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Troubleshooting Identification and Upset Conditions Effect of LNG Plant

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Abstract

The liquefied natural gas (LNG) plant has a lot of troubleshooting and upset conditions which appear during operating processing units for petroleum fields. These undesirable situations and obstacles have a great influence on plant performance and production. Therefore, the main objective of this paper is to identify LNG plant troubleshooting and determine its upset conditions. A full description for troubleshooting produced from operating plant units, which are not presented in operating manuals, is categorized. Additionally, the effect of upset conditions on each unit is presented. In order to solve these troubleshooting and disturbed situations, the best remedial and corrective actions are then proposed. The best operating practice is also suggested. A real case study of the LNG plant is done for the main 19 units of the plant: U01, U02, U07, U08, U12, U13, U14, U15, U16, U18, U51, U55, U56, U58, U63, U71, and U76. It is found that the effect of the upset condition are loss of electrical power, loss of instrument air, loss of gas feed, and troubleshooting. Most of the LNG units are suffering from disturbed conditions and troubleshooting during operation except U01, U02, U07, U65, and U71.

Keywords: *LNG plant; Troubleshooting; Good operating practice; Upset conditions.*

1. Introduction

LNG is an acronym for Liquefied Natural Gas, which is basically constituted of methane (C1) supplemented by ethane (C2), propane (C3), and butane (C4). LNG is an odorless, non-toxic, colorless, flammable, noncorrosive cryogenic liquid at normal atmospheric pressure, liquefied at -161ºc at 1.0 bar, owned vapor heavier than air < -130 ºC, cold burned when in contact, and expanded 600 x from liquid to gaseous [1-4]. The boiling point of LNG alters with its composition, typically –162C (–259 F). The LNG density typically ranges between 430 kg/m^3 and 470 kg/m^3 (3.5 to 4 lb/US gal), which is less than half the water density. However, natural gas released from the LNG may produce asphyxiation due to O_2 lack in an unventilated, closed area, and maybe ignited if combined with the right concentrations of air. Additionally, when LNG is released in an enclosed space or low spot, it will tend to displace air, causing the area hazardous for breathing [1,3]. In order to make LNG, the natural gas, which is coming from feed gas supply of gas or oil wells, should be processed through several separations and petrochemical processes' units in an LNG plant (Fig. 1).

LNG plants are classified into large baseload, peak-shaving, and small- to medium-scale plants depending on their sizes and functions. LNG plants of petroleum fields are extensively used all over the world. However, the majority of the baseload plants are positioned in large gas reservoirs in Asia, Australia, the Middle East, and West Africa and are megaprojects [1,4]. These plants provide natural gas as LNG from the natural gas fields to the remote consumer nations. However, all kinds of LNG plants have a lot of troubleshooting and problems during operating plants. This troubleshooting and problems, which occurred in plant units, lead to reduce plant profitability, safety, production, and performance. Moreover, they may cause hazards to the environment, personnel, and production. LNG plants may certainly lose their integrity due to some of this troubleshooting. Some of these problems and troubleshooting are previously presented stated by vendors and unit operating manual. In addition to those presented by vendors or unit operating manual, few authors, published articles, and textbooks have already discussed troubleshooting and unset conditions effect of LNG plants in general or for a specific unit. However, there are many upset conditions and troubleshooting that occurred during operating LNG plants, which are not presented or discussed previously.

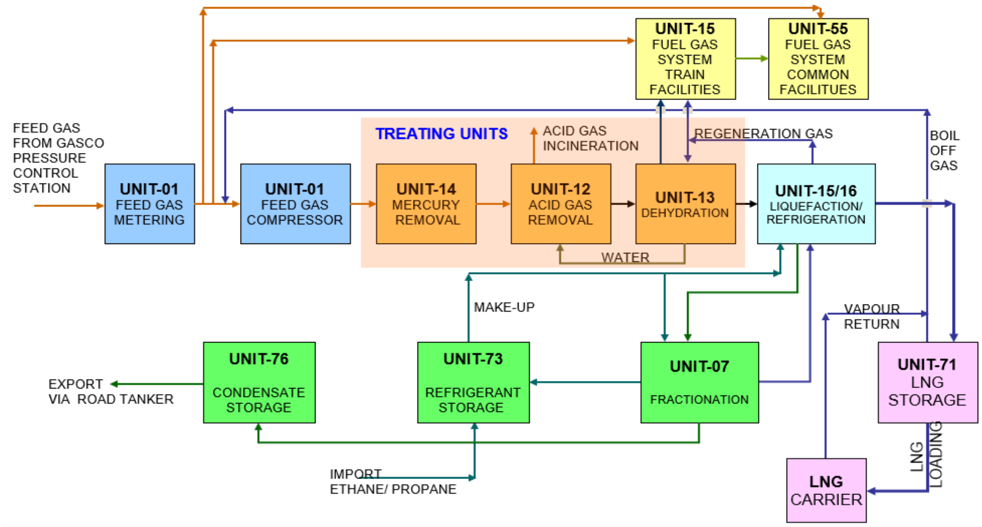

Fig. 1. LNG processes' units and block flow diagram

Consequently, the demand for a collective study to identify upset conditions effect and their remedial actions, troubleshooting causes and their corrective actions, and good practice operating guidelines for the LNG plant became extensively desirable. Therefore, the aim of this article is to identify and review LNG plant troubleshooting and upset conditions effect during operating. In order to maximize the profit contribution of plant processing facilities, optimize units' performance, reduce maintenance costs, and ascertain the integrity of processing units, remedial actions and corrective procedures are proposed.

2. LNG plant description and overview

The LNG plant facilities, located on the Mediterranean coast - seaport area, is designed to receive 5.93 bcm/year inlet natural gas, to handle 487 ton LNG/hour – 4.26 million ton LNG/year as production capacity, to provide 55,000 m^3 – 180,000 m^3 of LNG Cargo Ships as a Jetty berthing capacity, to store 2 x 135,000 m^3 of LNG as storage capacity for 7-8 days of production, to have performance efficiency of 87.7%, to be available 338 days/year (92.6% of the year), to reach 45% Turn Down Ratio using APCI technology, 295 Air Coolers as a cooling media, gas supply from sea gas grid and completely self-sufficient in utilities such as Power Generator (5 x 22.5 MW). The plant takes the natural gas from the gas grid at about 35°C and 33 bara and produces and store LNG at about -161°C and 1.1 bara. The LNG plant handles either "lean" gas having a low heavy hydrocarbon content or "rich" gas having a significant heavy hydrocarbon content. Feed gas arrives at the plant from the offshore gas network. The feed gas is metered by one of two ultrasonic flow meters 01-FT-3001 and 01-FT-3002. It is then compressed to 68bar_a, using a motor-driven centrifugal compressor (01-MJ01), to feed the LNG train. The LNG plant has a number of processing utility and offsite units. The flow diagram of the LNG units is shown in Fig. 2.

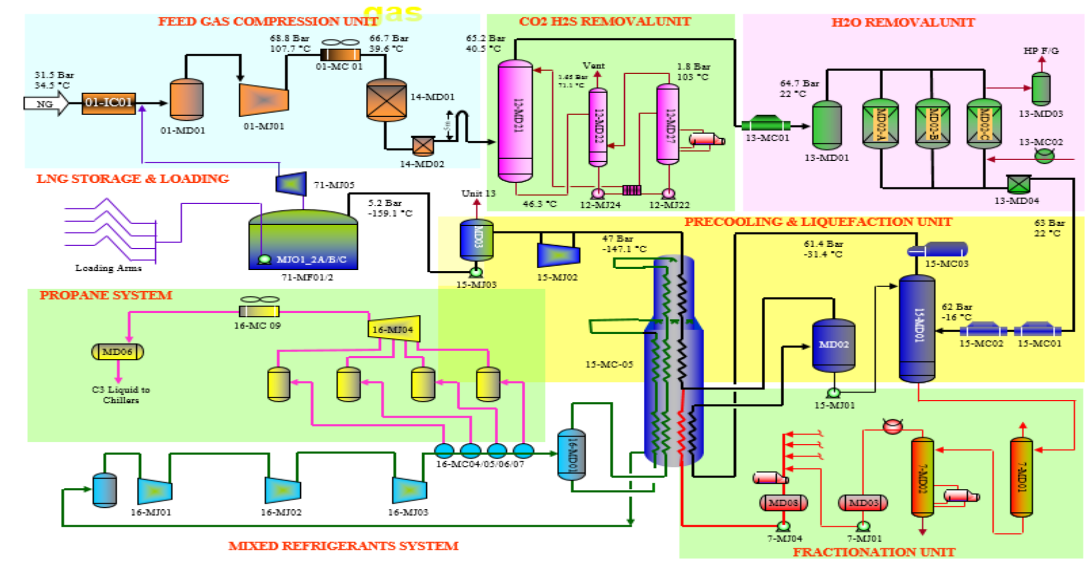

Fig. 2. LNG process train and units

3. Upset conditions effect and troubleshooting of LNG plant

3.1. Unit 01 – Plant feed conditioning

Upset conditions effect (UCE) on the plant feed conditioning of LNG plant include loss of electrical power, loss of instrument air, loss of feed gas, and unit troubleshooting:

I. Loss of electrical power. Loss of power to the compressor 01-MJ01 will trip the motor and will result in a train shutdown. Loss of power to the aftercooler 01-MC01 will not necessarily trip the feed gas compressor, but it is likely the feed gas compressor throughput will have to be reduced.

II. Loss of instrument air. Loss of instrument air will cause control valves to fail in their safe position. Consequences of the loss of instrument air for the major control and isolation valves are given: Valves 01-ESDV-1000, 01-ESDV-1012, 01-ESDV-1035 will fail close, and Valves 01-BDV1036, 01-UV1016, 01-BDV1040, 01-XV1063 will fail open.

III. Loss of feed gas. The loss of natural gas feed will result in a total shutdown of the system. The feed gas compressor can remain on full recycle until the conditions are stabilized, and the gas flow is re-established. (Depending on the nature of the trip). It may be necessary to shut down the compressor if the interruption is lengthy.

IV. Troubleshooting. No observed troubleshooting during operation other than that stated by vendor or existed in operating manuals.

3.2. Unit 02 – Acid gas removal (common facilities)

Acid gas removal unit of LNG plant is affected by certain upset conditions during operating such as:

I. Loss of electrical power. All pump motors will stop. Solvent circulation/transfer will cease. Close pump isolation valves. Close solvent transfer valve from offloading Containers/Drums. Ensure all water make-up valves are closed to the solvent inventory.

II. Loss of instrument air. Since there are no pneumatic control systems on this unit and level measurements are electronic, the loss of instrument air should not affect the system.

III. No observed troubleshooting during operations

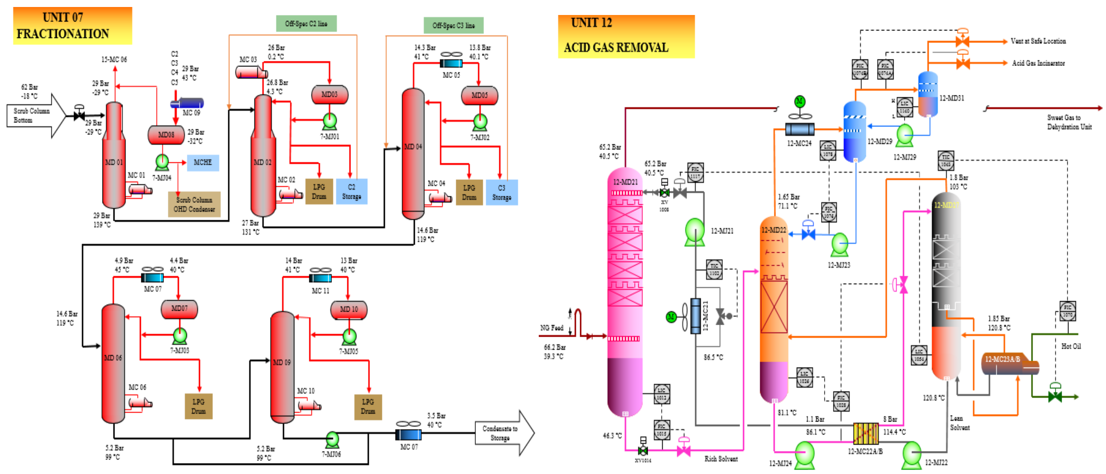

Fig. 3a. Unit 07-Fractionation 3b. Unit 12- Acid gas removal

3.3. Unit 07 – Train 1 Fractionation

Loss of Utilities and UCE of Train 1 fractionation of LNG plant (Fig. (3-a)) are divided into:

I. Loss of electrical power. A general loss of power causes the pumps to trip and would result in a loss of reflux to the columns, a high level in the bottom of the Depentanizer 07-MD09, and a high level in the LPG Reinjection Drum 07-MD08. The system is safeguarded by low flow alarms on the discharge of the reflux pumps, and high-level alarms in the Depentanizer, and LPG Reinjection Drum. When the MCC indicates both LPG Reinjection Pumps 07-MJ04/-A are stopped, Interlock I-720 will close 15-ESDV-1114 the LPG Reinjection into the MCHE 15-MC05, and 15-ESDV-1223, the LPG + Pentane Reinjection upstream of the Scrub Column Overhead Condenser, 15-MC03. For individual scenarios, the particular operating mode determines which of these ESDVs are actioned, depending upon the feed gas case. The Fractionation Refrigeration Package 07-ML01 will shut down. Loss of power may eventually lead to a Unit 07 shutdown. Following a Unit shutdown, all the liquid from the Scrub Column, 15-MD01, will be required to be manually routed to Unit 65 for disposal.

II. Loss of instrument air. The plant will continue to operate satisfactorily until the air pressure reduces significantly. This reduction in instrument air pressure will force all control valves to manual and fail to their safe position. This will rapidly cause interruption of the main process flow. NGL feed to the Fractionation Unit will cease, and all the liquid will remain in the Scrub Column, 15-MD01. Feed-in the Fractionation Unit will be effectively isolated in the columns, under pressure. In addition, hot oil flow to the reboilers will cease, and MP, LP propane flow from the Fractionation Refrigeration Package 07-ML01 will be lost. Loss of instrument air over a prolonged period may result in a de-pressuring of the entire plant, as air pressure is lost to blowdown valves. Although this is an extremely rare event, the operator should take the necessary precautions to depressurize the Unit in advance of an entire loss of instrument air.

III. Loss of feed. When Unit 07 is required to operate, it is an integral part of the LNG Train. Loss of natural gas feed to the plant will result in a total shutdown of the LNG train. Loss of feed to the Fractionation Unit 07 will result in a high liquid level accumulating in the Scrub Column 15-MD01. This is safeguarded by a high-level alarm 15-LIC 1011. Reduced flows will feed the downstream columns, and the Unit will go into full recycling. All column bottoms FVs will close. The overhead vapour flows will reduce to maintain column pressure. As column levels fall, the vapour breakthrough protection interlocks are initiated on the columns: Deethanizer I-0710, Depropanizer I-0740, Debutanizer I-0760, and Depentanizer I-0765. A low liquid level sensed in the LPG Reinjection Drum 07-MD08, or 07-ESDV1209 positioned less than 80% open, will initiate Interlock I-0780, LPG Reinjection Backflow Protection. This ensures the LPG Reinjection Pumps 07-MJ04/-A are tripped and isolates the drum via Interlock I-0720. Since levels will fall in the reflux drums and product purity may be affected, controlled manual shutdown of the Unit should be initiated if the feed cannot be restored.

IV. Loss of hot oil. Hot Oil, as Shell Hermia 'B', supplies the reboiling capacity of the Unit. Loss of this heating medium will effectively stop all fractionation of the feed, and ultimately the bottom purity. Therefore, a controlled manual Unit 07 shutdown should be initiated to stop the feed flow forward.

V. Loss of cooling water. Tempered water is provided as cooling water in the lube oil coolers for the Fractionation Refrigeration Package 07-ML01 compressors. Since this package supplies the propane coolant to the LPG Reinjection Cooler 07-MC09, and the Deethaniser Condenser 07-MC03, these vapors will fail to be sufficiently condensed. A manual shutdown should be initiated to stabilize the plant.

3.4. Units 08, 18 and 58 – Hot Oil System (Common Facilities)

UCE of the hot oil system in the LNG plant is appeared in power loss, air instrument loss, and troubleshooting. They are explained as follows:

I. Loss of electrical power. Loss of electric power will trip the motor of the hot oil pump 08-MJ02, and it will shut the pump down. For unit 18, hot oil circulation will cease and restart the system as per the normal start procedure.

II. Loss of instrument air. Since there are no pneumatic control systems on this unit and pressure, level measurements are electronic; loss of instrument air should not affect the system. For units 18 and 58, will cease, loss of instrument air will activate the hot oil furnace trip as a result of the closure of fuel gas isolation valves. The flow of hot oil through the unit will cease, and all the control valves will go to the failsafe position.

III. Loss of feed or flow. Not Applicable but for unit 18, 18-MJ01, or 18-MJ01A failure. The spare pump will start up automatically. For unit 58, loss of Fuel Gas will result in a Hot Oil furnace, 58-MB01 trip due to flame out of burners. When fuel gas supplies are re-established, re-start the furnace as per the normal start-up procedure.

IV. Troubleshooting. Hot oil system has troubleshooting due to low discharge pressure problems at 08-PG-1001 (unit 08), 18-PG-1009/1011 (unit 18), and 58-PG-1010/1011 (unit 58) because of air in the system (pump gassed up), dirty suction strainer, and pump wear rings worn. The corrective actions are to vent pump, change over pumps and clean strainer, and change over pumps to check, respectively.

3.5. Unit 12 – Acid Gas Removal

UCE in LNG Plant that appeared in unit 12 (Fig. (3-b)) Includes:

I. Loss of electrical power. In the event of loss of electrical power, the train emergency shut down interlocks will ensure the safe shut down of unit 12 when Manual ESD HS - 1000 is operated. The emergency Diesel Generator, however, provides emergency lighting and other essential facilities. Load shedding is provided to cater to transient disturbances.

II. Loss of instrument air. Loss of instrument air requires immediate train shut down. The main air receiver has a capacity for 15 minutes of back-up supply if both instrument air compressors fail. Operation of the train emergency shut down interlocks will ensure the safe shut down of the train within this time when Manual ESD HS - 1000 is operated. Valves on critical service are provided with air reservoirs, which supply sufficient air for three strokes of the valve independent of the main air supply. The action of control and trip valves on-air failure is selected such that they move into a safe position. The control/trip valve isolations should be backed up by manual isolations where appropriate.

III. Loss of feed gas. Loss of feed gas will initiate a shutdown of Unit 12 via HS-1000. The diesel generators will supply essential power as defined in "loss of electrical power" and will allow the restart of the gas turbine generators when feed gas is restored.

IV. Troubleshooting. If there has been an emergency shutdown, investigate the cause of the stoppage, and rectify the problem. Consideration should be given to the following scenarios to aid speedy rectification:

- Re-establish solvent circulation. If the trip occurred due to charge or booster pump failure, restart the spare Pumps in the system to re-establish flows. Reset Unit 12 ICS when all trip signals are healthy. Re-establish normal flows and levels. Balance levels carefully. The inventory is seriously imbalanced at this stage, and care must be exercised in establishing adequate flow through 12-MD21 without losing the level in 12-MD27. Loss of level in 12-MD27 will indirectly reintroduce the trip condition. As the feed gas flow will not be interrupted during either of these pump losses, a CO_2 and H_2S breakthrough will occur within a few minutes of the loss of solvent flow. If the circulation cannot be re-established within this period, then the feed gas flow should be reduced by a reduction in LNG production. The analyzers must be closely monitored for the first signs of breakthrough during this period.
- Loss of heat transfer fluid. The loss of the Solvent Regenerator Reboilers 12-MC23-A/B will result in the loss of solvent regeneration capability resulting in a train shutdown if prolonged. The feed gas flow should be reduced. The analyzer 12-AI-1004 must be closely monitored for the first signs of breakthrough during this period. Shutdown 12-MJ23/23-A if the level cannot be maintained in 12-MD22.
- Loss of reflux pumps, 12-MJ23/23-A. If the reflux flow is not re-established quickly, the viscosity of the lean solvent will eventually increase because of the excessive loss of water. Increases in the solvent viscosity will reduce the heat transfer and mass transfer rates leading to poor heat exchange performance and more time required to absorb H2S and CO2 from the natural gas. The reboilers' 12-MC23-A/B temperature should be reduced to maintain the same overhead temperature.
- Loss of utility. It is divided into 1. Power failure: All pumps and fin fan motors will stop. Feed gas flow and solvent circulation will cease. Check all column and vessel levels, close level control valves after ensuring a good liquid inventory for a subsequent startup. Ensure that all water make-up valves are closed to the solvent inventory. Control 12-MD21 pressure by venting, as required, via 12-HIC-1005, 2. Instrument air failure: On instrument air supply failure, the fin fans for 12-MC21 and 12-MC24 will continue operating. The flow of feed gas through the unit will cease, and all control valves will go to the fail-safe position, 3. Acid gas incineration failure: An alternative route, when the incinerator has tripped or cannot receive the acid gas, is the high point vent to the atmosphere at the top of the propane refrigerant gas turbine stack. The flow is automatically diverted to this route by the action of 12-PV-1074B. Table A.1 shows troubleshooting for the antifoam injection package; 12-ml12 for Unit 12 – Acid Gas Removal.

3.6. Unit 13 – Dehydration

Emergency procedures effect and troubleshooting in LNG plant are:

I. Loss of electrical power. Loss of electrical power will cause the fan motors for the Regeneration Gas Cooler 13-MC03 to stop. If the regeneration cycle is in its heating stage, this may cause a high temperature that will close 13-XV-1059, interrupting the flow of regeneration gas to Unit 15 and diverting it to flare. The operation of the fuel gas system will not be affected, as the back-up supply to Unit 15 will take over automatically.

II. Loss of instrument air. Loss of instrument air will cause control valves to fail in their safe position. This will rapidly cause interruption of both the main gas processing flow and also the drier regeneration process. The sequencing valves around the drier will either fail locked or fail closed, depending on their function.

III. Loss of feed gas. Unit 13 is an integral part of the LNG train. Loss of natural gas feed will result in a total shutdown of the LNG train. An APCI and any Level II trip initiated downstream in Unit 15 will have the effect of firstly drastically reducing the gas flow then within two minutes, completely stopping the flow-through Unit 13. This does not create a problem in Unit 13 as the system can remain static until conditions are stabilized and the gas flow re-established (depending on the nature of the trip). It may be necessary to pause the regeneration cycle if the interruption is lengthy.

IV. Troubleshooting. Troubleshooting for dehydration unit occurred during operating are identified, and the remedial actions are proposed as shown in Table A.2

3.7. Unit 14 – Mercury removal

I. Loss of utilities and troubleshooting observed in Unit 14 – Mercury Removal are:

II. Loss of electrical power. Unit 14 is not directly affected by the loss of electrical power. A general loss of power will cause interruption of the main process gas flow. This does not create a problem in Unit 14 as the system can remain static until conditions are stabilized and the gas flow re-established.

III. Loss of instrument air. Loss of instrument air will cause control valves to fail in their safe position. This will rapidly cause interruption of the main process gas flow. This does not create a problem in Unit 14 as the system can remain static until conditions are stabilized and the gas flow re-established.

IV. Loss of feed gas. Unit 14 is an integral part of the LNG Train. The loss of natural gas feed will result in a total shutdown of the LNG Train. A trip initiated downstream of Unit 15 will have the effect of firstly drastically reducing the gas flow then within two minutes, completely stopping the flow-through Unit 14. This does not create a problem in Unit 14 as the system can remain static until conditions are stabilized and the gas flow re-established.

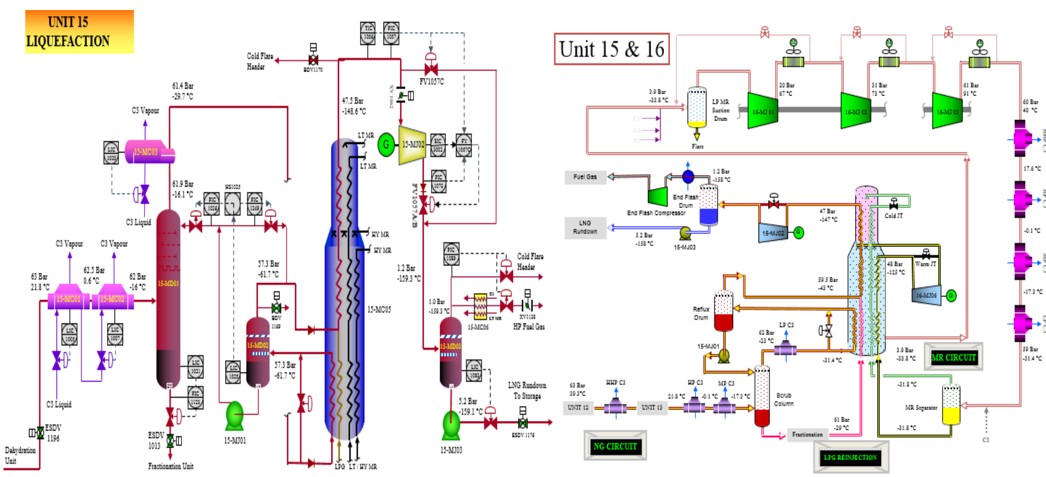

Fig. 4a. Liquefaction Unit 15; 4b. Refrigeration Unit 16

Table 1. Load shedding arrangement scenario

Status	Scenario	Outcome
Status 1	5 units online (80%), 1 unit trips	4 units online (100%), No load shedding required
Status 2	Plant at turndown, 4 units online (partially loaded), 1 unit trips	No-load shedding
Status 3	Actual power required exceeds that available	Trip End Flash Gas compressor, Trip 15-MC08

3.8. Unit 15 – Liquefaction

UCE and troubleshooting happened in unit 15 – liquefaction (Fig. (4-a)) are:

I. Loss of electrical power. There is three status defined for the electrical power/load shedding scenarios. Refer to Table 1 for details of the load shedding arrangement. With 5 units working in parallel operation (5 units at 80%) and one trips (Status 1) – the other 4 units at 100% will pick up the full load, so there is no change to the Liquefaction Unit operation. If 4 units are partially loaded and one trips but with the plant at turndown throughput, load shedding will not be required. Any other scenario may result in the power consumption exceeding that available – in this case, the End Flash Gas Compressor will be tripped along with 15-MC08. The Items on the Liquefaction Unit that are directly affected by the loss of electrical power are Scrub Column Reflux Pump (15-MJ01), LNG Expander (15-MJ02), LNG Product Pump (15-MJ03), End Flash Gas Compressor (15-MJ04), and End Flash Gas Coolers (15-MC08, 15-MC09, and 15-MC10)

II. Loss of instrument air. The plant will continue to operate satisfactorily until air header, and accumulator pressures fall. The operator must make a judgment as to the best course of action should the instrument air failure persist for a prolonged period. Loss of instrument air will cause control valves to fail to their safe position unless protected by air accumulators. This will rapidly cause interruption of both the main gas processing flow and the major liquid flows on the unit. Consequences of air failure for the major control and isolation valves are given below: The loss of instrument air, for a prolonged period, may ultimately result in loss of air to all of the blow-down valves. This will necessitate the depressurization of the entire plant. Action should be taken to depressure the plant in advance of a total loss of instrument air – should this unlikely event occur.

III. Loss of feed gas. Loss of feed gas will result in over cooling of the MCHE. The MR refrigeration produced will be fixed, at least in the initial part of the transient. The loss of feed gas will mean that the MR is not warmed as much as it would normally be prior to reaching the bottom of the MCHE. The control response is initially to raise the LNG flow controller setpoint 15-FIC-1057 in an attempt to raise the NG/LNG flow through the feed gas circuit. This will depressurize the NG stream in the upstream units. The temperature at the warm end of the MCHE will start to fall. Primary diagnostics will be:

- Propane compressor on recycling
- High levels in the propane kettles 16-MC04, 16-MC05, 16-MC06, 16-MC07
- Low LNG flow 15-FIC-105
- MR compressor low suction temperature alarm and recycle (Cold suction temperature protection).

Operator action is: Rapidly identify the cause of loss of feed gas and rectify, if possible. If feed gas cannot be re-established, manually initiate APCI Trip. A trip initiated in Unit 15 will have the effect of firstly reducing the gas flow drastically and then, within two minutes, stopping the flow completely through the Unit. This does not create a problem for the End Flash Gas Compressor as this can remain on full recycle until conditions are stabilized and the gas flow re-established (depending on the nature of the trip). It may be necessary to shut down the compressor if the interruption is lengthy. All other rotating equipment on the Liquefaction Unit will be shut down once the feed has been stopped.

IV. Troubleshooting. Operator response to operational upsets is defined below for likely significant events. Faults of low consequence such as failure of a refrigerant make-up function are of low criticality and are not discussed. Operations in response to the failure of individual valves are also not discussed. The objective of the operator response will be to either attempt to maintain unit production, where appropriate, by sufficiently rapid intervention, or if a plant trip is inevitable, to bring the plant to a safe condition ready for restart - if appropriate. The problems and their causes in the liquefaction unit, respectively, corrective action are shown in Table A.3.

3.9. Unit 16 – Refrigeration

UCE and troubleshooting happened in unit 16 – Refrigeration (Fig. (4-b)) are:

I. Loss of Electrical Power. There is three status defined for the electrical power/load shedding scenarios, as discussed in the previous unit. With 5 units working in parallel operation (5 units at 80%) and one trips (Status 1) – the other 4 units at 100% will pick up the full load, so there is no change to the Liquefaction Unit operation. If 4 units are partially loaded and one trips but with the plant at turndown throughput, load shedding will not be required. Any other scenario may result in the power consumption exceeding that available – in this case, the End Flash Gas Compressor, 15-MJ04 will be tripped along with the LP End Flash Gas Compressor Intercooler, 15-MC08. The Items on the Refrigeration Unit that are directly affected by the loss of electrical power are Mixed Refrigerant

Compressors 16-MJ01/02/03, and MR Compressors Inter and After Coolers 16-MC01/02/03.

II. Loss of Instrument Air. Loss of instrument air will cause control valves to fail in their safe position. Consequences of the loss of instrument air for the isolation/shutdown valves are given below:

- Fail close. The following valves will all fail close on the loss of instrument air: 16-XV1107, 16-XV1044,16-XV1098, 16-XV1035, 16-XV1181,16-XV1173, 16-XV1189, 16-XV1195, 16-XV1201, 12-XV1203.
- Fail Open. The following valves will all fail open on loss of instrument air: 16-XV1315, 16-XV1312, 16-XV1505, 16-XV1073, 16-XV1406,16-XV1419. In addition, all the Blow-Down valves will fail open.
- Impact on compressors. On the loss of Instrument Air, the shut-off valves downstream of both the MR and Propane Compressors, as well as the shut-off valves downstream of their Inter and After Coolers, will fail close. Their minimum flow recycles valves will fail open to put the compressors on minimum flow recycle. No overpressure will result, therefore no requirement to shutdown.

I. Loss of feed gas. Loss of natural gas feed will result in a partial shutdown of the plant and a Train shutdown. However, the MR and Propane Compressors can remain on full recycle until the conditions are stabilized, and the gas flow is re-established. However, depending on the length of the loss of Feed gas, it may be necessary to shut down the compressors if the interruption is lengthy. Loss of feed gas will cause the Propane Compressor hot gas by-pass valves (16-XV1312, 16-XV1505, and 16-XV-1315) as well as MR compressor hot gas bypass valve; 16-XV1073 to trip open. These would need to be reset to the closed position before the Train can re-start.

II. Troubleshooting. Operator response to operational upsets is defined below for likely significant events. Faults of low consequence, like the failure of a refrigerant, make up a function are of low criticality and is not discussed. Operations in response to the failure of individual valves are also not discussed. The objective of the operator response will be to either attempt to maintain unit production where appropriate by sufficiently rapid intervention or if a plant trip is inevitable, to bring the plant to a safe condition ready for restart if appropriate. Troubleshooting in the refrigeration unit is shown in Table A.4.

3.10. Unit 51 – Power generation/Diesel fuel system

Troubleshooting and UCE of Unit 51 – Power generation/Diesel fuel system are:

I. Loss of Electrical Power. Load Shedding. If during the Turbo-generators operation one of them was disconnected by trip protection or any other cause and the generation capacity of the remaining generators is not able to reach the power demanded by the loads connected to the Plant Electrical System the Plant Management System (PMS) will indicate this through commutated contacts, voltage-free, wired to terminals, to disconnect those loads of the plant defined as "dispensable." HOLD "Loads Shedding" System awaiting document from vendor Safety Control System.

II. Loss of Instrument Air. Instrument air to the power generator system will be lost through either air compressor failure or blockage of the header. The Instrument air receiver holds 15 minutes' worth of air supply, after which the whole distribution will depressurize. In the event of the total loss of instrument air to the power generators, the header will begin to depressurize, and the valves will fail to their fail / safe position resulting in a trip of the turbo-generators that are in commission at that time

III. Loss of Feed. Total loss of feed gas will result in a loss of all fuel gas from Unit 01 Feed Gas Metering to Unit 55. If the loss of feed gas is due to a Feed Gas Compressor trip, then 'back up' fuel gas will still be available from Unit 01 Feed Gas Metering to maintain a supply of fuel gas to Unit 51.

IV. Emergency Shutdown is divided into:

- Manual Emergency Trip Switches. There are two manual hard-wired trip switches in this unit

- Emergency Generator Start. On initiation of either of the following will result in 'an open circuit breaker from 51-EL24' signal being transmitted to 51-XS-1023 to start the Emergency Generators.
- Turbine Emergency Trip Protection. The emergency shutdown is initiated by pressing the EMERGENCY STOP push-button. An emergency shutdown can also be mechanically initiated by closing the manual emergency trip valve on the gauge cabinet assembly, or the manual trip button on the over-speed trip mechanism mounted on the side of the accessory gear. The main emergency trip protection for the turbine is: over-speed, exhaust temperature high, vibration high, fire extinguishing activated, loss of flame, trip oil pressure low, bearing oil pressure low, bearing supply oil temperature high, and a manual emergency trip

V. Troubleshooting. They include turbo generator (stator and supervisory equipment) the troubleshooting in power generation including's turbogenerator (fault tracing), turbogenerator (bearings), fans, bearings, excitation system, type r diesel pump, emergency diesel compressors are represented respectively in Tables A.5 through A.12

3.11. Unit 55 – Fuel gas system

UCE and troubleshooting of unit 55- Fuel gas system are:

I. Loss of Electrical Power. Unit 55 valves will fail close at the inlet to safeguard equipment: 55-MD01, 51-MJ01-A/E, 58-MB01, and 15-MD01. Other users, leading to flare, will use up the remaining fuel gas. Nitrogen is introduced manually to prevent air from being present through a drop-in pressure.
II. Loss of Instrument Air. As the previous unit
III. Loss of Feed Gas. As the previous unit
IV. Troubleshooting. No Heat to Fuel Gas is observed because of fault with Start-up Fuel Gas Heater 55-ML01, and the corrective action is to check vendor manual for unit 55

3.12. Unit 56 – Instrument and service air

UCE and troubleshooting of unit 55 - Instrument and Service Air are:

I. Loss of Electrical Power. In the event of loss of electrical power, the air compressor within the system will fail, and hence air supply will cease.
II. Loss of Instrument Air. Instrument air will be lost through either compressor failure or blockage of some kind. The Instrument air receiver holds 15 minutes' worth of air supply, after which the air distribution will depressurize. In the event of the total loss of instrument air, the following valves will fail to safe guard the system: 56-ESDV-1028Fail Closed, 56-ESDV-1043 Fail Closed, and 56-LV-1011 Fail Open. Pressure, Level, and temperature measurement is electronic or mechanical, and therefore loss of instrument air should not affect their operation.
III. Loss of Feed Gas. Loss of feed gas will have no effect on this system.
IV. Troubleshooting. Air compressor. Before carrying out any maintenance or repair, stop the compressor. When the compressor has stopped press the emergency stop button. Switch off voltage. Safeguard against unintentional 'switch-on.' The troubleshooting in instrument and service air, including's the air compressor, Chiller/Refrigeration, are represented respectively in Tables A.13 and A.14.

3.13. Unit 63 – Fire protection system

UCE and troubleshooting of unit 63 – Fire protection system include:

I. Loss of electrical power. Both the freshwater and the seawater fire pumps have standby diesel pumps; therefore, no loss in capacity is envisaged.
II. Loss of instrument air. The only instruments which will be affected by the loss of instrument air are the bubbler tube level transmitters 63-LT-1000 on Firewater Storage tank 63-MF01.
III. Loss of feed gas. Loss of feed gas will have no direct effect on Unit 63.

IV. Troubleshooting. In this chapter, procedures to cover problems that may occur during normal operations are given. Although this recommendation covers most problems that may be experienced, some situations that might occur which are not covered in this instruction are represented in Table A.15.

3.14. Unit 64 – Effluent and wastewater treatment

UCE and troubleshooting of unit 64 – Effluent and wastewater treatment include:

I. Loss of Electric Power. In the event of loss of electric power, all motors will stop. As the pumps and air blowers are in intermittent operation loss of power will not have an immediate effect

II. Loss of Instrument air. The only instruments that will be affected by the loss of instrument air are the bubbler tube level transmitters 64-LT-1007 and 64-LT-1012 on the Discharge Holding Basin 64-CV02. This will result in an apparent low, low level in the holding basin, a trip of the running Effluent Discharge Pump 64-MJ04/MJ04-A, an apparent low, low level in the oil separation section and the trip of the Contaminated Water Recycle Pump 64-MJ02 if it is running.

III. Troubleshooting. Unit 64 Troubleshooting is shown in Table 2.

Table 2. Unit 64 - Effluent and wastewater treatment troubleshooting

Problem	Cause	Corrective Action
High pressure drops across carbon filter	The buildup of hydrocarbons on the filter	Backwash with service water
Water specification of treated water exceeds oil in the water of 0.5 ppm	Insufficient treatment	Recycle oily water to the treatment unit
Treated water specification from Bio unit does not meet specification	Insufficient oxidation	Modify air injection rates and liquid residence times
Treated water specification from discharge holding basin does not meet specification	Various	Recycle to Oily Water Treatment Unit, or Remove by truck for disposal

3.15. Unit 65 – Flare System

Loss of utilities and troubleshooting of unit 65 – Flare System are:

I. Loss of Electrical Power. In the event of loss of electrical power, the emergency diesel generators supply power to the essential services.

II. Loss of Instrument Air. The unit will fail-safe, and the process units will shut down on an ESD and or BD, and ESD valves will fail-safe.

III. Loss of Feed Gas. Loss of feed gas will have no direct effect on this system. Should the feed Gas be shut down and the LNG train shut down, the whole system/equipment will be isolated depressurized and inerted to stop the ingress of air into the flare header.

3.16. Unit 71 – LNG Storage and Loading

Loss of utilities and troubleshooting of unit 71 – LNG storage and loading are:

I. Loss of electrical power. 5 turbo generators are provided for the LNG Plant. With 5 units working in parallel operation (5 units at 80%) and one trip (Status 1) – the other 4 units at 100% will pick up the full load, so there is no change to the Liquefaction Unit operation. If 4 units are partially loaded and one trips but with the plant at turndown throughput, load shedding will not be required. Any other scenario may result in the power consumption exceeding that available. This will require "load shedding" of non-critical loads. Unit 71 falls into this category. The Items on Unit 71 are directly affected by the loss of electrical power as follows:

- Loss of LNG loading pumps 71-MJ01A/B/C will result in the shutdown of loading operation.
- Loss of power to the Boil Off Gas Compressor 15-MJ05A/B/C will result in the shutdown of rundown and loading operation, and therefore shutdown of the LNG train.

II. Loss of instrument air. The plant will continue to operate satisfactorily until air header, and accumulator pressures fall. The operator must make a judgment as to the best course of action should the instrument air failure persist for a prolonged period. Loss of instrument air will cause control valves to fail to their safe position unless protected by air accumulators. This will rapidly cause interruption of both the main gas processing flow and the major liquid flows on the unit. This will lead to the closedown of rundown and loading operations.
III. Loss of feed gas. The direct consequence of loss of feed gas is that LNG rundown to storage will cease.
IV. Troubleshooting. No observed other than that existed in vendor manuals

Table 3. Unit 64 - Effluent and wastewater treatment troubleshooting

Problem	Cause	Corrective action
Less Condensate flow to 76-MD01	Malfunction of 76-ESDV-1003 to close.	Halt, the flow of Condensate to road tanker. Route condensate flow to the warm liquid header, BO-76002
Less Condensate flow to Tanker	Malfunction of 76-ESDV-1010 to close.	Route condensate flow to the warm liquid header, BO-76001

3.17. Unit 76 – Condensate Storage System

Loss of utilities and troubleshooting of unit 71 – LNG storage and loading are:

I. Loss of electrical power. In the event of loss of electrical power, then the Emergency Shutdown Valves will fail closed, and the Condensate Storage Bullet 76-MD01 will be isolated.
II. Loss of instrument air. In the event of loss of instrument air, then the Emergency Shutdown Valves will fail closed, and the Condensate Storage Bullet 76-MD01 will be isolated.
III. Loss of fuel gas. A loss of condensate may mean a low level in the Condensate Storage Bullet, 76-MD01 if it is being transferred to the tanker. A low-level alarm will be activated by 76-LI-1008, and if no action is taken, at a low level the unit will trip, the Emergency Shutdown Valves will fail closed, and the Condensate Storage Bullet 76-MD01 will be isolated. A loss of High-Pressure Fuel Gas would mean a loss of fuel to the power generators and plant shutdown.
IV. Troubleshooting observed are shown in Table 3.

4. Recommendation and good operating practice

Finally, it is recommended to check certain guidelines in order to achieve good operating practice. Operation Consideration: Operate the compressor in accordance with this Instruction Manual & the Instruction Manual for MOTOR, GEAR & COOLER. Especially the following items shall be observed and recorded every day on a graph, to use than data to discover any abnormality:

A. Performance for Compressor: rotating Speed, process gas flow rate, suction, and discharge pressure, suction, and discharge temperature.
B. Shaft Vibration and Axial Displacement for Compressor, Fluid Coupling, and Motor: Some of the most common causes of vibration are as follows: Improper alignment, improper coupling installation, coupling unbalance and/or lock, damage or unbalance to compressor rotor, damage or unbalance to the motor rotor, failing bearings, moved machine by means of thermal growth, high thrust load, improper lube oil pressure and/or temperature, compressor surging phenomena, worsen oil property.
C. Bearing & Temperature for Compressor, Gear, and Motor: When a difference in the oil temperature between the oil at the oil cooler outlet and at the bearing is 5°C higher than that of the normal operation without any change of other operating condition, pay sufficient attention to and observe the temperature change.

D. Operating Data for Motor: shaft vibration, purge air temperature, winding temperature, bearing temperature.
E. Operating Data for Lube Oil & Buffer Gas System: delivery pressure of oil pump, inlet and outlet temperature of oil cooler, differential pressure of lube oil filter, then the oil level in the oil reservoir, differential pressure of buffer gas filter, differential pressure of buffer gas supply, dry gas seal leakage pressure.
F. Observation of Lube Oil for Oil Unit: observe the color and the foaming of the oil, and analyze the oil in the oil reservoir.
G. Compressor Surging: Be sure the compressor is not operating in a condition of the surge. Severe surging can be recognized by a heavy thumping noise in the compressor, accompanied by excessive vibrations, a Fluctuating pressure, and the process temperature increases.
H. Flow Rate of Lubricant: Lubricant oil shall be periodically checked for the static electricity, kinetic viscosity, water content, sulfur content, color, etc.
I. Pump checks: the spare pump should be set to auto ready to cut in if a failure occurs on the running pump, the flow of lube oil through the sight glass, and the leaks on mechanical seals and bearings, the lineup of the filters must be controlled. The temperature and the vibration of the bearings/ shaft. Report any abnormal noise or smell.
J. Electrical motor checks: The load current (amps consumption), the level in the oil reservoir, the vibrations of the bearing must be checked. The connection of electrical earth cables, the air is coming out of the fan, the cooling fins are clean must be controlled. Report any abnormal noise and/or smell.
K. Oil filters check: If the differential pressure across the filter is above normal value (depends on type), change over the filter. In this case, be sure that the clean one is put in service first, once cleaned, line up the filter on stand-by.
L. Oil coolers check: the outlet temperature of the oil, the lineup of the spare cooler, and the leaks must be controlled.

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Appendix

Table A.1. Troubleshooting for the antifoam injection package; 12-ml12

Problem	Corrective action
Flow rate too low	See if: check valve has jammed closed Pressure relief valve in operation or leaking Excessive leakage through packing Check dosing pump's actual flowrate
Flow rate too high	Wrong stroke length Strokes per minute more than nominal
Electrical motor overheating	Discharge pressure too high Check injection pump
Noisy operation	Excessive wear of the mechanism/Gearbox Check injection pump
Pipe vibrations	Pipe diameter too small Check injection pump flowrate

Table A.2. Troubleshooting for Unit 13 – Dehydration

Problem	Cause	Corrective action
Gas product moisture content is too high.	Bed insufficiently regenerated.	Check that regeneration gas flow, heater outlet temperature and heating time
	Gas flow rates in excess of design.	Reduce gas production rate.
	13-MC01 outlet temperature is too high.	Decrease propane refrigerant pressure (13-PIC-1007).
	Beds kept on line for too long	Return to automatic 16h / 8h cycle.
	Low process gas flow resulting in channelling through beds.	Increase gas throughput to a minimum of 40% of design.
	Molecular sieve becoming inefficient or contaminated.	Investigate cause and replace molecular sieve if necessary.
Process gas flow restricted.	Hydrate formation in 13-MC01 (outlet temperature too low).	Increase propane refrigerant pressure (13-PIC-1007).
	Filter elements in 13-MD04 clogged.	Confirm using 13-PDT-1162. Clean filter.
Regeneration gas flow restricted	Hydrate formation in 13-MC03 or 13-MD03.	Reduce cooling in 13-MC03.
Gas product moisture content is too high.	Bed insufficiently regenerated.	Check that regeneration gas flow, heater outlet temperature and heating time
Gas flow rates in excess of design.	Reduce gas production rate.	
	13-MC01 outlet temperature is too high.	Decrease propane refrigerant pressure (13-PIC-1007).
	Beds kept on line for too long	Return to automatic 16h / 8h cycle.
	Low process gas flow resulting in channeling through beds.	Increase gas throughput to a minimum of 40% of design.
	Molecular sieve becoming inefficient or contaminated.	Investigate cause and replace molecular sieve if necessary.
Process gas flow restricted.	Hydrate formation in 13-MC01 (outlet temperature too low).	Increase propane refrigerant pressure (13-PIC-1007).
	Filter elements in 13-MD04 clogged.	Confirm using 13-PDT-1162. Clean filter.
Regeneration gas flow restricted	Hydrate formation in 13-MC03 or 13-MD03.	Reduce cooling in 13-MC03.

Table A.3. Troubleshooting for unit 15 – liquefaction

Problem	Cause	Corrective Action
Scrub Column 15-MD01		
High Level	Bottoms outlet valve failure Excessive cooling Mal-operation of LPG Reinjection	Increase setpoint of Fractionation Unit Feed Valve, 15-FV1123. Reduce reflux flow Increase operating temperature in Scrub Column (15-MC01 & 02) Use of the handwheel if control valve has failed Manual draining to re-establish normal level quickly
High Level	Loss of Fractionation Unit 07	Train shutdown required; 20 minutes of surge time available in the column.
Low Level.	Bottoms outlet valve failure. Insufficient cooling. Mal-operation of LPG Reinjection.	Decrease setpoint of Valve 15-FV-1123. Reduce reflux flow. Decrease operating temperature in Scrub Column (15-MC01 & 02). Use of the hand wheel if control valve has failed.

Problem	Cause	Corrective Action
LNG Expander 15-MJ02		
Expander Trip (see section 2.1.2.2.6 for further vendor details)	Unit Shutdown Mechanical Problem	Follow procedure for unit shutdown Bypass valve, 15-FV1057C, will automatically open to maintain LNG flowrate recorded sixty seconds before the expander trip.
Rated pressure and flow levels not attained	Leaks Wear ring worn Runner or nozzle Damaged runner	Ensure gaskets and O-rings are undamaged and sealing properly Disassemble and replace Disassemble and clean clogged passages Replace
Turbine vibration	Worn bearings Turbine operating near zero-torque condition while energized Damaged rotating element Excessive fluid flashing or boiling Runner clogged	Disassemble and replace Increase flow Locate damage and replace or repair Reduce temperature of fluid entering turbine Clean as necessary
Low power production	Galled internal clearances Worn bearings Generator fault or operating single phased Electrical problems other than generator	Disassemble and repair Disassemble and replace Check voltages for balance, repair if not balanced Check system and repair
Scrub Column Reflux Pump 15-MJ01 A/B		
Pump Trip Loss of reflux with normal throughput may result in heavy hydrocarbons passing through to the MCHE resulting in freezing and blockage.	Unit Shutdown Mechanical Problem with pumps.	Follow procedure for unit shutdown Start stand-by pump if this has not automatically started This is achieved by closing the guide vanes on the refrigerant compressors Then a plant shutdown is required by pressing MCHE trip button. Plant will then be shutdown with compressors in full recycle – preventing heavy hydrocarbons passing overhead from the reflux drum into the MCHE.
Problem	Cause	Corrective Action
Loss of Defrost Gas Heater 15-ML01		
Heater Trip	Miscellaneous	This heater is only required during plant start up or during defrost operations.
MR/End Flash Gas Heat Exchanger 15-MC06		
High Differential Temperature higher than 28ºC will result in damage to the exchanger. Unexpected	Unbalanced flows Manual handswitch 15-HS-1134 in incorrect position	Must adjust LNG throughput or refrigerant flow. This will balance the temperatures across the exchanger. Check position of 15-HS-1134 with respect to concentration of benzene in feed gas.

End Flash Gas Compressor 15-MJ04			
NOTE: This section intended for use when the compressor is operating unsatisfactorily. The following table lists the common problems, possible cause and the remedy in each case. If the problem cannot be completely solved by use of the table, refer all questions to the vendor representative.			
PROBLEM	Possible Causes	Phenomenon	Remedy
VIBRATION	Unbalance	The amplitude roughly increases in proportion RPM.	Check the marks that are stamped on the coupling bolts.
	Decline of bearing rigidity	The amplitude at a certain speed is especially large It is afraid that the compressor may be operated at the critical speed.	Check the interference of the bearing cap. Check the bearing clearance. More strongly tighten the bolts.
	Misalignment	The vibration cycle depends upon the speed cycle	Check the hot alignment.
	Bad angle of thrust bearing collar	The axial amplitude is large. The vibration depends upon the speed and the compressor load	Check whether the thrust bearing collar is at the right angle or not.
	Oil-whirl	The vibration cycle is roughly a half of the speed cycle.	Check the clearance of Journal bearing. Replace the journal bearing

Table A.4. Troubleshooting for unit 16 – Refrigeration

Problem	Cause	Corrective Action
MR Liquid Expander, 16-MJ06		
High Pressure Propane Section		
MR and Feed gas entering the propane system Impure propane in system leading to reduced refrigeration efficiency	Tube rupture in kettles Injection of off-spec propane from storage	Sampling required throughout propane system to ensure leakage not occurring. Sampling required of offsite propane
High Pressure in MR Section		
Inadequate control of makeup MR	Mal-operation	See below

Table A.5. Troubleshooting for Unit 51 – Power Generation / Diesel Fuel System: Turbo generator (Stator and supervisory equipment)

Trouble indication	Probable cause	Resolving method
Differences in slot temperatures between top bar and bottom bar of stator winding	Malfunction of measuring equipment (esp. slot thermometers)	Check embedded RTD's
High warm air temperature and/or high cold air temperature - direct air cooling	Drawn-in cold air too warm	If the cold air temperature downstream of the cooler cannot be reduced, reduce generator load
	Filter contaminated	Check and clean, if necessary, air passage s and filters
High warm air temperature and/or high cold air temperature - totally enclosed water/air cooling	Insufficient cooler capacity	Check cooling water system Cooler cleansing during generator standstill
	Insufficient cooling water volumetric flow or higher cooling water temperature	Increase cooling water volumetric flow Vent cooler If the cold air temperature downstream of the cooler cannot be reduced, reduce generator load
	Loss of cooling water flow	Restore flow immediately, if not, shutdown the generator

Trouble indication	Probable cause	Resolving method
Unbalanced load	Unequal phase loading of the system connected to generator	Take steps to distribute the system load more uniformly Ensure permissible load is not exceeded
Power supplied fluctuates	Excitation system incorrectly adjusted	Check and adjust excitation system
Generator remains dead	Open circuit in field circuit	check All switchgears and supply circuits for breaks
	Speed too low	The prime mover speed has to be increased accordingly
	Excitation speed defective	The function of the excitation system has to be checked
Rated voltage not obtained when generator loaded	overload	reduce the loading immediately to the permissible value
	Interturn short-circuit in field winding	Contact manufacturer in order to remove
Generator draws inductive reactive power	Open circuit in field circuit	Check All switchgears and supply circuits for breaks
	Excitation system defective	The function of the excitation system has to be checked
	Interturn short-circuit in field winding	Contact manufacturer in order to remove
Unequal stator currents	Unbalanced load	Check whether unequal stator currents are due to unbalanced load. Check terminal bushings at bus bars resp. cables for proper connection and reliable contact making
	Poor contact conditions	
	Interturn short-circuit in stator winding	
Unequal phase voltages	One supply phase disconnected	Check All switchgears and supply circuits for breaks
	Stator winding incorrectly connected	Correct the connection In the case of an incorrectly connected stator winding
	Interturn short-circuit in stator winding	Contact manufacturer in order to remove

Table A.6. Troubleshooting for Unit 51 – Power Generation / Diesel Fuel System: Turbo generator (fault tracing)

Trouble indication	Probable cause	Resolving method
Sudden deterioration of rotor running condition	Interturn short-circuit in field winding	Check whether deteriorated running condition originated due to the turbine or whether the rotor bearings are damaged. May be caused by a change in the balancing condition or by a rotor winding short. If cause cannot be located, shutdown at feasible time and contact manufacturer.
	Rotor unbalanced	
	Rotor out of true. Shaft distorted; unequal air gap over poles	
	Misalignment	
	Unbalance/shocks from turbine	
	Uneven running caused by gearing	
	Resonance with foundation	
	Changes in foundation	

Table A.7. Troubleshooting for Unit 51 – Power Generation / Diesel Fuel System: Turbo generator (bearings)

Trouble indication	Probable cause	Resolving method
Temperatures of bearings too high	Cold oil temperature too high	Check and correct if necessary, the cold oil temperature and the bearing oil pressure
	Bearing oil pressure too low	
	Oil contaminated or aged	Clean the bearing house Possible oil is to be renewed
	Low oil level	Check oil level Fill up if necessary
	Oil ring out of true, rotates irregularly or stalls	Oil rings to be realigned, straightened or replaced
	Oil viscosity too high	If oil viscosity too high, change oil (thinner oil)
	Forced lubrication fails; oil or cooling water failure	Inspect oil supply system
	Residual oil pressure of bearings with oil jacking.	Check jacking oil piping and the non-return valve

Trouble indication	Probable cause	Resolving method
	Excessive axial thrust resp. radial load	Check magnetic center and the alignment. In the case of deviations, the bearings and/or the machine have to be realigned
	Inadequate radial clearance	The concerning bearing shell has to be adapted by scraping or re-machining
	Damage to bearing lining. Defective bond between lining and supporting block of bearing shell	If the bond is in poor condition, the lining has to be replaced. In this connection, the correct shape of oil pockets and oil grooves has to be ensured
	Oil pockets too small; transitation to bearing surface not smooth enough	The oil pockets have to be refinished accordingly
	Bearing currents	The bearing insulation has to be checked and, if necessary, cleaned or replaced to remove possible creepage paths
Bearing oil pressure indicated in the shaft lift (if exists) oil pipe drops	Bearing oil inlet temperature has changed	Check to determine whether the pressure drop was caused by an oil temperature variation
	Leakage in the shaft lift oil system	
	Non-return valve leaky	
Oil blackens prematurely or contains abraded matter	Low oil level	Check oil level. Fill up if necessary
	Oil ring out of true, rotates irregularly or stalls	Realign, straighten or replace oil rings
	Oil viscosity too low	If viscosity is low, replace for thicker
	Residual oil pressure of bearings with oil jacking drops during operation with jacking oil pump inoperative	Check jacking oil piping and the non-return valve
	Excessive radial clearance	Change oil for a higher viscosity oil
	Speed (crawl speed) too low for radial clearance	To avoid mixed friction, the minimum speed must not be less than the transition speed
	Damage to bearing lining. Defective bond between lining and supporting	If the bond is in poor condition, replace lining In this connection, the correct shape of oil pockets and oil groves has to be ensured
	Bearing currents	check bearing insulation, and if necessary, cleaned or replaced to remove possible creepage paths
Bearing loses oil; oil drawn into machine	Oil viscosity too low	If the oil viscosity is too low, it should be changed for thicker one
	Oil viscosity too high due to low oil temperature	Bearing or oil have to be heated during or prior to start-up
	Oil foams	Check bearing vent for perfect function. Use different oil Consider anti-foam additive
	Oil pressure of forced lubrication system too high (>0.5 bar)	Reduce pressure, if necessary, using an additional pressure reducing valve
	Forced-lubricated bearing flooded	Check and adjust, bearing oil rate and bearing oil level. There must not be obstructions in the oil discharge
	Sealing rings defective. Gap between shaft and sealing ring too large	The sealing rings can serve its purpose only restrictively and shoul therefore be replaced
	Sealing air supply incorrectly adjusted	Tubing, valves and seals have to be inspected. The original pressure has to be readjusted
	Leak in bearing point joint	The bearing part joint should be replaced

Table A.8. Troubleshooting for Unit 51 – Power Generation / Diesel Fuel System: Fans

Trouble indication	Probable cause	Resolving method
Fan vibration	Particles sticking on the impeller blades	Clean the impeller, retighten the screws,
	Impeller corroded	Clean and rebalance the impeller, unless heavily corroded.
Fan does not start		Check power supply, Check motor
Impeller rubbing		Check the impeller Check fastening of the motor
Protective motor switch triggers when starting the fan		Check if the motor turns hard (bearing and winding damaged) Check power supply Check blade adjustment angle
The fan does not reach its rated output		Clean the impeller, Clean the duct system

Table A.9. Troubleshooting for Unit 51 – Power Generation / Diesel Fuel System: BEARINGS

Trouble indication	Probable cause	Resolving method
Temperature rise of bearings	Not enough lubricant	Check lubricant level
Leakages	Too much lubricant	Check lubricant level

Table A.10. Troubleshooting for Unit 51 – Power Generation / Diesel Fuel System: EXCITATION SYSTEM

Trouble indication	Exciter field current	Probable cause
Generator output voltage droops or power factor goes leading when load is applied	high	Defective diodes or fuses
		Short circuit in rotor or stator or generator stator
		Multiple grounds in rotor, stator, diode wheel, or generator field winding
	low	Voltage regulator malfunction
Low to zero voltage	high	Defective diodes or fuses
		Open rotor or stator windings
	low	Voltage regulator malfunction
Unstable voltage	High	Intermittent short or ground in the exciter windings
	unstable	Intermittent short or ground in the exciter windings

Table A.11. Troubleshooting for Unit 51 – Power Generation / Diesel Fuel System: Type R Diesel Pump

Symptom	Probable cause	Corrective action
Pump does not deliver liquid	Pump and suction pipe have not been filled completely	Thoroughly vent suction pipe and pump casing.
Pump does not deliver enough liquid	Air leaks into suction pipe	Check and tighten bolts on suction flange. Replace gasket on suction flange.
	Suction lift too high	Check installation against drawings
	Speed too low	Check driver electrical or steam connections
	Wrong direction of rotation	Change power input cables to motor. Check rotation arrows on turbine and pump.
	Impeller(s) damaged	Replace impeller(s)
	Worn wear rings	Replace wear rings
Pump loses prime after startup	Air or gas in liquid – seen° 2 & 3	Tighten bolts on suction piping or replace gaskets on suction line.
Insufficient discharge pressure	Viscosity too high or seen° 4 & 7	Check actual liquid against pump data sheet
Pump overloads driver	Specific gravity or viscosity of the pumped liquid different from the rated ones	Check pump and motor data sheet.
	Head and capacity different from the rated ones	Adjust discharge valve
	Wrong alignment	Re-align the unit - see Section 4

Symptom	Probable cause	Corrective action
	Mechanical defects: bent shaft, internal rubbing	Disconnect coupling and check shaft runout. Replace shaft if runout exceeds 0.025 mm at shaft end - Refer to Section 8.
	Seal spring too tight, causing excessive friction	Loosen packing gland bolts. Check setting of mechanical seal.
Pump vibrations	Pump operates at too low capacity	Open valve on discharge piping
	Misalignment	Disconnect coupling and check alignment as per Sec. 4
	Worn bearings	Replace bearings Refer to Section 8.
	Unbalanced coupling	Remove coupling halves and check for unbalance.
	Piping strain	Check piping supports. Refer to Section 4.
Bearing failure	Improper lubrication	Verify that the proper lubricant is being used. Check oil for sediments and condensate.
	Improper water cooling	Adjust water cooling to maintain oil temperature as recommended by Section 5.
	Misalignment	See *Vibrations n° 16*
	Excessive thrust	See *Mechanical defects n° 13*
	Rust	Rust may develop during improper storage of the unit. Refer to Section 3.
Seal failure	Improper flushing of seal cavity	Check flushing line(s) for circulation of the flushing liquid
	Wear of the shaft sleeve	See *Mechanical Defects n° 13*

Table A.12. Troubleshooting for Unit 55 - Instrument and Service: Emergency Diesel compressors

Fault	Cause	Trouble-shooting
The compressor requires an unusually long time to fill up the compressed air containers	Air intake filter dirty	Remove air filter and check
	Valves dirty or seals on the valves are not in perfect condition	Check functioning of valves on display of pressure gauge
	Suction valve side – combined valves 1st stage leaks	Irregular noises when valve closes, air is blown back out of the filter
	Pressure valve side – combined valve 1st stage leaks	Intermediate pressure is not reached
	Suction valve 2nd stage leaks	Intermediate pressure on pressure gauge 1st stage is more than 20% above the specification value
	Pressure valve 2nd stage leaks	The air temperature on the exhaust nozzle increases
	Piston rings and oil scraper rings worn	In crank casing, unusually high pressure is found
	Oil and water separator	Sinter filter cartridge.
	Valves coked up	Remove valves and check for leaks
	Safety valves blow off	Oil and water separator
Creaking noise in crank casing	Crank shaft bearings not in order	Excessive overheating increase in temperature of bearing.
Knocking sounds in the crank casing	Connecting rod pans worn or piston pin bushing knocked out	Whilst crank casing is open, move connecting rod to. Max. Play 0.08 – 0.1 mm in connecting rod bearing.
	Valve of 2nd stage	Clean valves, if necessary, replace
Unusually high oil consumption	Crank casing leaks	Check all seals, especially shaft sealing ring and spacer ring
	Setting for cylinder lubrication has been wrongly adjusted	Observe oil supply after air filter has been removed and idling
	Cylinder worn out	Replace cylinder
	Oil scraper ring burnt in	Check oil scraper ring
	Piston rings worn	Increase in pressure in crank casing
Piston rings wear out quickly	Insufficient cylinder lubrication	Increase in pressure in crank casing, oil level too low, cylinder lubrication not set correctly
Water in the lubricating oil	Condensation from the air deposits itself on the piston rings of the 2nd stage as condensation	Drain cooler more frequently.
Rattling of coupling	Elastic rubber studs are defective	Replace rubber elements

Table A.13. Troubleshooting for Unit 55 - Instrument and Service: Air compressor

Compressor starts running, but does not load after a delay time	Pressure in air net is above pre-set loading pressure	Compressor will load when pressure in air net drops to pre-set loading pressure
	Located solenoid valve inoperative	Check, replace if necessary
	Full-load/no-load valve malfunctioning	Have valve inspected
Compressor capacity or working pressure lower than normal	Air consumption exceeds capacity of compressor	Check pneumatic plant
	Safety valve leaking	Remove leaking valve
	Unloading pressure incorrectly set	
Oil pressure too low	Oil level too low	Top up level to the middle of the oil level sight glass
	Oil filters clogged	Replace filters
Air temperature above normal	Inlet temperature too high due to bad room ventilation or recirculation of cooling air	Improve ventilation of compressor room and avoid cooling air recirculation
	Insufficient cooling water flow	Check water temperature and increase cooling water flow
	Restriction in cooling water system due to formation of scale or settling down of dirt	Consult vendor

Table A.14. Troubleshooting for Unit 55 - Instrument and Service: Chiller/Refrigeration

Unit does not start	Power failure or main switch open	Check with tester for voltage, close main switch
	Compressor failure	See point 6.
	External devices do not allow the start up	Check the working operation of the water pumps, safety flow switches, vent the circuit.
	Control thermostat is open	System on temperature, no cooling demand. Check thermostat is working.
	Antifreeze thermostat is open	Check thermostat setting and working
	A safety device is open	See points 8 or 9.
	Delay timer working	Wait for 5 minutes
	Fan motor protector is open	See point 10.
A compressor does not start	Compressor burnt	Replace it
	Compressor circuit breaker is open	Close the switch after having checked the cause
	Thermal motor protection is open	Compressor has run under bad working conditions or lack of refrigerant charge in the system. See point 11.
	Compressor contactors are not energized	Check contactor coil and replace if it is defective
Compressor starts and stop repeatedly	Compressor is defective	Check and replace
	Low pressure switch is open	See point 9.
	Oil differential pressure switch is closed	Check that differential pressure between oil pump discharge and low pressure gauge is higher than 1 bar.
	Set-point values not properly set	Modify set-point values accordingly
	Lack of refrigerant	See point 11.
A Compressor does not start since high pressure switch is open	High pressure switch is defective	Check and replace
	Excessive refrigerant charge	Discharge the unit
	Presence of incondensable fluids in refrigerant circuit	Discharge the unit, vacuum the circuit and recharge the unit.
	Refrigerant filter is clogged	Check and replace
	Condensing coil metallic filters are clogged. The air flow is too low	Clean metallic filters with compressed air or with water
	Condensing coil fans are not working	See point 10.
	Low pressure switch is defective	Check and replace
	Complete lack of refrigerant	See point 11.

A Compressor does not start since low pressure switch is open	Liquid line shut-off valve is not fully open	Check and eventually open
	Thermostatic expansion valve is not working properly	Check, clean and eventually replace
	Refrigerant filter is clogged	Check and replace
	Condensing coil metallic filters are clogged. air flow is too low	Clean metallic filters with compressed air
	Condensing coil fans are not working	See point 10.
	Water pump is defective (too low water flow)	Check the pump and replace if necessary
Fans do not start	Fans contactors are not energized	Check contactor coil. Replace if defective
	Fan motor protection is open	Check fan motor winding insulation
	Loose connections	Review and tighten
	Fan motor is defective	Check and replace if necessary
Lack of refrigerant	Leakage in the refrigerant circuit	Pressurize the refrigerant circuit and use a leak finder to find problem.
Liquid line at high temperature	Low refrigerant charge	See point 11.
Liquid line frosted	Liquid shut off valve is partially closed	Fully open shut off valve
	Clogged liquid filter	Replace filter
Unit operates too long or continuously	Lack of refrigerant	See point 11.
	Compressor not performing	Check, grind or replace
	Excessive thermal load	reduce thermal load
	Control thermostat does not work or has a wrong setting	Check the operation of the thermostat, replace if defective, modify set-point
	Refrigerant filter clogged	Clean or replace
The unit works but has too low capacity	Low refrigerant charge	See point 11.
	Moisture presence in the hydraulic circuit	Remove the filter, dry it and recharge the circuit.
Compressor suction line frosted	Thermostatic expansion valve is not working properly	Check, clean or replace if necessary
	Low refrigerant charge	See point 11.
	Liquid line shut-off valve not fully open	Check and open
	Refrigerant filter is clogged	Clean or replace
	Water pump is defective (too low water flow)	Check the pump and replace if necessary
Abnormal noise in the system	Compressor is noisy	Check and replace if necessary
	Expansion valve hissing	Check and charge the system
	Piping vibrating	Support piping
	Badly fitted panels	Install correctly
Continuous top up of water required	Leaks in the system	Repair any leaks
	Water seepage from safety valve	Reduce pressure on initial fill water
	Drain and vent valves are open	Shut drain and vent valves
Lack of water in system	Availability of initial fill water	Open initial fill valves to allow water into system
	Leaks in the system	Seal any leaks
High system water pressure	initial fill connected direct to high pressure water supply	Fit pressure reducing valve
	Ingress of pressurized gas from independent source	Seal source of leakage
	High water pressure due to emergency supply	Seal or shut valves of emergency supply and reduce system pressure
	Expansion tank diaphragm punctured	Operate pump. replace
	Due to expansion tank pre-charge	Set to 1 bar
Water overheating	Wrong pump motor direction	Stop pump and change its direction
	Problems with water flow rate	Readjust flow control valves
	Water flow restrictions	Open isolating valves
	Faulty interconnecting pipework not circuiting	Change circuiting if necessary
Pump fails to circulate water when running	Airlocked pump	Vent air from pump
	Wrong pump rotation	Stop pump and change rotation
	Closed valves	Check and open valves

Water frozen in pipes	leaks	Switch off cooling system, thaw system slowly. Repair leaks.
Variation in pump noise	Air in pump	Vent air from pump
Excessive fluctuation of pressure gauge pointer	Low water levels in system	Allow water to flow into the system via the initial fill
	Excessive air in the system	Switch off pump, vent system of air throughout.
No change in pressure when flow control is open or closed	Pump not running	Switch on pump
	Excessive air in the system	Switch off pump, vent system of air throughout.
	Wrong pump rotation	Change pump rotation

Table A.15. Troubleshooting for Unit 63 – Fire Protection System

Problem	Possible cause	Corrective action
Foam flow at foam generator	lack of water intercept ional valve is closed	operate at feeding source open the valve
	blockage in the piping line	Check piping line.
	malfunction of the automatic deluge valve	Check automatic deluge valve
	foam concentrate shut-off valve closed	Open
	malfunction of the solenoid	Check the solenoid valve
	valve	
	malfunction of the automatic	Check the automatic
	deluge valve unit	deluge valve unit
	malfunction of the automatic proportionier unit	Check the automatic proportioner unit
Water/foam flows at foam generator without fire alarm	malfunction of the solenoid valve malfunction of the automatic deluge valve unit	Check the solenoid valve check automatic deluge valve unit.
Waterflow pressure switch does not send any signal when clapper of automatic deluge valve is open	alarm exclusion valve closed blockage in trim line malfunction of the waterflow pressure switch	Open the valve check trim line check waterflow pressure switch.

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