Minimal Cut Sets

CUT SET	
5300-1,5300-2,5300-3	5400-1,5400-2,5420-3
5410-1,5410-2,5410-3	5400-1,5420-2,5410-3
5410-1,5410-2,5400-3	5400-1,5420-2,5400-3
5410-1,5410-2,5420-3	5400-1,5420-2,5420-3
5410-1,5400-2,5410-3	5420-1,5410-2,5410-3
5410-1,5400-2,5400-3	5420-1,5410-2,5400-3
5410-1,5400-2,5420-3	5420-1,5410-2,5420-3
5410-1,5420-2,5410-3	5420-1,5400-2,5410-3
5410-1,5420-2,5400-3	5420-1,5400-2,5400-3
5410-1,5420-2,5420-3	5420-1,5400-2,5420-3
5400-1,5410-2,5410-3	5420-1,5420-2,5410-3
5400-1,5410-2,5400-3	5420-1,5420-2,5400-3
5400-1,5410-2,5420-3	5420-1,5420-2,5420-3
5400-1,5400-2,5410-3	
5400-1,5400-2,5400-3	

Tabel IV.7.4 Empat Komponen Minimal Cut Sets

CUT SET	
5200-1,5200- 2,5200- 3,5200- 4	5100-A,5110-B,5120-C,5110-D
8000-A1,8000 A-2,8000 A-3,8000 A4	5100-A,5110-B,5120-C,5100-D
8000 B-1,8000 B-2,8000 B-3,8000 B-4	5100-A,5110-B,5120-C,5120-D
8000-A5,8000 A-6,8000 A-7,8000 A-8	5100-A,5100-B,5110-C,5110-D
8000 B-5,8000 B-6,8000 B-7,8000 B-8	5100-A,5100-B,5110-C,5100-D
5110-A,5110-B,5110-C,5110-D	5100-A,5100-B,5110-C,5120-D
5110-A,5110-B,5110-C,5100-D	5100-A,5100-B,5100-C,5110-D
5110-A,5110-B,5110-C,5120-D	5100-A,5100-B,5100-C,5100-D
5110-A,5110-B,5100-C,5110-D	5100-A,5100-B,5100-C,5120-D
5110-A,5110-B,5100-C,5100-D	5100-A,5100-B,5120-C,5110-D
5110-A,5110-B,5100-C,5120-D	5100-A,5100-B,5120-C,5100-D
5110-A,5110-B,5120-C,5110-D	5100-A,5100-B,5120-C,5120-D
5110-A,5110-B,5120-C,5100-D	5100-A,5120-B,5110-C,5110-D
5110-A,5110-B,5120-C,5120-D	5100-A,5120-B,5110-C,5100-D
5110-A,5100-B,5110-C,5110-D	5100-A,5120-B,5110-C,5120-D
5110-A,5100-B,5110-C,5100-D	5100-A,5120-B,5100-C,5110-D
5110-A,5100-B,5110-C,5120-D	5100-A,5120-B,5100-C,5100-D
5110-A,5100-B,5100-C,5110-D	5100-A,5120-B,5100-C,5120-D
5110-A,5100-B,5100-C,5100-D	5100-A,5120-B,5120-C,5110-D
5110-A,5100-B,5100-C,5120-D	5100-A,5120-B,5120-C,5100-D
5110-A,5100-B,5120-C,5110-D	5100-A,5120-B,5120-C,5120-D
5110-A,5100-B,5120-C,5100-D	5210-1,5210-2,5210-3,5210-4
5110-A,5100-B,5120-C,5120-D	5210-1,5210-2,5210-3,5220-4
5110-A,5120-B,5110-C,5110-D	5210-1,5210-2,5220-3,5210-4
5110-A,5120-B,5110-C,5100-D	5210-1,5210-2,5220-3,5220-4
5110-A,5120-B,5110-C,5120-D	5210-1,5220-2,5210-3,5210-4
5110-A,5120-B,5100-C,5110-D	5210-1,5220-2,5210-3,5220-4
5110-A,5120-B,5100-C,5100-D	5210-1,5220-2,5220-3,5210-4
5110-A,5120-B,5100-C,5120-D	5210-1,5220-2,5220-3,5220-4
5110-A,5120-B,5120-C,5110-D	5220-1,5210-2,5210-3,5210-4
5110-A,5120-B,5120-C,5100-D	5220-1,5210-2,5210-3,5220-4
5110-A,5120-B,5120-C,5120-D	5220-1,5210-2,5220-3,5210-4
5100-A,5110-B,5110-C,5110-D	5220-1,5210-2,5220-3,5220-4
5100-A,5110-B,5110-C,5100-D	5220-1,5220-2,5210-3,5210-4
5100-A,5110-B,5110-C,5120-D	5220-1,5220-2,5210-3,5220-4
5100-A,5110-B,5100-C,5110-D	5220-1,5220-2,5220-3,5210-4
5100-A,5110-B,5100-C,5100-D	5220-1,5220-2,5220-3,5220-4
5100-A,5110-B,5100-C,5120-D	

Disamping jumlah komponen tiap *minimal cut set,* komponen penyebab kerusakan juga dapat dikategorikan dalam komponen pasif dan komponen aktif Komponen aktif akan menyebabkan kemungkinan terjadinya kegagalan lebih besar dibandingkan dengan komponen pasif. Dari hasil analisa dapat diketahui komponen aktif dab komponen pasif sebagai berikut :

Tabel IV.7.6 Komponen Aktif Pasif

Komponen Aktif	Komponen Pasif
Soot Blower Control 1,2	SootBlower
Soot Blower Electric motor 1,2	1L,2L,3L,4L,5L,6L,7L,8L,9L
Condensate pump A,B	1R,2R,3R,4R,5R,6R,7R,8R,9R
Sea Water Feed Pump A,B,C,D	Dearator
Suction Valve sea water A,B,C,D	Condenser
Discharge Valve sea water A,B,C,D	Strainer 1 sea water A,B,C,D
Gate valve 1 sea water strainer 1 sea water A,B,C,D	Strainer 2 sea water A,B,C,D
Gate valve 2 sea water strainer 1 sea water A,B,C,D	Suction Pipe 4A, 4B, 4C
Gate valve 1 sea water strainer 2 sea water A,B,C,D	Suction Strainer 4A, 4B, 4C
Gate valve 2 sea water strainer 2 sea water A,B,C,D	Discharge Pipe 4A, 4B, 4C
Water Treatment Supply Pump No1,2,3	Burner A1,A2, A3, A4, A5, A6, A7,A8, B1,B2,B3,B4,B5,B6,B7,B,C1,C2,C3,C4
Suction valve WT Supply Pump No1,2,3	Draft Indicator A,B
Discharge valve WT Supply Pump No1,2,3	
Desalination Valve 1,2,3,4	
Make up water transfer pump 1,2,3,4	
Suction valve M U transfer pump 1,2,3,4	
Disc valve M U transfer pump 1,2,3,4	
Boiler Feed Pump 4A, 4B, 4C	
Booster Pump 4A, 4B, 4C	
Suction Valve 4A, 4B, 4C	
Discharge Valve 4A, 4B, 4C	
Discharge Control Valve 4A, 4B, 4C8	
Steam pressure control	
Force Draft Fan A,B	

BAB V
KESIMPULAN

BAB V
KESIMPULAN

Setelah dilakukan analisa dan pembahasan pada bab sebelumnya maka dapat diambil suatu kesimpulan sesuai dengan tujuan dari masalah yang diangkat dalam tugas akhir ini. Kesimpulan dari tugas akhir ini adalah sebagai berikut:

1. Dengan metode analisa Fault Tree Analysis dapat diidentifikasi penyebab utama kerusakan secondary superheater Unit IV PLTU Gresik dapat disebabkan oleh dua faktor utama yaitu penurunan kekuatan material dan *over pressure*.
2. Penurunan kekuatan material disebabkan oleh proses penipisan material dan *overheating*, *Over pressure* disebabkan karena *fail*-nya komponen *Steam control pressure*, *Force Draft Fan* A, B, *Draft indicator* A,B.
3. Dari *Minimal Cut Set* yang terbentuk dapat dilihat bahwa gagalnya komponen *Dearator* dan *Condenser*, *Steam control pressure* dan tidak adanya fungsi *Inhibitor* skid bahan bakar adalah penyebab kerusakan yang paling kritis.

SARAN

- Untuk menjaga agar kerusakan yang sama tidak terjadi lagi maka perlu perhatian perawatan yang lebih terhadap komponen yang paling kritis dalam hal ini *Dearator*, *Condenser* dan *Steam pressure control*.

- Perlu dilakukan peertimbangan untuk mengadakan fungsi Inhibitor Skid bahan bakar pada Burner.
- Perlu dilakukan analisa secara kuantitatif untuk lebih mengetahui kandalan sistem penyebab kerusakan secara lebih komplek dan mendalam.

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DAFTAR PUSTAKA

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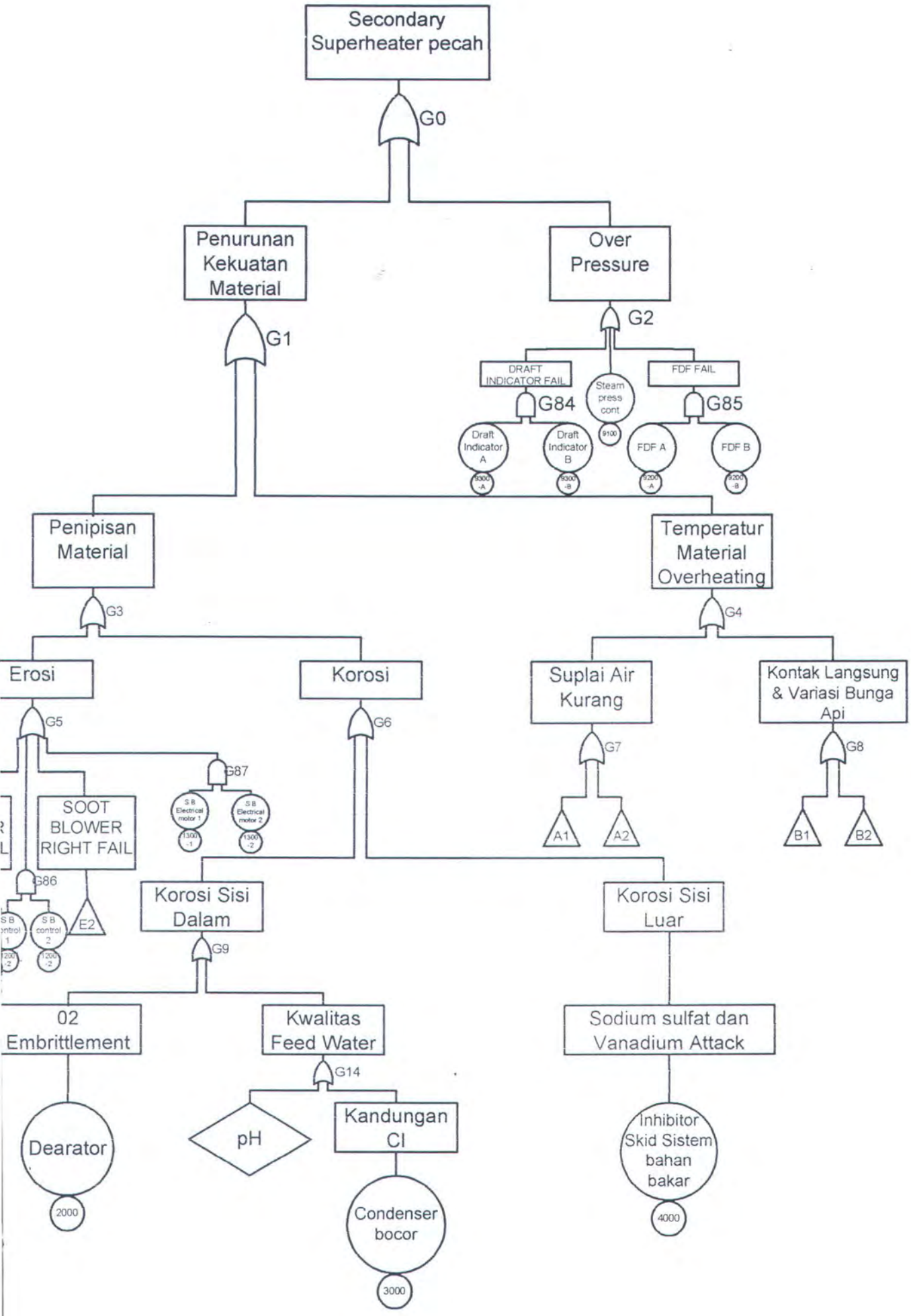
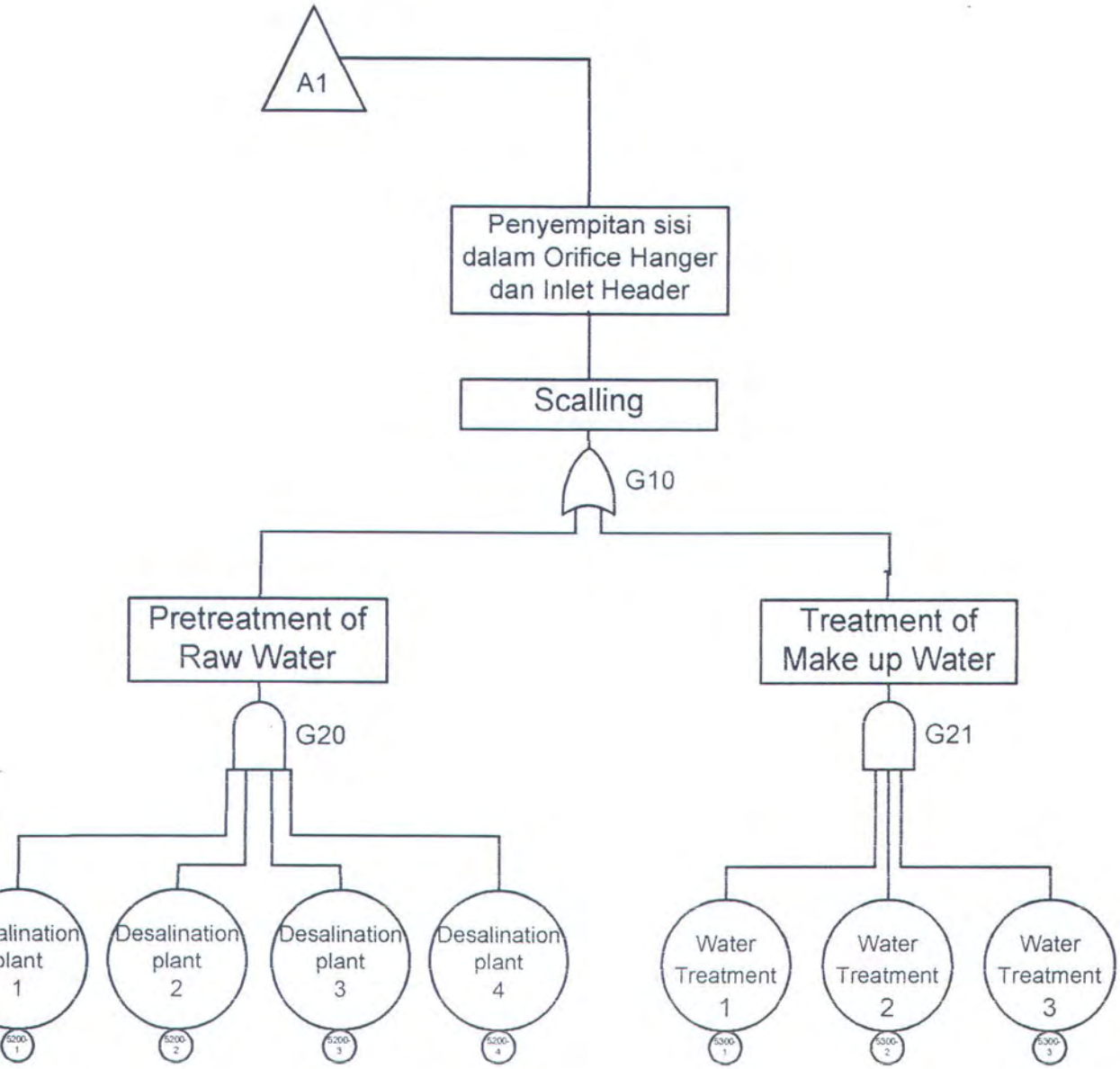
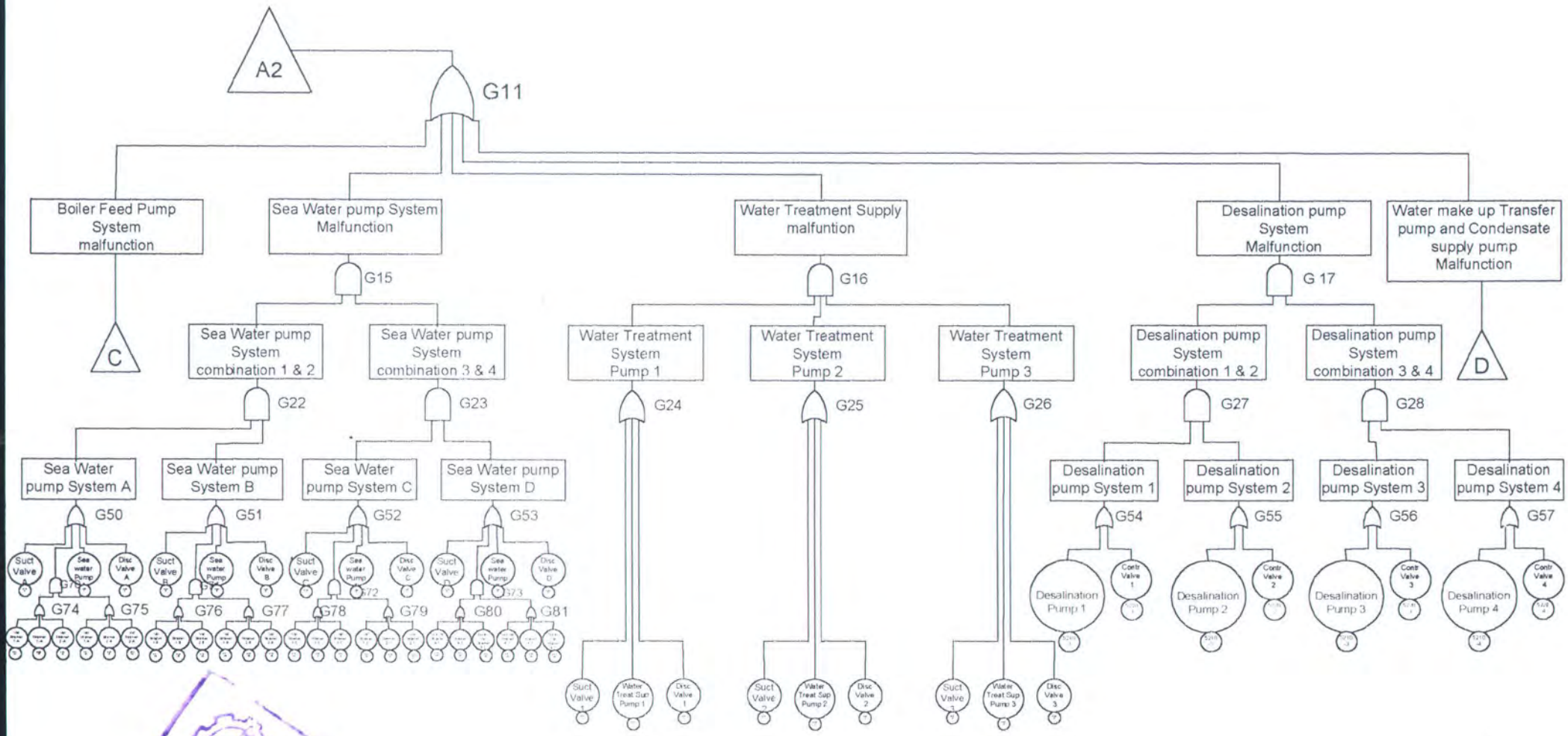
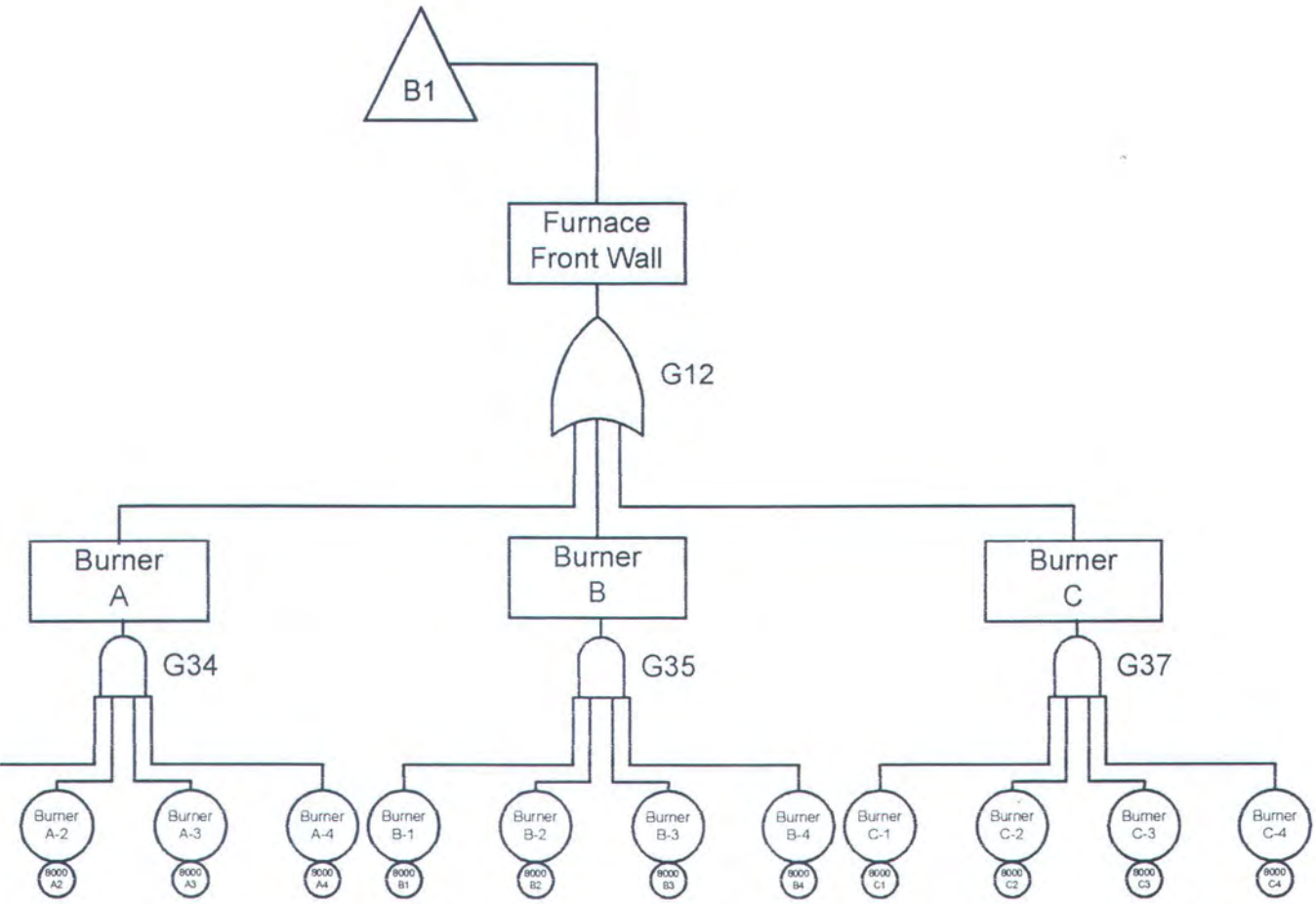
LAMPIRAN

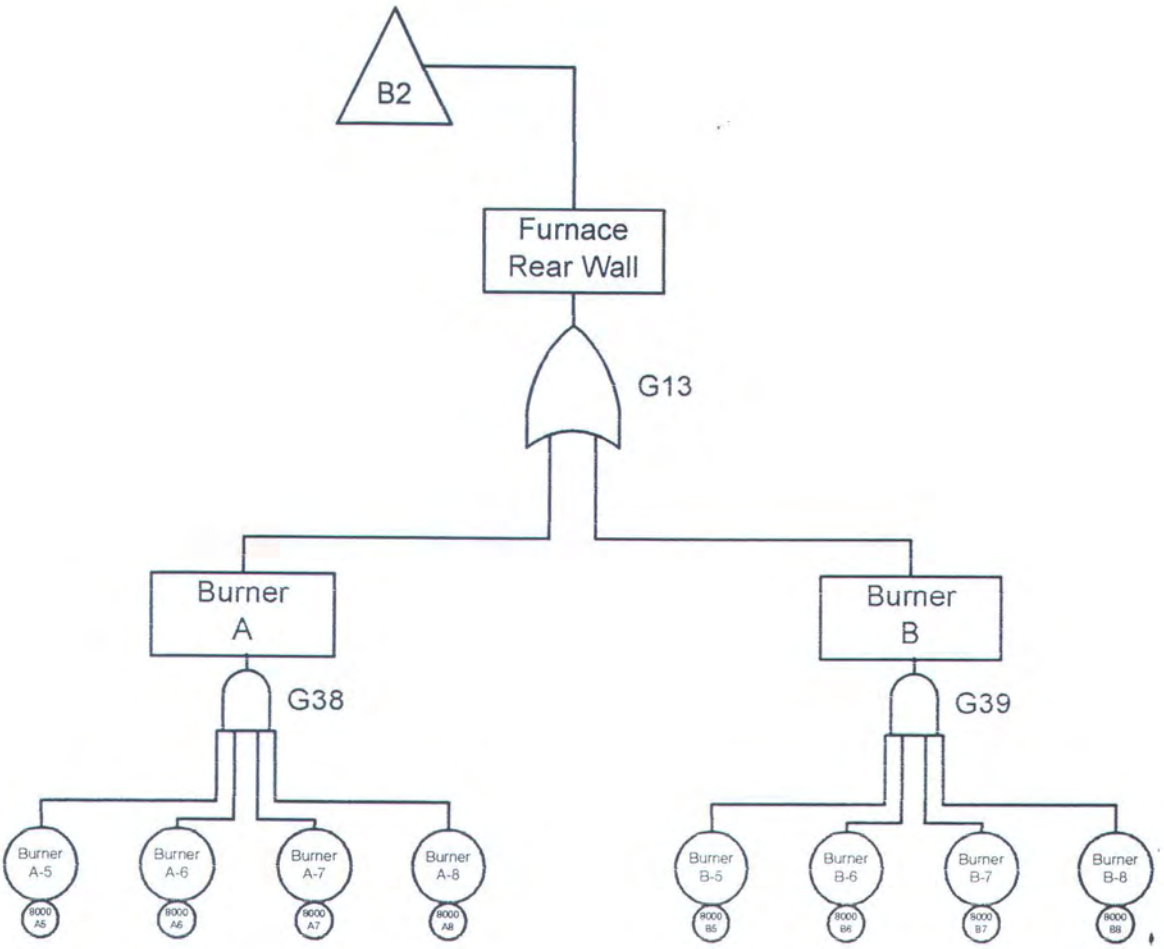
LAMPIRAN A
FAULT TREE DIAGRAM

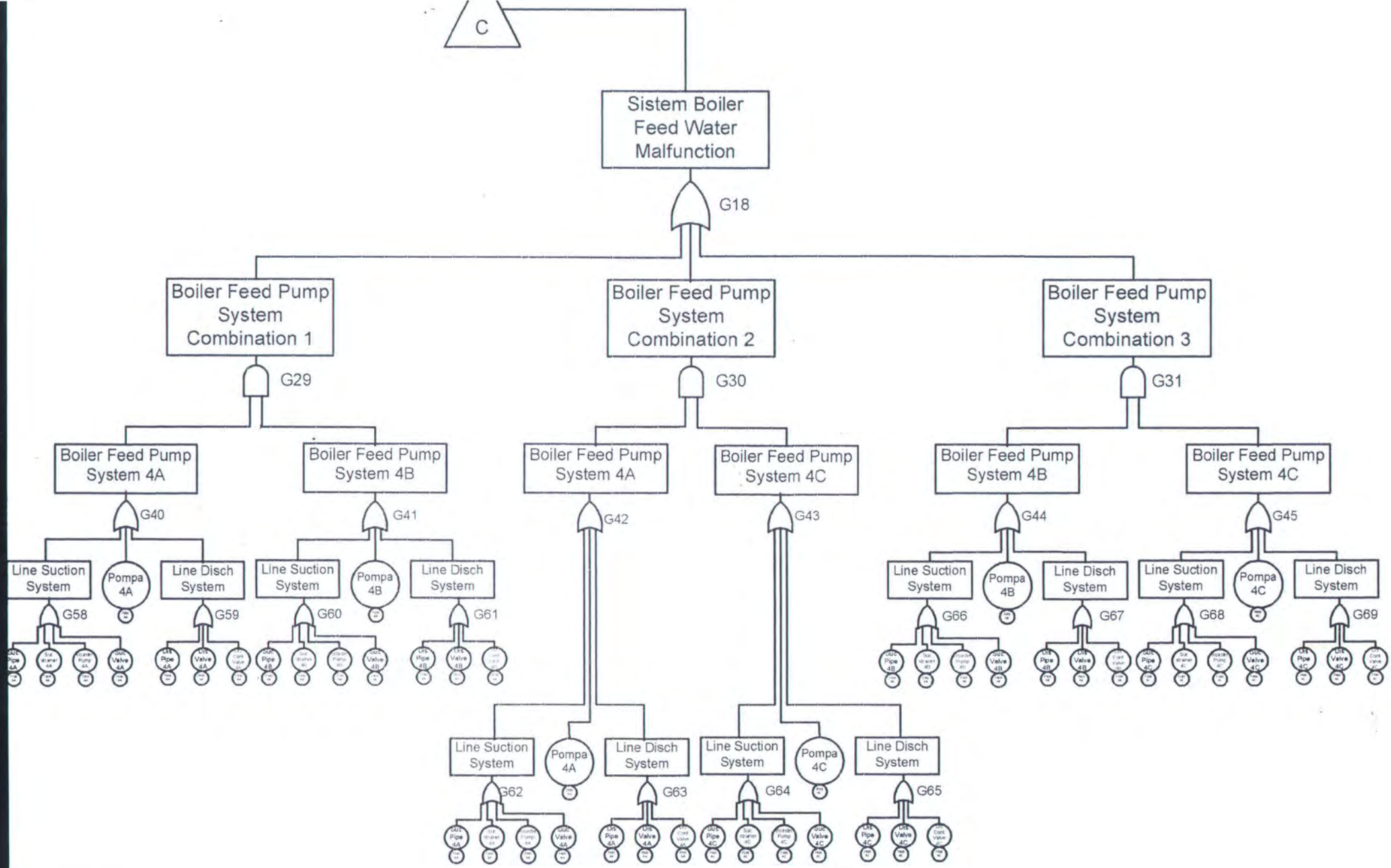

Secondary Superheater pecah
G0
Penurunan Kekuatan Material
G1
Over Pressure
G2
DRAFT INDICATOR FAIL
G84
Steam press cont
9100
FDF FAIL
G85
Draft Indicator A
9300 -A
Draft Indicator B
9300 -B
FDF A
9200 -A
FDF B
9200 -B
Penipisan Material
G3
Temperatur Material Overheating
G4
Erosi
G5
Korosi
G6
Suplai Air Kurang
G7
Kontak Langsung & Variasi Bunga Api
G8
A1
A2
B1
B2
G87
S B Electrical motor 1
1300 -1
S B Electrical motor 2
1300 -2
SOOT BLOWER RIGHT FAIL
G86
S B control 1
S B control 2
E2
Korosi Sisi Dalam
G9
Korosi Sisi Luar
02 Embrittlement
Kwalitas Feed Water
G14
Sodium sulfat dan Vanadium Attack
Dearator
2000
pH
Kandungan Cl
Condenser bocor
3000
Inhibitor Skid Sistem bahan bakar
4000

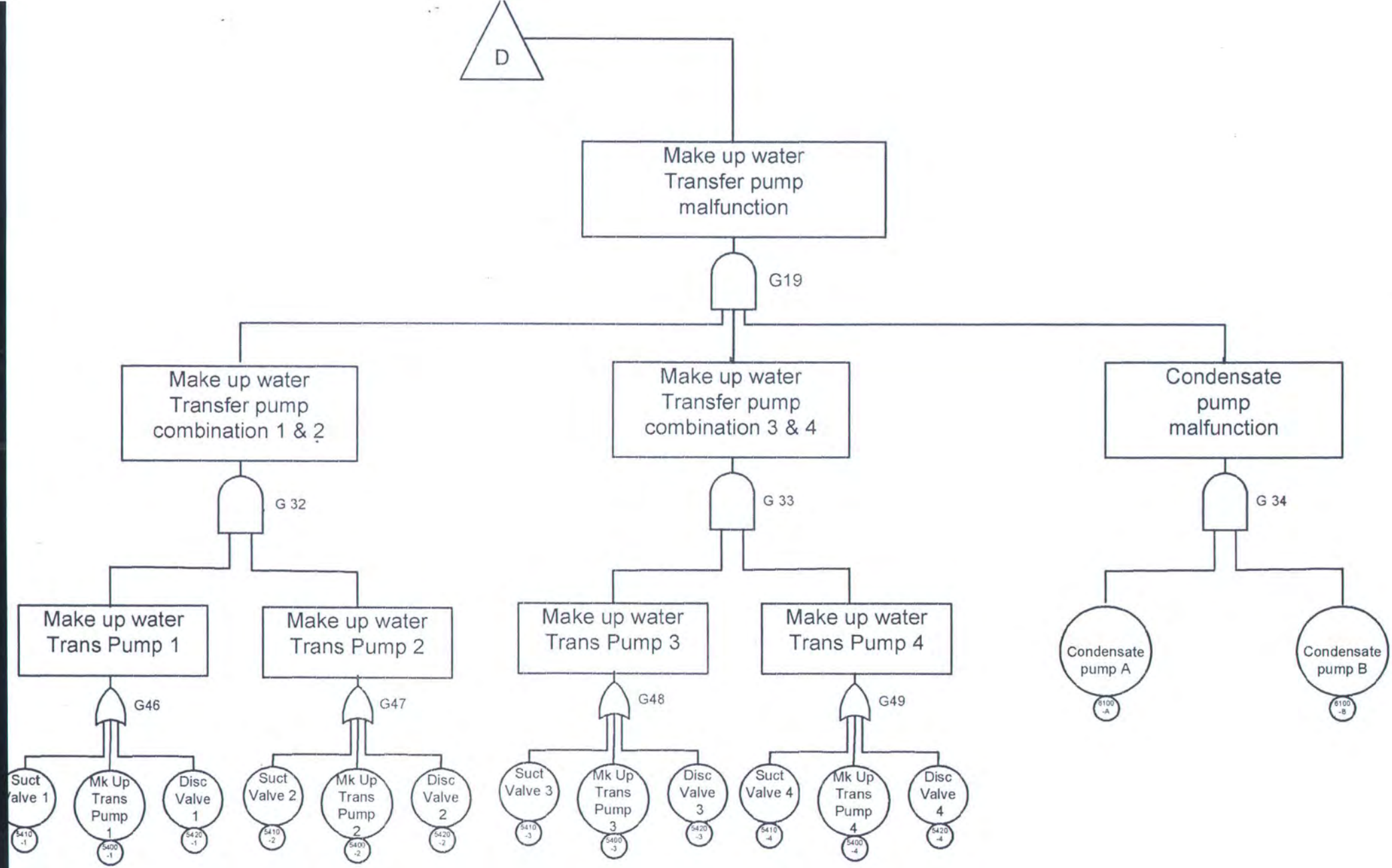

A1
Penyempitan sisi dalam Orifice Hanger dan Inlet Header
Scalling
G10
Pretreatment of Raw Water
Treatment of Make up Water
G20
G21
alination plant 1
Desalination plant 2
Desalination plant 3
Desalination plant 4
Water Treatment 1
Water Treatment 2
Water Treatment 3

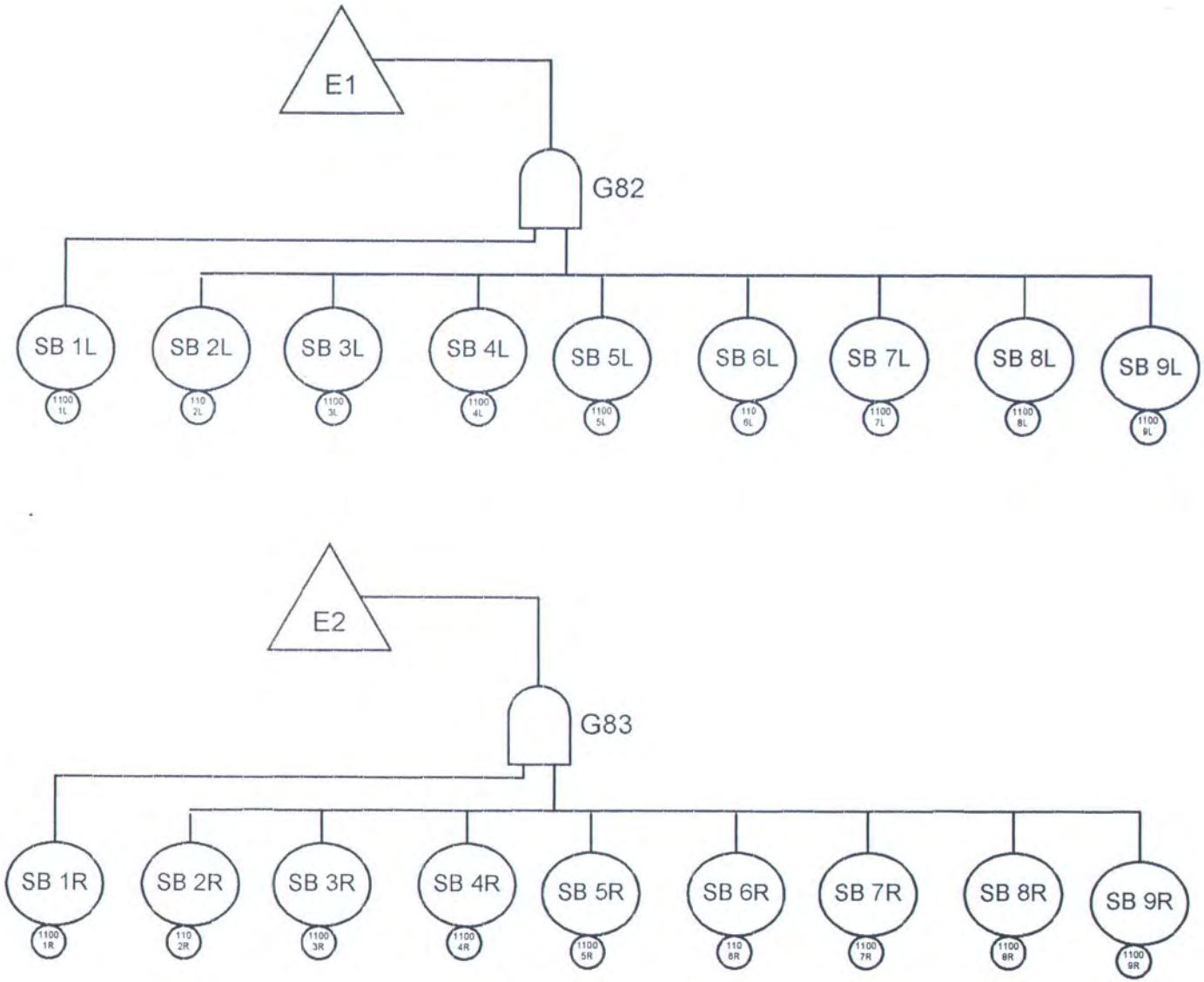



B1
Furnace Front Wall
G12
Burner A
Burner B
Burner C
G34
G35
G37
Burner A-2
Burner A-3
Burner A-4
Burner B-1
Burner B-2
Burner B-3
Burner B-4
Burner C-1
Burner C-2
Burner C-3
Burner C-4
9000 A2
9000 A3
9000 A4
9000 B1
9000 B2
9000 B3
9000 B4
9000 C1
9000 C2
9000 C3
9000 C4


B2
Furnace
Rear Wall
G13
Burner
A
Burner
B
G38
G39
Burner
A-5
Burner
A-6
Burner
A-7
Burner
A-8
Burner
B-5
Burner
B-6
Burner
B-7
Burner
B-8


C
Sistem Boiler Feed Water Malfunction
G18
Boiler Feed Pump System Combination 1
G29
Boiler Feed Pump System Combination 2
G30
Boiler Feed Pump System Combination 3
G31
Boiler Feed Pump System 4A
G40
Boiler Feed Pump System 4B
G41
Boiler Feed Pump System 4A
G42
Boiler Feed Pump System 4C
G43
Boiler Feed Pump System 4B
G44
Boiler Feed Pump System 4C
G45
Line Suction System
Pompa 4A
Line Disch System
G58
G59
Line Suction System
Pompa 4B
Line Disch System
G60
G61
Line Suction System
Pompa 4A
Line Disch System
G62
G63
Line Suction System
Pompa 4C
Line Disch System
G64
G65
Line Suction System
Pompa 4B
Line Disch System
G66
G67
Line Suction System
Pompa 4C
Line Disch System
G68
G69


D
Make up water Transfer pump malfunction
G19
Make up water Transfer pump combination 1 & 2
G 32
Make up water Transfer pump combination 3 & 4
G 33
Condensate pump malfunction
G 34
Make up water Trans Pump 1
Make up water Trans Pump 2
Make up water Trans Pump 3
Make up water Trans Pump 4
Condensate pump A
Condensate pump B
G46
G47
G48
G49
Suct Valve 1
Mk Up Trans Pump 1
Disc Valve 1
Suct Valve 2
Mk Up Trans Pump 2
Disc Valve 2
Suct Valve 3
Mk Up Trans Pump 3
Disc Valve 3
Suct Valve 4
Mk Up Trans Pump 4
Disc Valve 4


E1
G82
SB 1L
SB 2L
SB 3L
SB 4L
SB 5L
SB 6L
SB 7L
SB 8L
SB 9L
1100 1L
110 2L
1100 3L
1100 4L
1100 5L
110 6L
1100 7L
1100 8L
1100 9L
E2
G83
SB 1R
SB 2R
SB 3R
SB 4R
SB 5R
SB 6R
SB 7R
SB 8R
SB 9R
1100 1R
110 2R
1100 3R
1100 4R
1100 5R
110 6R
1100 7R
1100 8R
1100 9R

LAMPIRAN B
SPESIFIKASI

SPESIFIKASI HIGH PRESSURE HEATER

	HP 6	HP 7	HP 8
TYPE	Horizontal Closed tubular		
Total Heating Surface (m^2)	610	750	620
Feed water flow (kg/H)	652321	652321	652321
Feed Water inlet temp (^0C)	177,3	201,9	241,2
Feed Water Outlet Temp (^0C)	201,9	241,2	277,9
Heating steam flow (kg/H)	22802	49150	54191
Heating Steam pressure (kg/cm^2)	16,12	34,8	62,3
Heating steam temp (^0C)	439,9	318,35	398,28
Drain Flow (kg/H)	126143	103341	54191
Feed water velocity in Tubes (m/s)	1,9	1,9	1,9

SPESIFIKASI LOW PRESSURE HEATER

	LP 1	LP 2	LP 3	LP 4
TYPE	Horizontal Closed tubular			
Total Heating Surface (m^2)	270	260	280	230
Condensate flow (kg/H)	421580	512527	512527	512527
Condensate inlet temp (^0C)	50,9	85	102,6	126,2
Condensate Outlet Temp (^0C)	84,5	102,6	126,2	144,4
Heating steam flow (kg/H)	24381	14834	20269	16263
Heating Steam pressure (kg/cm^2)	0,644	1,249	2,67	4,51
Heating steam temp (^0C)	87,3	105,4	129,0	147,2
Drain Flow (kg/H)	90947	51366	36532	16263
Condensate velocity in Tubes (m/s)	2,1	2,1	2,1	2,1

SPESIFIKASI DEAERATOR

Type : Horizontal tray

Feed Water Quantity : 512527 kg/H

Heating Steam Flow : 23651 kg/H

Outlet temperature of feed water : 172,7 ^{0}C

Dissolved Oxygen contain of deaerated water 0,005 cc/L

Design Pressure : 9,9 kg/cm^{2}

Design Temp : 183 ^{0}C

Storage capacity of deaeratd water : 120 m^{2}

SPESIFIKASI CONDENSER

Type : Two pass, reverse flow, divided water box

Condenser Surface : 10590 m^{2}

Heat Quality Exchange : 2,141 x 10^{8} k cal/H

Vacum of Exhaust steam : 65 mmHg

Tube cleanless factor : 0,85

Heating transfer coefisien : 2883 kcal/ m^{2} H ^{0}C

Circulating Water

- Quality : sea water
- Quantity : 21660 m^{2} /H
- Inlet : 30 ^{0}C
- Temp Rise : 9,89 ^{0}C
- Velocity In tubes : 2 m/s

Condensate Temp : 43,1 ^{0}C

SPESIFIKASI GLAND STEAM CONDENSER

Type : Horizontal surface cooling type

Cooling Surface : 40 m^2

Cooling Water

Quality : Condensate

Quantity : 293926 kg/H (normal flow)

75000 kg/H (maximum flow)

Gland Steam Quantity : 1279 kg/H

Gland air Quantity : 344 kg/H

Design Press

Shell Side : Atmosfer

Tube Side : 29 kg/cm^2

Design Temp

Shell side : 100 ^0C

Tube Side : 65 ^0C

SPESIFIKASI FORCE DRAFT FAN

Design Data

Manufacture : EBARA

Type : Double inlet airfoil fan

Size :No 17 DMA

Type of Blade : Air foil

Numberof Blade : 12 x 2

Volume of Fan : 5560 m^3/min

Power Required : 1116 kw

Drive motor : 1220 kw

Eff : 81 %

SPESIFIKASI SEA WATER FEED PUMP

Type : Vertical mied flow type

Capacity : 321,1 m^3/H

Total Head: 33

Efficiency :74 %

NPSH : Ample

Rated Motor out put : 45 kw

Speed RPM : 1460

Discharge Size : 200 mm

SPESIFIKASI SEA WATER STRAINER

TYPE : Self cleaning type

Flow Rate: 300 m^3/H

Design Press : 4,5 kg/cm^2

Design Temp : 40 ^{0}C

Ratio of open are ; 2,6

Brush Speed : 4,7 rpm

Rate motor output : 0,4 kw

SPESIFIKASI DESALINATION PLANT

Type of process: Multi stage Flash, brine Recirculation

Scale Prevention : Scale inhibitor injection

Plat capacity : 500 Ton/ day

Performa Ratio : 6 kg distillate/ kg heating steam upstream of desuperheater

Quality product water

- Total Dissolved solid : less than 10 ppm
- Total iron : less than 0,2 ppm
- Ph : 6,5 – 7,0
- Temp : less than 40 ^{0} C

WATER TREATMENT

Process Demineralisasi

Kapasitas : 15 m^3/H

Conductivity : less than 1 µs/m

Silica less than 0,015 mg/L as Si02

Dissolven solid less than 0,4 mg/L as CaCo3

SPESIFIKASI WATER TREATMENT SUPPLY PUMP

Type : Centrifugal ETA N 65 X 50 – 160

Manufacture : Torishima

Capacity : 30 m^3/H

Discharged Head : 40 m

NPSH : 3,5

Speed : 2900 rpm

Shaft Horse power : 5,4 kw

Motor : 7,5 kw X 2p x 50 Hz

Weight

- Pump : 33 kg
- Complete : 141 kg

SPESIFIKASI SOOT BLOWING ELECTRIC MOTOR

Type : Motor driven long rectractable type

Model BLR – 503 – 65,5

Manufacture :KIKAN BUHIN MFG.CO. Ltd

Flow Rate : 3 660 kg/H

Operation travel	Total 5912 mm
	Blowing 5325 mm
	Speed 1256 mm/min
Operation Time	Total 9,4 min
	Blowing 8,5 min

SPESIFIKASI BOILER FEED PUMP

Model : 6 X 10 ¼ - 5 STAGE HDB

Number of stage : 5

Pump Speed : 750 rpm

Pump eff : 80 %

Shaft power : 2627,9 kw

Capacity : 365 Ton/H

Inlet Temperatur : 176,1 ^{0}C

Discharged Pressure : 202,5 kg/cm^{2}

Suction Pressure : 14 kg/cm^{2}

Total Pressure 188,5 kg/cm^{2}

SPESIFIKASI BOPSTER PUMP

Model 200 UCW

RPM : 1480

Doscharge pressure : 14 kg/cm^{2}

Suction Pressure : 10 kg/cm^2

Total Pressure : 4kg/cm^2

SPESIFIKASI MAKE UP WATER TRANSFER PUMP

Type :USEJ

Suc bore : 125 mm

Dis bore : 100 mm

Capacity : 80 m^3/H

Total Head 60 m

Speed : 3000 rpm

NPSH : 4M

1. Tubes

Classification of spare parts: Required

Name of equipment: Superheater, Attemperator and Reheater								
Ref. No.	Name of part	Outline sketch diagram and material	Quantity Spare	Quantity Work	Required Period for delivery	Manufacturer's drawing number	Storage place	Remarks
	Tubes	ϕ50.8 × ^{t}6 × L 7000 JIS-STB42	49m	2450m	4 months	PAA06184 & BAA06186	arrangement of Primary Superheater Tubes	
	Tubes	ϕ38.1 × ^{t}8.7 × L 7000 ※STBA27	63m	3150m	4 months	BAA07140 ~ BAA07147	Arrangement of Secondary Superheater Tubes	
	Tubes	ϕ38.1 × ^{t}4.4 × L 7000 ※STBA27	63m	3150m	4 months			
	Tubes	ϕ38.1 × ^{t}6.9 × L 7000 ※STBA27	126m	6300m	4 months			
	Tubes	ϕ31.9 × ^{t}4.4 × L 7000 JIS-SUS347HTB	14m	700m	4 months			
	Tubes	ϕ38.1 × ^{t}5.4 × L 7000 JIS-SUS347HTB	63m	3150m	4 months	BAA07148 & BAA07149	Arrangement of Final Superheater Tubes	

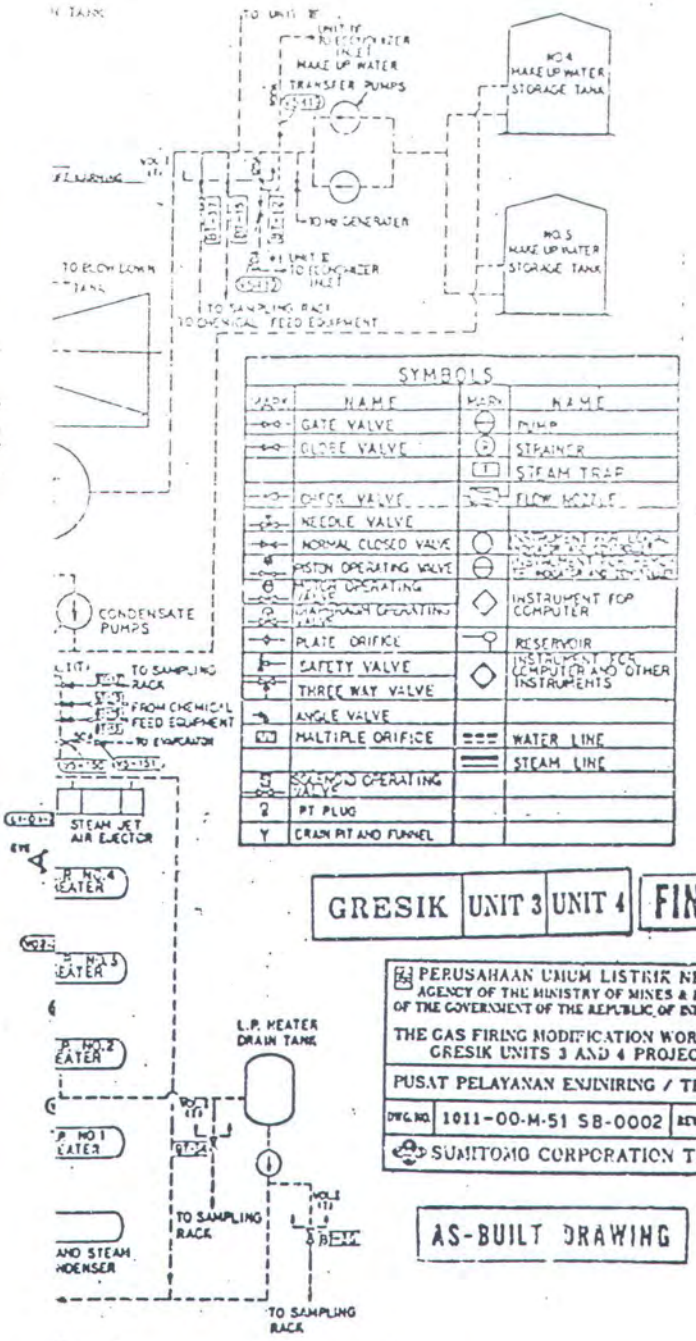
Table 4-2 (1/3)

IV-99

LAMPIRAN C
DIAGRAM SISTEM

第一角法 FIRST ANGLE PROJECTION

第三角法 THIRD ANGLE PROJECTION



SYMBOLS			
MARK	NAME	MARK	NAME
	GATE VALVE		PUMP
	GLOBE VALVE		STRAINER
			STEAM TRAP
	CHECK VALVE		FLOW NOZZLE
	NEEDLE VALVE		
	NORMAL CLOSED VALVE		
	PISTON OPERATING VALVE		
	MOTOR OPERATING VALVE		INSTRUMENT FOR COMPUTER
	DIAPHRAM OPERATING VALVE		
	PLATE ORIFICE		RESERVOIR
	SAFETY VALVE		INSTALMENT FOR COMPUTER AND OTHER INSTRUMENTS
	THREE WAY VALVE		
	ANGLE VALVE		
	MALTIPLE ORIFICE		WATER LINE
			STEAM LINE
S	SOLENOID OPERATING VALVE		
P	PT PLUG		
Y	DRAIN PIT AND FUNNEL		

GRESIK | UNIT 3 | UNIT 4 | **FINAL DRAWING**

PERUSAHAAN UMUM LISTRIK NEGARA
AGENCY OF THE MINISTRY OF MINES & ENERGY OF THE GOVERNMENT OF THE REPUBLIC OF INDONESIA

THE GAS FIRING MODIFICATION WORKS OF GRESIK UNITS 3 AND 4 PROJECT

PUSAT PELAYANAN ENJINIRING / TEPSCO

DWG NO. 1011-00-M-51 SB-0002 REV 01

SUMITOMO CORPORATION TOKYO

AS-BUILT DRAWING

NO	DATE	DESCRIPTION	DRAWN	DESIGNED	CHECKED	APPROVED
	1992	...used for final d... with SC/PLR/B-021		T.K		
B	Mar. 23 1992	Revised in accordance with TEPSCO's letter Ref.No.SDC-30001 dated 29 Nov.,1991 and transcribed the title on covering of A4 size to this drawing. Issued for final approval with SC/PLR/B-0080	T.Takahashi	K.H		
A	Sep. 27 1991	Issued for approval.	T.Takahashi	K.H		K.TADA
0	Sep. 3 1991	This dwg. is modified from original dwg. for the existing units(Work No. 5411-475, Dwg.No. BA96016 Rev.C), and added FCV(FY-76-1B to PRIMARY SPRAY WATER LINE.	T.M	K.H		K.TADA

SCALE

PERUSAHAAN UMUM LISTRIK NEGARA
JAKARTA INDONESIA
THE GAS FIRING MODIFICATION WORKS OF GRESIK UNITS 3 AND 4 PROJECT

1ST ANGLE PROJECTION

3RD ANGLE PROJECTION

FLOW DIAGRAM
STEAM AND WATER SYSTEM

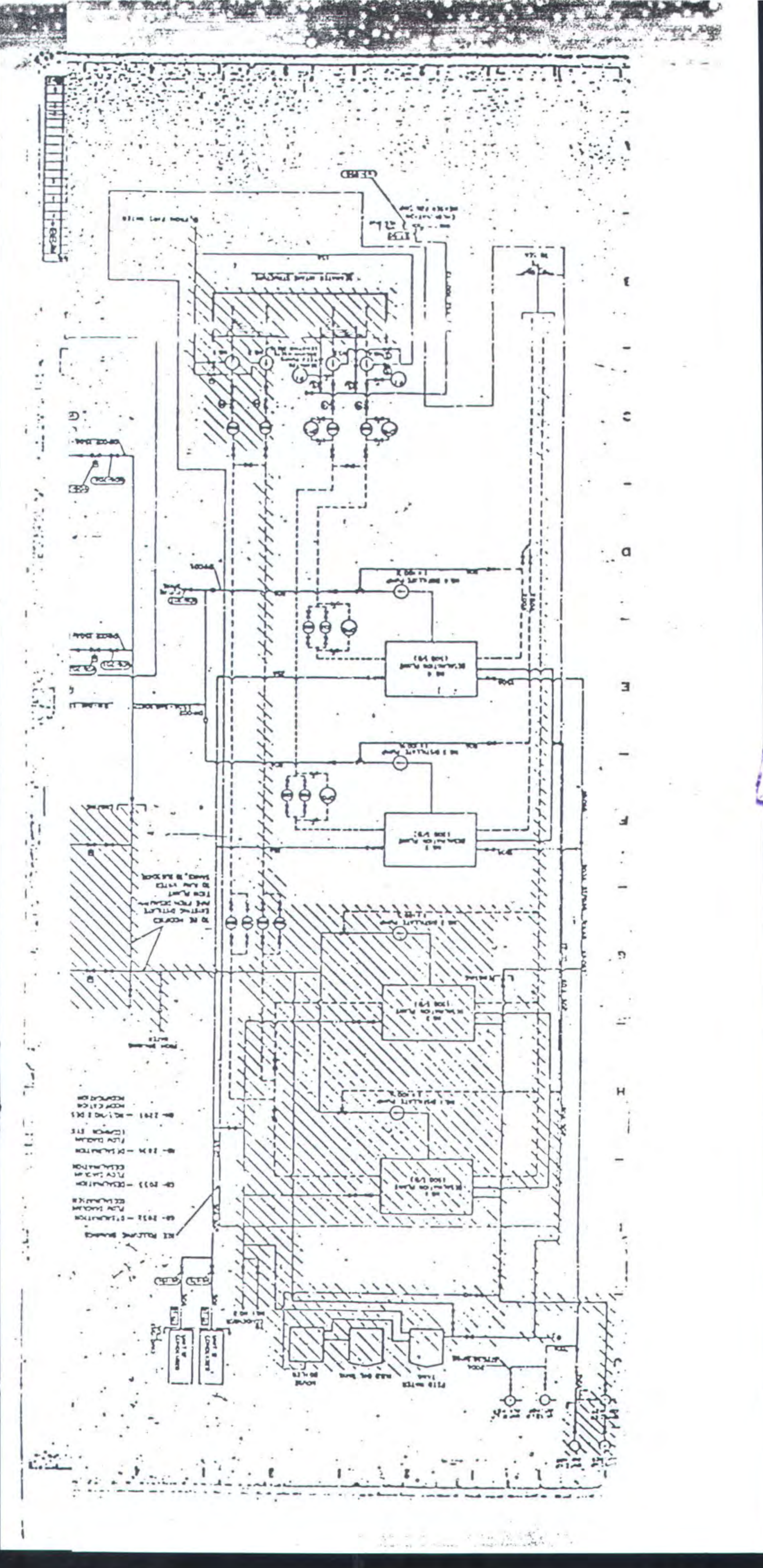
IHI CODE NO. K060-100

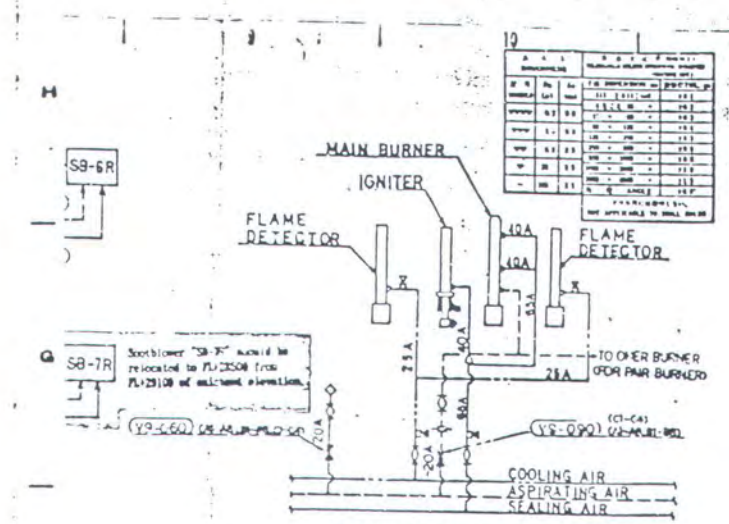
IHI BOILER PLANT DIV. PLANT DESIGN DEPT.

JOB NO. 5413-139

DRAWING NO. BAA06414 REV. B

Ishikawajima-Harima Heavy Industries Co., Ltd.





AS-BUILT DRAWING

FINAL DRAWING

GRESIK | UNIT 3 | UNIT 4

PERUSAHAAN UMUM LISTRIK NEGARA
AGENCY OF THE MINISTRY OF MINES & ENERGY OF THE GOVERNMENT OF THE REPUBLIC OF INDONESIA

THE GAS FIRING MODIFICATION WORKS OF GRESIK UNITS 3 AND 4 PROJECT

PUSAT PELAYANAN ENJINIRING / TEPSCO

DWG NO. 1011- REV

SUMITOMO CORPORATION TOKYO

NO	DATE	DESCRIPTION	DRAWN	DESIGNED	CHECKED	APPROVED
0	12 May 1993	Issued for final drawing with SC/PLN/B-0273	T.k.			
	Nov. 9 1992	Added ☐ parts to the as-built dwg. (Owner's dwg. No. 64-3023 & IHI's code No. K063- one of job no. 5411-475) for existent Unit 3 & 4, and prepared as new dwg. for the modification works. Issued for approval with SC/PLN/B-0983.				

PERUSAHAAN UMUM LISTRIK NEGARA
JAKARTA INDONESIA
THE GAS FIRING MODIFICATION WORKS OF GRESIK UNITS 3 AND 4 PROJECT

1ST ANGLE PROJECTION

3RD ANGLE PROJECTION

FLOW DIAGRAM
SEALING AND ASPIRATING AIR SYSTEM

IHI CODE NO. K061-115

IHI Boiler Plant Div. Plant Design Dept.

JOB NO. 5413-139

DRAWING NO. BA A 06633 REV. 0 1/1

Ishikawajima-Harima Heavy Industries Co., Ltd.

LAMPIRAN D
MOCUS

Algoritma MOCUS (Methode for Obtaining Cut Sets)

Step	1	2.	3	4	5	6	7	8	9	10	11
	G1	G3	G5	1100 1L,2L,3L, L,5L,6L,7 L,8L,9L 1200 ,2L,3L,L, 5L,6L,7L, 8L,9L 1200							
				G86	1200- 1,1200- 2						
				G87	1300 1,13002						
			G6	4000							
				G9	2000						
					G14	3000					
		G4	G7	G10	G20	5200 – 1,5200 – 2,5200 – 3,5200 – 4					
					G21	5300 – 1,5300 – 2,5300 – 3					
				G11	G15	G22,GG23	G50,G51,G23	5110-A,G51,G23	5110-A,5110-B,G23	5110-A,5110-B,G52,G53	5110-A,5110-B,5110-C,G53 5110-A,5110-B,G72,G53 5110-A,5110-B,5100-C,G53 5110-A,5110-B,5120-C,G53

									5110-A,G71,G23	5110-A,G76,G77,G23	5110-A,5141-1B,G77,G23 5110-A,5130-1B,G77,G23 5110-A,5142-1B,G77,G23
									5110-A,5100-B,G23	5110-A,5100-B,G52,G53	5110-A,5100-B,5110-C,G53 5110-A,5100-B,G72,G53 5110-A,5100-B,5100-C,G53 5110-A,5100-B,5120-C,G53
									5110-A,5120-B,G23	5110-A,5120-B,G52,G53	5110-A,5120-B,5110-C,G53 5110-A,5120-B,G72,G53 5110-A,5120-B,5100-C,G53 5110-A,5120-B,5120-C,G53
								G70,G51,G23	G74,G75,G51,G23	5141-1A, G75,G51,G23	5141-1A, 5141-2A,G51,G23 5141-1A, 5130-2A,G51,G23 5141-1A, 5142-2A,G51,G23
										5130-1A, G75,G51,G23	5130-1A, 5141-2A,G51,G23 5130-1A, 5130-2A,G51,G23 5130-1A, 5142-2A,G51,G23
										5142-1A, G75,G51,G23	5142-1A, 5141-2A,G51,G23 5142-1A, 5130-2A,G51,G23 5142-1A, 5142-2A,G51,G23
								5100-A,G51,G23	5100-A,5110-B,G23	5100-A,5110-B,G52,G53	5100-A,5110-B,5110-C,G53 5100-A,5110-B,G72,G53 5100-A,5110-B,5100-C,G53 5100-A,5110-B,5120-C,G53

									5100-A,G71,G23	5100-A,G76,G77,G23	5100-A,5141-1B,G77,G23 5100-A,5130-1B,G77,G23 5100-A,5142-1B,G77,G23
									5100-A,5100-B,G23	5100-A,5100-B,G52,G53	5100-A,5100-B,5110-C,G53 5100-A,5100-B,G72,G53 5100-A,5100-B,5100-C,G53 5100-A,5100-B,5120-C,G53
								5120-A,G51,G23	5100-A,5120-B,G23	5100-A,5120-B,G52,G53	5100-A,5120-B,5110-C,G53 5100-A,5120-B,G72,G53 5100-A,5120-B,5100-C,G53 5100-A,5120-B,5120-C,G53
					G16	G24,G25,G26	5410-1,G25,G26	5410-15410-2,G26	5410-1,5410-2,5410-3 5410-1,5410-2,5400-3 5410-1,5410-2,5420-3		
								5410-1,5400-2,G26	5410-1,5400-2,5410-3 5410-1,5400-2,5400-3 5410-1,5400-2,5420-3		
								5410-1,5420-2,G26	5410-1,5420-2,5410-3 5410-1,5420-2,5400-3 5410-1,5420-2,5420-3		
							5400-1,G25,G26	5400-15410-2,G26	5400-1,5410-2,5410-3 5400-1,5410-2,5400-3		

									5400-1,5410-2,5420-3		
								5400-1,5400-2,G26	5400-1,5400-2,5410-3 5400-1,5400-2,5400-3 5400-1,5400-2,5420-3		
								5400-1,5420-2,G26	5400-1,5420-2,5410-3 5400-1,5420-2,5400-3 5400-1,5420-2,5420-3		
							5420-1,G25,G26	5420-15410-2,G26	5420-1,5410-2,5410-3 5420-1,5410-2,5400-3 5420-1,5410-2,5420-3		
								5420-1,5400-2,G26	5420-1,5400-2,5410-3 5420-1,5400-2,5400-3 5420-1,5400-2,5420-3		
								5420-1,5420-2,G26	5420-1,5420-2,5410-3 5420-1,5420-2,5400-3 5420-1,5420-2,5420-3		
					G17	G27,G28	G54,G55,G28	5210-1,G55,G28	5210-1,5210-2,G28	5210-1,5210-2,G56,G57	5210-1,5210-2,5210-3,G57 5210-1,5210-2,5220-3,G57
									5210-1,5220-2,G28	5210-1,5220-2,G56,G57	5210-1,5220-2,5210-3,G57 5210-1,5220-2,5220-3,G57
								5220-1,G55,G28	5220-1,5210-2,G28	5220-1,5210-2,G56,G57	5220-1,5210-2,5210-3,G57 5220-1,5210-2,5220-3,G57
									5220-1,5220-2,G28	5220-1,5220-2,G56,G57	5220-1,5220-2,5210-3,G57 5220-1,5220-2,5220-3,G57

					G18	G29	G40,G41	G58,G41	7100-4A,G41	7100-4A,G60	7100-4A, 7100-4B 7100-4A, 7200-4B 7100-4A, 7300-4B 7100-4A, 7400-4B
										7100-4A,7000-4B	
										7100-4A,G61	7100-4A,7500-4B 7100-4A, 7600-4B 7100-4A, 7700-4B
									7200-4A,G41	7200-4A,G60	7200-4A, 7100-4B 7200-4A, 7200-4B 7200-4A, 7300-4B 7200-4A, 7400-4B
										7200-4A,7000-4B	
										7200-4A,G61	7200-4A,7500-4B 7200-4A, 7600-4B 7200-4A, 7700-4B
									7300-4A,G41	7300-4A,G60	7300-4A, 7100-4B 7300-4A, 7200-4B 7300-4A, 7300-4B 7300-4A, 7400-4B
										7300-4A,7000-4B	
										7300-4A,G61	7300-4A,7500-4B 7300-4A, 7600-4B

											7300-4A, 7700-4B
									7400-4A,G41	7400-4A,G60	7400-4A, 7100-4B 7400-4A, 7200-4B 7400-4A, 7300-4B 7400-4A, 7400-4B
										7400-4A,7000-4B	
										7400-4A,G61	7400-4A,7500-4B 7400-4A, 7600-4B 7400-4A, 7700-4B
								7000-4A,G41	7000-4A,G60	7000-4A, 7100-4B 7000-4A, 7200-4B 7000-4A, 7300-4B 7000-4A, 7400-4B
									7000-4A,7000-4B		
									7000-4A,G61	7000-4A, 7500-4B 7000-4A, 7600-4B 7000-4A, 7700-4B
								G59,G41	7500-4A,G41	7500-4A,G60	7500-4A, 7100-4B 7500-4A, 7200-4B 7500-4A, 7300-4B 7500-4A, 7400-4B
										7500-4A,7000-4B	
										7500-4A,G61	7500-4A, 7500-4B 7500-4A, 7600-4B 7500-4A, 7700-4B
									7600-4A,G41	7600-4A,G60	7600-4A, 7100-4B

											7600-4A, 7200-4B 7600-4A, 7300-4B 7600-4A, 7400-4B
										7600-4A,7000-4B	
										7600-4A,G61	7600-4A, 7500-4B 7600-4A, 7600-4B 7600-4A, 7700-4B
									7700-4A,G41	7700-4A,G60	7700-4A, 7100-4B 7700-4A, 7200-4B 7700-4A, 7300-4B 7700-4A, 7400-4B
										7700-4A,7000-4B	
										7700-4A,G61	7700-4A, 7500-4B 7700-4A, 7600-4B 7700-4A, 7700-4B
						G30	G42,G43	G62,G64	7100-4A,G43	7100-4A,G64	7100-4A, 7100-4C 7100-4A, 7200-4C 7100-4A, 7300-4C 7100-4A, 7400-4C
										7100-4A,7000-4C	
										7100-4A,G65	7100-4A,7500-4C 7100-4A, 7600-4C 7100-4A, 7700-4C
									7200-4A,G43	7200-4A,G64	7200-4A, 7100-4C 7200-4A, 7200-4C 7200-4A, 7300-4C

											7200-4A, 7400-4C
										7200-4A,7000-4C	
										7200-4A,G65	7200-4A,7500-4C 7200-4A, 7600-4C 7200-4A, 7700-4C
									7300-4A,G43	7300-4A,G64	7300-4A, 7100-4C 7300-4A, 7200-4C 7300-4A, 7300-4C 7300-4A, 7400-4C
										7300-4A,7000-4C	
										7300-4A,G65	7300-4A,7500-4C 7300-4A, 7600-4C 7300-4A, 7700-4C
									7400-4A,G43	7400-4A,G64	7400-4A, 7100-4C 7400-4A, 7200-4C 7400-4A, 7300-4C 7400-4A, 7400-4C
										7400-4A,7000-4C	
										7400-4A,G65	7400-4A,7500-4C 7400-4A, 7600-4C 7400-4A, 7700-4C
									7000-4A,G43	7000-4A,G64	7000-4A, 7100-4C 7000-4A, 7200-4C 7000-4A, 7300-4C 7000-4A, 7400-4C

									7000-4A,7000-4C		
									7000-4A,G65	7000-4A, 7500-4C 7000-4A, 7600-4C 7000-4A, 7700-4C	
								G63,G43	7500-4A,G43	7500-4A,G64	7500-4A, 7100-4C 7500-4A, 7200-4C 7500-4A, 7300-4C 7500-4A, 7400-4C
										7500-4A,7000-4C	
										7500-4A,G65	7500-4A, 7500-4C 7500-4A, 7600-4C 7500-4A, 7700-4C
									7600-4A,G43	7600-4A,G64	7600-4A, 7100-4C 7600-4A, 7200-4C 7600-4A, 7300-4C 7600-4A, 7400-4C
										7600-4A,7000-4C	
										7600-4A,G65	7600-4A, 7500-4C 7600-4A, 7600-4C 7600-4A, 7700-4C
									7700-4A,G43	7700-4A,G64	7700-4A, 7100-4C 7700-4A, 7200-4C 7700-4A, 7300-4C 7700-4A, 7400-4C
										7700-4A,7000-4C	
										7700-4A,G65	7700-4A, 7500-4C

											7700-4A, 7600-4C 7700-4A, 7700-4C
						G31	G44,G45	G66,G68	7100-4B,G45	7100-4B,G68	7100-4B, 7100-4C 7100-4B, 7200-4C 7100-4B, 7300-4C 7100-4B, 7400-4C
										7100-4B,7000-4C	
										7100-4B,G69	7100-4B, 7500-4C 7100-4B, 7600-4C 7100-4B, 7700-4C
									7200-4B,G45	7200-4B,G68	7200-4B, 7100-4C 7200-4B, 7200-4C 7200-4B, 7300-4C 7200-4B, 7400-4C
										7200-4B,7000-4C	
										7200-4A,G69	7200-4B, 7500-4C 7200-4B, 7600-4C 7200-4B, 7700-4C
									7300-4B,G45	7300-4B,G68	7300-4B, 7100-4C 7300-4B, 7200-4C 7300-4B, 7300-4C 7300-4B, 7400-4C
										7300-4B,7000-4C	
										7300-4B,G69	7300-4B, 7500-4C 7300-4B, 7600-4C

											7300-4B, 7700-4C
									7400-4B,G45	7400-4B,G68	7400-4B, 7100-4C 7400-4B, 7200-4C 7400-4B, 7300-4C 7400-4B, 7400-4C
										7400-4B,7000-4C	
										7400-4B,G69	7400-4B, 7500-4C 7400-4B, 7600-4C 7400-4, 7700-4C
									7000-4B,G45	7000-4B,G68	7000-4B, 7100-4C 7000-4B, 7200-4C 7000-4B, 7300-4C 7000-4B, 7400-4C
										7000-4B,7000-4C	
										7000-4,G69	7000-4B, 7500-4C 7000-4B, 7600-4C 7000-4B, 7700-4C
									G67,G45	7500-4B,G45	7500-4B,G68	7500-4B, 7100-4C 7500-4B, 7200-4C 7500-4B, 7300-4C 7500-4B, 7400-4C
											7500-4B,7000-4C	
											7500-4B,G69	7500-4B, 7500-4C 7500-4B, 7600-4C 7500-4B, 7700-4C
										7600-4B,G435	7600-4B,G68	7600-4B, 7100-4C

											7600-4B, 7200-4C 7600-4B, 7300-4C 7600-4B, 7400-4C
										7600-4B,7000-4C	
										7600-4B,G69	7600-B, 7500-4C 7600-B, 7600-4C 7600-B, 7700-4C
									7700-4B,G45	7700-4B,G68	7700-4B, 7100-4C 7700-4B, 7200-4C 7700-4B, 7300-4C 7700-4B, 7400-4C
										7700-4B,7000-4C	
										7700-4B,G65	7700-4B, 7500-4C 7700-4B, 7600-4C 7700-4B, 7700-4C
					G19	G32,G33,G34	G46,G47,G33,G34	5410-1,G47,G33,G34	5410-1,5410-2,G33,G34	5410-1,5410-2,G48,G49,G34	5410-1,5410-2,5410-3,G49,G34 5410-1,5410-2,5400-3,G49,G34 5410-1,5410-2,5420-3,G49,G34
									5410-1,5400-2,G33,G34	5410-1,5400-2,G48,G49,G34	5410-1,5400-2,5410-3,G49,G34 5410-1,5400-2,5400-3,G49,G34 5410-1,5400-2,5420-3,G49,G34
									5410-1,5420-2,G33,G34	5410-1,5420-2,G48,G49,G34	5410-1,5420-2,5410-3,G49,G34 5410-1,5420-2,5400-3,G49,G34 5410-1,5420-2,5420-3,G49,G34
								5400-1,G47,G33,G34	5400-1,5410-2,G33,G34	5400-1,5410-2,G48,G49,G34	5400-1,5410-2,5410-3,G49,G34 5400-1,5410-2,5400-3,G49,G34 5400-1,5410-2,5420-3,G49,G34

									5400-1,5400-2,G33,G34	5400-1,5400-2,G48,G49,G34	5400-1,5400-2,5410-3,G49,G34 5400-1,5400-2,5400-3,G49,G34 5400-1,5400-2,5420-3,G49,G34
									5400-1,5420-2,G33,G34	5400-1,5420-2,G48,G49,G34	5400-1,5420-2,5410-3,G49,G34 5400-1,5420-2,5400-3,G49,G34 5400-1,5420-2,5420-3,G49,G34
								5420-1,G47,G33,G34	5420-1,5410-2,G33,G34	5420-1,5410-2,G48,G49,G34	5420-1,5410-2,5410-3,G49,G34 5420-1,5410-2,5400-3,G49,G34 5420-1,5410-2,5420-3,G49,G34
									5420-1,5400-2,G33,G34	5420-1,5400-2,G48,G49,G34	5420-1,5400-2,5410-3,G49,G34 5420-1,5400-2,5400-3,G49,G34 5420-1,5400-2,5420-3,G49,G34
									5420-1,5420-2,G33,G34	5420-1,5420-2,G48,G49,G34	5420-1,5420-2,5410-3,G49,G34 5420-1,5420-2,5400-3,G49,G34 5420-1,5420-2,5420-3,G49,G34
			G8	G12	G35	8000-A1,8000 A-2,8000 A-3,8000 A4					
					G36	8000 B-1,8000 B-2,8000 B-3,8000 B-4					
					G37	8000 C-1,8000 C-2,8000 C-3,8000 C-4					

				G13		8000- A5,8000 A- 6,8000 A- 7,8000 A-8 8000 B- 5,8000 B- 6,8000 B- 7,8000 B-8					
	G2	G84 9100 G85	9300 A,93 00B 9200 A,92 00B								

Algoritma MOCUS (Methode for Obtaining Cut Sets)

11	12	13	14	15
5110-A,5110-B,5110-C,G53	5110-A,5110-B,5110-C,5110-D 5110-A,5110-B,5110-C,G73	5110-A,5110-B,5110-C,G80,G81	5110-A,5110-B,5110-C,5141-1D,G81	5110-A,5110-B,5110-C,5141-1D,5141-2D 5110-A,5110-B,5110-C,5141-1D,5130-2D 5110-A,5110-B,5110-C,5141-1D,5142-2D
			5110-A,5110-B,5110-C,5130-1D,G81	5110-A,5110-B,5110-C,5130-1D,5141-2D 5110-A,5110-B,5110-C,5130-1D,5130-2D 5110-A,5110-B,5110-C,5130-1D,5142-2D
			5110-A,5110-B,5110-C,5142-1D,G81	5110-A,5110-B,5110-C,5142-1D,5141-2D

				5110-A,5110-B,5110-C,5142-1D,5130-2D 5110-A,5110-B,5110-C,5142-1D,5142-2D
	5110-A,5110-B,5110-C,5100-D 5110-A,5110-B,5110-C,5120-D			
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			5110-A,5141-1B,5141-2B,5100-C,G53	5110-A,5141-1B,5141-2B,5100-C,5110-D 5110-A,5141-1B,5141-2B,5100-C,G73 5110-A,5141-1B,5141-2B,5100-C,5100-D 5110-A,5141-1B,5141-2B,5100-C,5120-D
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				5110-A,5141-1B,5130-2B,5110-C,5100-D 5110-A,5141-1B,5130-2B,5110-C,5120-D
			5110-A,5141-1B,5130-2B,G72,G53	5110-A,5141-1B,5130-2B,G78,G79,G53
			5110-A,5141-1B,5130-2B,5100-C,G53	5110-A,5141-1B,5130-2B,5100-C,5110-D 5110-A,5141-1B,5130-2B,5100-C,G73 5110-A,5141-1B,5130-2B,5100-C,5100-D 5110-A,5141-1B,5130-2B,5100-C,5120-D
			5110-A,5141-1B,5130-2B,5120-C,G53	5110-A,5141-1B,5130-2B,5120-C,5110-D 5110-A,5141-1B,5130-2B,5120-C,G73 5110-A,5141-1B,5130-2B,5120-C,5100-D 5110-A,5141-1B,5130-2B,5120-C,5120-D
	5110-A,5141-1B,5142-2B,G23	5110-A,5141-1B,5142-2B,G52,G53	5110-A,5141-1B,5142-2B,5110-C,G53	5110-A,5141-1B,5142-2B,5110-C,5110-D 5110-A,5141-1B,5142-2B,5110-C,G73 5110-A,5141-1B,5142-2B,5110-C,5100-D 5110-A,5141-1B,5142-2B,5110-C,5120-D
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			5110-A,5141-1B,5142-2B,5100-C,G53	5110-A,5141-1B,5142-2B,5100-C,5110-D 5110-A,5141-1B,5142-2B,5100-C,G73 5110-A,5141-1B,5142-2B,5100-C,5100-D 5110-A,5141-1B,5142-2B,5100-C,5120-D
			5110-A,5141-1B,5142-2B,5120-C,G53	5110-A,5141-1B,5142-2B,5120-C,5110-D 5110-A,5141-1B,5142-2B,5120-C,G73 5110-A,5141-1B,5142-2B,5120-C,5100-D 5110-A,5141-1B,5142-2B,5120-C,5120-D
5110-A,5130-1B,G77,G23	5110-A,5130-1B,5141-2B,G23	5110-A,5130-1B,5141-2B,G52,G53	5110-A,5130-1B,5141-2B,5110-C,G53	5110-A,5130-1B,5141-2B,5110-C,5110-D 5110-A,5130-1B,5141-2B,5110-C,G73

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			5110-A,5130-1B,5141-2B,G72,G53	5110-A,5130-1B,5141-2B,G78,G79,G53
			5110-A,5130-1B,5141-2B,5100-C,G53	5110-A,5130-1B,5141-2B,5100-C,5110-D 5110-A,5130-1B,5141-2B,5100-C,G73 5110-A,5130-1B,5141-2B,5100-C,5100-D 5110-A,5130-1B,5141-2B,5100-C,5120-D
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	5110-A,5130-1B,5130-2B,G23	5110-A,5130-1B,5130-2B,G52,G53	5110-A,5130-1B,5130-2B,5110-C,G53	5110-A,5130-1B,5130-2B,5110-C,5110-D 5110-A,5130-1B,5130-2B,5110-C,G73 5110-A,5130-1B,5130-B,5110-C,5100-D 5110-A,5130-1B,5130-2B,5110-C,5120-D
			5110-A,5130-1B,5130-2B,G72,G53	5110-A,5130-1B,5130-2B,G78,G79,G53
			5110-A,5130-1B,5130-2B,5100-C,G53	5110-A,5130-1B,5130-2B,5100-C,5110-D 5110-A,5130-1B,5130-2B,5100-C,G73 5110-A,5130-1B,5130-2B,5100-C,5100-D 5110-A,5130-1B,5130-2B,5100-C,5120-D
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			5110-A,5130-1B,5142-2B,5100-C,G53	5110-A,5130-1B,5142-2B,5100-C,5110-D 5110-A,5130-1B,5142-2B,5100-C,G73 5110-A,5130-1B,5142-2B,5100-C,5100-D 5110-A,5130-1B,5142-2B,5100-C,5120-D
			5110-A,5130-1B,5142-2B,5120-C,G53	5110-A,5130-1B,5142-2B,5120-C,5110-D 5110-A,5130-1B,5142-2B,5120-C,G73 5110-A,5130-1B,5142-2B,5120-C,5100-D 5110-A,5130-1B,5142-2B,5120-C,5120-D
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			5110-A,5142-1B,5141-2B,G72,G53	5110-A,5142-1B,5141-2B,G78,G79,G53
			5110-A,5142-1B,5141-2B,5100-C,G53	5110-A,5142-1B,5141-2B,5100-C,5110-D 5110-A,5142-1B,5141-2B,5100-C,G73 5110-A,5142-1B,5141-2B,5100-C,5100-D 5110-A,5142-1B,5141-2B,5100-C,5120-D
			5110-A,5142-1B,5141-2B,5120-C,G53	5110-A,5142-1B,5141-2B,5120-C,5110-D 5110-A,5142-1B,5141-2B,5120-C,G73 5110-A,5142-1B,5141-2B,5120-C,5100-D 5110-A,5142-1B,5141-2B,5120-C,5120-D
	5110-A,5142-1B,5130-2B,G23	5110-A,5142-1B,5130-2B,G52,G53	5110-A,5142-1B,5130-2B,5110-C,G53	5110-A,5142-1B,5130-2B,5110-C,5110-D 5110-A,5142-1B,5130-2B,5110-C,G73 5110-A,5142-1B,5130-B,5110-C,5100-D 5110-A,5142-1B,5130-2B,5110-C,5120-D

			5110-A,5142-1B,5130-2B,G72,G53	5110-A,5142-1B,5130-2B,G78,G79,G53
			5110-A,5142-1B,5130-2B,5100-C,G53	5110-A,5142-1B,5130-2B,5100-C,5110-D 5110-A,5142-1B,5130-2B,5100-C,G73 5110-A,5142-1B,5130-2B,5100-C,5100-D 5110-A,5142-1B,5130-2B,5100-C,5120-D
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			5110-A,5142-1B,5142-2B,5100-C,G53	5110-A,5142-1B,5142-2B,5100-C,5110-D 5110-A,5142-1B,5142-2B,5100-C,G73 5110-A,5142-1B,5142-2B,5100-C,5100-D 5110-A,5142-1B,5142-2B,5100-C,5120-D
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		5110-A,5100-B,5142-1C,G79,G53	5110-A,5100-B,5142-1C,5141-2C,G53	5110-A,5100-B,5142-1C,5141-2C,5110-D
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			5110-A,5100-B,5142-1C,5130-2C,G53	5110-A,5100-B,5142-1C,5130-2C,5110-D
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			5110-A,5100-B,5142-1C,5142-2C,G53	5110-A,5100-B,5142-1C,5142-2C,5110-D
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				5110-A,5100-B,5142-1C,5142-2C,5120-D
5110-A,5100-B,5100-C,G53	5110-A,5100-B,5100-C,5110-D			
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		5110-A,5100-B,5100-C,5130-1D,G81	5110-A,5100-B,5100-C,5130-1D,5141-2D	
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			5110-A,5100-B,5110-C,5142-1D,G81	5110-A,5100-B,5110-C,5142-1D,5141-2D
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				5110-A,5100-B,5141-1C,5141-2C,5120-D
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				5110-A,5100-B,5141-1C,5130-2C,5120-D
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				5110-A,5100-B,5141-1C,5142-2C,5120-D
		5110-A,5100-B,5130-1C,G79,G53	5110-A,5100-B,5130-1C,5141-2C,G53	5110-A,5100-B,5130-1C,5141-2C,5110-D
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			5141-1A, 5141-2A,5110-B,5100-C,G53	5141-1A, 5141-2A,5110-B,5100-C,5110-D 5141-1A, 5141-2A,5110-B,5100-C,G73 5141-1A, 5141-2A,5110-B,5100-C,5100-D 5141-1A, 5141-2A,5110-B,5100-C,5120-D
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			5141-1A, 5141-2A,5100-B,5100-C,G53	5141-1A, 5141-2A,5100-B,5100-C,5110-D 5141-1A, 5141-2A,5100-B,5100-C,G73 5141-1A, 5141-2A,5100-B,5100-C,5100-D 5141-1A, 5141-2A,5100-B,5100-C,5120-D
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			5141-1A, 5141-2A,5120-B,5100-C,G53	5141-1A, 5141-2A,5120-B,5100-C,5110-D 5141-1A, 5141-2A,5120-B,5100-C,G73 5141-1A, 5141-2A,5120-B,5100-C,5100-D 5141-1A, 5141-2A,5120-B,5100-C,5120-D
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			5141-1A, 5130-2A,5110-B,5100-C,G53	5141-1A, 5130-2A,5110-B,5100-C,5110-D 5141-1A, 5130-2A,5110-B,5100-C,G73 5141-1A, 5130-2A,5110-B,5100-C,5100-D 5141-1A, 5130-2A,5110-B,5100-C,5120-D
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			5141-1A, 5130-2A,5120-B,5100-C,G53	5141-1A, 5130-2A,5120-B,5100-C,5110-D 5141-1A, 5130-2A,5120-B,5100-C,G73 5141-1A, 5130-2A,5120-B,5100-C,5100-D 5141-1A, 5130-2A,5120-B,5100-C,5120-D
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			5141-1A, 5142-2A,5100-B,5100-C,G53	5141-1A, 5142-2A,5100-B,5100-C,5110-D 5141-1A, 5142-2A,5100-B,5100-C,G73 5141-1A, 5142-2A,5100-B,5100-C,5100-D 5141-1A, 5142-2A,5100-B,5100-C,5120-D
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			5141-1A, 5142-2A,5120-B,5100-C,G53	5141-1A, 5142-2A,5120-B,5100-C,5110-D 5141-1A, 5142-2A,5120-B,5100-C,G73 5141-1A, 5142-2A,5120-B,5100-C,5100-D 5141-1A, 5142-2A,5120-B,5100-C,5120-D
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			5130-1A, 5142-2A,5110-B,5100-C,G53	5130-1A, 5142-2A,5110-B,5100-C,5110-D 5130-1A, 5142-2A,5110-B,5100-C,G73 5130-1A, 5142-2A,5110-B,5100-C,5100-D 5110-1A, 5142-2A,5110-B,5100-C,5120-D
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			5142-1A, 5141-2A,5100-B,5100-C,G53	5142-1A, 5141-2A,5100-B,5100-C,5110-D 5142-1A, 5141-2A,5100-B,5100-C,G73 5142-1A, 51412A,5100-B,5100-C,5100-D 5142-1A, 5141-2A,5100-B,5100-C,5120-D
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	5142-1A, 5141-2A,5120-B,G23	5142-1A, 5141-2A,5120-B,G23	5142-1A, 5141-2A,5120-B,5110-C,G53	5142-1A, 5141-2A,5120-B,5110-C,5110-D 5142-1A, 5141-2A,5120-B,5110-C,G73 514-1A, 5141-2A,5120-B,5110-C,5100-D 5142-1A, 5141-2A,5120-B,5110-C,5120-D
			5142-1A, 5141-2A,5120-B,G72,G53	5142-1A, 5141-2A,5120-B,G78,G79,G53
			5142-1A, 5141-2A,5120-B,5100-C,G53	5142-1A, 5141-2A,5120-B,5100-C,5110-D 5142-1A, 5141-2A,5120-B,5100-C,G73 5142-1A, 5141-2A,5120-B,5100-C,5100-D 5142-1A, 5141-2A,5120-B,5100-C,5120-D
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5142-1A, 5130-2A,G51,G23	5142-1A, 5130-2A,5110-B,G23	5142-1A, 5130-2A,5110-B,G23	5142-1A, 51430-2A,5110-B,5110-C,G53	5142-1A, 5130-2A,5110-B,5110-C,5110-D 5142-1A, 5130-2A,5110-B,5110-C,G73 5142-1A, 5130-2A,5110-B,5110-C,5100-D 5142-1A, 5130-2A,5110-B,5110-C,5120-D
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			5142-1A, 5130-2A,5110-B,5100-C,G53	5142-1A, 5130-2A,5110-B,5100-C,5110-D 5142-1A, 5130-2A,5110-B,5100-C,G73 5142-1A, 5130-2A,5110-B,5100-C,5100-D 5142-1A, 5130-2A,5110-B,5100-C,5120-D
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	5142-1A, 5130-2A,G72,G23	5142-1A, 5130-2A,G72,G23	5142-A, 5130-2A,5141-1C,G79,G23	5141-1A, 5130-2A,5141-1C,5141-2C,G23 5142-1A, 5130-A,5141-1C,5130-2C,G23 5142-1A, 5130-2A,5141-1C,5142-2C,G23
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			5142-1A, 5130-2A,5142-1C,G79,G23	5142-1A, 5130-2A,5142-1C,5141-2C,G23 5142-1A, 5130-2A,5142-1C,5130-2C,G23 5142-1A, 5130-2A,5142-1C,5142-2C,G23
	5142-1A, 5130-2A,5100-B,G23	5142-1A, 5130-2A,5100-B,G23	5142-1A, 5130-2A,5100-B,5110-C,G53	5142-1A, 5130-2A,5100-B,5110-C,5110-D 5142-1A, 5130-2A,5100-B,5110-C,G73 5142-1A, 5130-2A,5100-B,5110-C,5100-D 5142-1A, 5130-2A,5100-B,5110-C,5120-D
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			5142-1A, 5130-2A,5100-B,5100-C,G53	5142-1A, 5130-2A,5100-B,5100-C,5110-D 5142-1A, 5130-2A,5100-B,5100-C,G73 5142-1A, 5130-2A,5100-B,5100-C,5100-D 5142-1A, 5130-2A,5100-B,5100-C,5120-D
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	5142-1A, 5130-2A,5120-B,G23	5142-1A, 5130-2A,5120-B,G23	5142-1A, 5130-2A,5120-B,5110-C,G53	5142-1A, 5130-2A,5120-B,5110-C,5110-D 5142-1A, 5130-2A,5120-B,5110-C,G73 514-1A, 5130-2A,5120-B,5110-C,5100-D 5142-1A, 5130-2A,5120-B,5110-C,5120-D
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	5142-1A, 5142-2A,5100-B,G23	5142-1A, 5142-2A,5100-B,G23	5142-1A, 5142-2A,5100-B,5110-C,G53	5142-1A, 5142-2A,5100-B,5110-C,5110-D 5142-1A, 5142-2A,5100-B,5110-C,G73 5142-1A, 5142-2A,5100-B,5110-C,5100-D 5142-1A, 5142-2A,5100-B,5110-C,5120-D
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			5142-1A, 5142-2A,5100-B,5100-C,G53	5142-1A, 5142-2A,5100-B,5100-C,5110-D 5142-1A, 5142-2A,5100-B,5100-C,G73 5142-1A, 5142A,5100-B,5100-C,5100-D 5142-1A, 5142-2A,5100-B,5100-C,5120-D
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	5142-1A, 5142-2A,5120-B,G23	5142-1A, 5142-2A,5120-B,G23	5142-1A, 5142-2A,5120-B,5110-C,G53	5142-1A, 5142-2A,5120-B,5110-C,5110-D 5142-1A, 5142-2A,5120-B,5110-C,G73 514-1A, 5142-2A,5120-B,5110-C,5100-D 5142-1A, 5142-2A,5120-B,5110-C,5120-D
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			5142-1A, 5142-2A,5120-B,5100-C,G53	5142-1A, 5142-2A,5120-B,5100-C,5110-D 5142-1A, 5142-2A,5120-B,5100-C,G73 5142-1A, 5142-2A,5120-B,5100-C,5100-D 5142-1A, 5142-2A,5120-B,5100-C,5120-D
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			5100-A,5110-B,5110-C,5142-1D,G81	5100-A,5110-B,5110-C,5142-1D,5141-2D 5100-A,5110-B,5110-C,5142-1D,5130-2D 5100-A,5110-B,5110-C,5142-1D,5142-2D
	5100-A,5110-B,5110-C,5100-D 5100-A,5110-B,5110-C,5120-D			
5100-A,5110-B,G72,G53	5100-A,5110-B,G78,G79,G53	5100-A,5110-B,5141-1C,G79,G53	5100-A,5110-B,5141-1C,5141-2C,G53	5100-A,5110-B,5141-1C,5141-2C,5110-D 5100-A,5110-B,5141-1C,5141-2C,G80,G81 5100-A,5110-B,5141-1C,5141-2C,5100-D 5100-A,5110-B,5141-1C,5141-2C,5120-D
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			5100-A,5110-B,5130-1C,5142-2C,G53	5100-A,5110-B,5130-1C,5142-2C,5110-D
				5100-A,5110-B,5130-1C,5142-2C,G80,G81
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				5100-A,5110-B,5130-1C,5142-2C,5120-D
		5100-A,5110-B,5142-1C,G79,G53	5100-A,5110-B,5142-1C,5141-2C,G53	5100-A,5110-B,5142-1C,5141-2C,5110-D
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			5100-A,5110-B,5142-1C,5130-2C,G53	5100-A,5110-B,5142-1C,5130-2C,5110-D
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5100-A,5110-B,5100-C,G53	5100-A,5110-B,5100-C,5110-D			
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			5100-A,5110-B,5100-C,5130-1D,G81	5100-A,5110-B,5100-C,5130-1D,5141-2D
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			5100-A,5110-B,5120-C,5142-1D,G81	5100-A,5110-B,5120-C,5142-1D,5141-2D
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	5100-A,5110-B,5120-C,5120-D			
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			5100-A,5141-1B,5141-2B,G72,G53	5100-A,5141-1B,5141-2B,G78,G79,G53
			5100-A,5141-1B,5141-2B,5100-C,G53	5100-A,5141-1B,5141-2B,5100-C,5110-D
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			5100-A,5141-1B,5130-2B,G72,G53	5100-A,5141-1B,5130-2B,G78,G79,G53
			5100-A,5141-1B,5130-2B,5100-C,G53	5100-A,5141-1B,5130-2B,5100-C,5110-D 5100-A,5141-1B,5130-2B,5100-C,G73 5100-A,5141-1B,5130-2B,5100-C,5100-D 5100-A,5141-1B,5130-2B,5100-C,5120-D
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			5100-A,5141-1B,5142-2B,G72,G53	5100-A,5141-1B,5142-2B,G78,G79,G53
			5100-A,5141-1B,5142-2B,5100-C,G53	5100-A,5141-1B,5142-2B,5100-C,5110-D 5100-A,5141-1B,5142-2B,5100-C,G73 5100-A,5141-1B,5142-2B,5100-C,5100-D 5100-A,5141-1B,5142-2B,5100-C,5120-D

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			5100-A,5130-1B,5141-2B,G72,G53	5100-A,5130-1B,5141-2B,G78,G79,G53
			5100-A,5130-1B,5141-2B,5100-C,G53	5100-A,5130-1B,5141-2B,5100-C,5110-D 5100-A,5130-1B,5141-2B,5100-C,G73 5100-A,5130-1B,5141-2B,5100-C,5100-D 5100-A,5130-1B,5141-2B,5100-C,5120-D
			5100-A,5130-1B,5141-2B,5120-C,G53	5100-A,5130-1B,5141-2B,5120-C,5110-D 5100-A,5130-1B,5141-2B,5120-C,G73 5100-A,5130-1B,5141-2B,5120-C,5100-D 5100-A,5130-1B,5141-2B,5120-C,5120-D
	5100-A,5130-1B,5130-2B,G23	5100-A,5130-1B,5130-2B,G52,G53	5100-A,5130-1B,5130-2B,5110-C,G53	5100-A,5130-1B,5130-2B,5110-C,5110-D 5100-A,5130-1B,5130-2B,5110-C,G73 5100-A,5130-1B,5130-B,5110-C,5100-D 5100-A,5130-1B,5130-2B,5110-C,5120-D
			5100-A,5130-1B,5130-2B,G72,G53	5100-A,5130-1B,5130-2B,G78,G79,G53
			5100-A,5130-1B,5130-2B,5100-C,G53	5100-A,5130-1B,5130-2B,5100-C,5110-D 5100-A,5130-1B,5130-2B,5100-C,G73 5100-A,5130-1B,5130-2B,5100-C,5100-D 5100-A,5130-1B,5130-2B,5100-C,5120-D
			5100-A,5130-1B,5130-2B,5120-C,G53	5100-A,5130-1B,5130-2B,5120-C,5110-D

				5100-A,5142-1B,5141-2B,5120-C,5120-D
	5100-A,5142-1B,5130-2B,G23	5100-A,5142-1B,5130-2B,G52,G53	5100-A,5142-1B,5130-2B,5110-C,G53	5100-A,5142-1B,5130-2B,5110-C,5110-D 5100-A,5142-1B,5130-2B,5110-C,G73 5100-A,5142-1B,5130-B,5110-C,5100-D 5100-A,5142-1B,5130-2B,5110-C,5120-D
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			5100-A,5142-1B,5130-2B,5100-C,G53	5100-A,5142-1B,5130-2B,5100-C,5110-D 5100-A,5142-1B,5130-2B,5100-C,G73 5100-A,5142-1B,5130-2B,5100-C,5100-D 5100-A,5142-1B,5130-2B,5100-C,5120-D
			5100-A,5142-1B,5130-2B,5120-C,G53	5100-A,5142-1B,5130-2B,5120-C,5110-D 5100-A,5142-1B,5130-2B,5120-C,G73 5100-A,5142-1B,5130-2B,5120-C,5100-D 5100-A,5142-1B,5130-2B,5120-C,5120-D
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			5100-A,5142-1B,5142-2B,5100-C,G53	5100-A,5142-1B,5142-2B,5100-C,5110-D 5100-A,5142-1B,5142-2B,5100-C,G73 5100-A,5142-1B,5142-2B,5100-C,5100-D 5100-A,5142-1B,5142-2B,5100-C,5120-D
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5100-A,5100-B,G72,G53	5100-A,5100-B,G78,G79,G53	5100-A,5100-B,5141-1C,G79,G53	5100-A,5100-B,5141-1C,5141-2C,G53	5100-A,5100-B,5141-1C,5141-2C,5110-D 5100-A,5100-B,5141-1C,5141-2C,G80,G81 5100-A,5100-B,5141-1C,5141-2C,5100-D 5100-A,5100-B,5141-1C,5141-2C,5120-D
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		5100-A,5100-B,5142-1C,G79,G53	5100-A,5100-B,5142-1C,5141-2C,G53	5100-A,5100-B,5142-1C,5141-2C,5110-D
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5100-A,5100-B,5100-C,G53	5100-A,5100-B,5100-C,5110-D			
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			5100-A,5100-B,5100-C,5130-1D,G81	5100-A,5100-B,5100-C,5130-1D,5141-2D
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				5100-A,5100-B,5100-C,5130-1D,5142-2D
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	5100-A,5100-B,5100-C,5100-D			
	5100-A,5100-B,5100-C,5120-D			
5100-A,5100-B,5120-C,G53	5100-A,5100-B,5120-C,5110-D			
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				5100-A,5100-B,5120-C,5141-1D,5142-2D
			5100-A,5100-B,5120-C,5130-1D,G81	5100-A,5100-B,5120-C,5130-1D,5141-2D
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			5100-A,5100-B,5120-C,5142-1D,G81	5100-A,5100-B,5120-C,5142-1D,5141-2D
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				5100-A,5100-B,5120-C,5142-1D,5142-2D
	5100-A,5100-B,5120-C,5100-D			
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5100-A,5120-B,5110-C,G53	5100-A,5120-B,5110-C,5110-D			
	5100-A,5120-B,5110-C,G73	5100-A,5120-B,5110-C,G80,G81	5100-A,5120-B,5110-C,5141-1D,G81	5100-A,5120-B,5110-C,5141-1D,5141-2D
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				5100-A,5120-B,5110-C,5141-1D,5142-2D
			5100-A,5120-B,5110-C,5130-1D,G81	5100-A,5120-B,5110-C,5130-1D,5141-2D
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				5100-A,5120-B,5110-C,5130-1D,5142-2D
			5100-A,5120-B,5110-C,5142-1D,G81	5100-A,5120-B,5110-C,5142-1D,5141-2D
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5100-A,5120-B,G72,G53	5100-A,5120-B,G78,G79,G53	5100-A,5120-B,5141-1C,G79,G53	5100-A,5120-B,5141-1C,5141-2C,G53	5100-A,5120-B,5141-1C,5141-2C,5110-D 5100-A,5120-B,5141-1C,5141-2C,G80,G81 5100-A,5120-B,5141-1C,5141-2C,5100-D 5100-A,5120-B,5141-1C,5141-2C,5120-D
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			5100-A,5120-B,5141-1C,5142-2C,G53	5100-A,5120-B,5141-1C,5142-2C,5110-D 5100-A,5120-B,5141-1C,5142-2C,G80,G81 5100-A,5120-B,5141-1C,5142-2C,5100-D 5100-A,5120-B,5141-1C,5142-2C,5120-D
		5100-A,5120-B,5130-1C,G79,G53	5100-A,5120-B,5130-1C,5141-2C,G53	5100-A,5120-B,5130-1C,5141-2C,5110-D 5100-A,5120-B,5130-1C,5141-2C,G80,G81 5100-A,5120-B,5130-1C,5141-2C,5100-D 5100-A,5120-B,5130-1C,5141-2C,5120-D
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			5100-A,5120-B,5130-1C,5142-2C,G53	5100-A,5120-B,5130-1C,5142-2C,5110-D 5100-A,5120-B,5130-1C,5142-2C,G80,G81 5100-A,5120-B,5130-1C,5142-2C,5100-D 5100-A,5120-B,5130-1C,5142-2C,5120-D
		5100-A,5120-B,5142-1C,G79,G53	5100-A,5120-B,5142-1C,5141-2C,G53	5100-A,5120-B,5142-1C,5141-2C,5110-D

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