Quantitative Risk Assessment Study (QRA)

For North Giza Power Plant

(3 x750 Mwatt)

January 2011

12 El Saleh Ayoub St., Zamalek, Cairo, Egypt 11211
Tel: + 20 2 27359079 – 2736 4818
Fax: + 20 2 2736 5397
E-mail: general@ecolconserv.com
URL: http://www.ecolconserv.com
Executive Summary

The North Giza Power Station is to be situated to the north west of Cairo. The power station will include 3 x 750 MW combined cycle facilities and is to be erected in an agricultural area away from residential villages. The facility will use natural gas for combustion in the combustion turbines and fuel oil for steam generation.

EcoConServ was assigned by Cairo Electricity Generation Company to prepare a Quantitative Risk Assessment (QRA) study for the proposed North Giza Power Station. This report is the main deliverable of this assignment and depends on Engineering Research and Consulting Co. in-house program.

This document sets out the North Giza Power Station Quantitative Risk Assessment (QRA) in order to identify the key hazards and risks associated with the new facility. The focus is on the major, worst-case hazards, essentially in order to prioritize the off-site risks and potential impacts to the public.

RISK CRITERIA

Individual risks are the key measure of risk acceptability for this type of study, where it is proposed that:

- Risks to the public can be considered to be broadly acceptable if below \(10^{-6}\) per year. Although risks of up to \(10^{-4}\) per year may be considered acceptable if shown to be ALARP, it is recommended that \(10^{-5}\) per year is adopted for this study as the maximum tolerable criterion.

- Risks to workers can be considered to be broadly acceptable if below \(10^{-5}\) per year and where risks of up to \(10^{-3}\) per year may be considered acceptable if ALARP. Societal risk criteria are also proposed, although these should be used as guidance only.

RISK RESULTS - PUBLIC

The maximum extent of the predicted individual risk contours does not cross the canal to the West, and does not reach the populated areas to the North of the facility.

The \(10^{-7}\) individual risk contour almost traces the North and West facility boundary. Hence any future settlements beyond those two facility boundaries would still be safe. However, a buffer zone of agricultural low-population land needs to be maintained to the East of the facility since the individual risk in that vicinity is around \(10^{-5}\).

The risks in all directions outside the facility do not reach any residential areas. The QRA results suggest that the risk to the nearby populations would be well within the proposed risk criteria and hence would be acceptable.
RISK RESULTS - WORKERS
The predicted $10^{-4}$ and $10^{-5}$ per year individual risk contours have potential to affect the adjacent industrial populations within the proposed power plant. These risks are potentially significant but are considered to be manageable and within the ALARP for workers.

HAZARDS/RISKS TO ASSETS
Significant overpressure levels of around 0.3 barg will not extend any significant distance offsite, but are likely to affect the key admin / office and control buildings at the facility. This suggests that with the current layout these two key buildings should have blast protection of the order of 0.3 barg. The explosion frequency contours suggest that all buildings on-site should have protection against blast loads of at least 0.1 barg. The above results can be concluded with reasonable confidence.

Significant fire hazards will also exist inside the facility and it should be noted that the potential for escalation / asset damage will also apply due to jet and pool fire hazards for similar levels to discussed above with respect to explosions.

RECOMMENDATIONS
The results of this QRA report show that the risks to the public were shown to be low (and possibly negligible). The risks to the workers were shown to be As Low As Reasonably Practicable (ALARP).

Other recommendations are:

- The emphasis on risk reduction should be on preventative measures, i.e. to minimize the potential for leaks to occur. This would chiefly be achieved through appropriate design (to recognized standards) and through effective inspection, testing and maintenance plans / procedures.

- Rapid isolation of significant leaks will not eliminate the risks but will help to minimize the hazards and, particularly, the ignition probability (by limiting the total mass of flammable vapor released). For isolation to be effective, first requires detection to occur and hence best practice fire and gas detection systems, with associated shutdown systems and procedures, will be important mitigation measures.
# TABLE OF CONTENTS

- **Risk Criteria** ........................................................................................................ II
- **Risk Results - Public** .......................................................................................... II
- **Risk Results - Workers** ..................................................................................... III
- **Hazards/Risks to Assets** .................................................................................... III
- **Recommendations** ................................................................................................ III
- **Abbreviations** ....................................................................................................... XI

## 1 Introduction
- **1.1 Background** .................................................................................................. 1
- **1.2 Objectives and Scope** .................................................................................. 1
- **1.3 Layout of Study** ............................................................................................ 1

## 2 Site Description
- **2.1 Location** ....................................................................................................... 3
- **2.2 Land Use** ....................................................................................................... 3
- **2.3 Meteorological Conditions** .......................................................................... 7

## 3 Project Description
- **3.1 Power Station** ................................................................................................ 9
- **3.1.1 Plant Layout** .............................................................................................. 9
- **3.1.2 Process Description** .................................................................................. 9
- **3.2 Fire Fighting Systems** .................................................................................. 13

## 4 Risk Acceptance Criteria
- **4.1 Risk Assessment Framework** ...................................................................... 16
- **4.2 Individual Risk Criteria** ............................................................................... 17
- **4.3 Societal Risk Criteria** .................................................................................. 19

## 5 Methodology
- **5.1 Data Collection** ............................................................................................ 20
- **5.2 Hazard Identification (HAZID)** .................................................................. 21
- **5.3 Frequency Analysis** ..................................................................................... 21
- **5.4 Consequence Analysis** ................................................................................ 21
- **5.5 Risk Calculations** ........................................................................................ 21
- **5.6 Risk Software Tools** .................................................................................... 22

## 6 Assumptions
- **6.1 Introduction** .................................................................................................. 24
- **6.2 Background Assumptions** .......................................................................... 24
- **6.2.1 Weather Categories** ................................................................................ 24
- **6.2.2 Wind Direction** ....................................................................................... 25
- **6.2.3 Atmospheric Parameters** ......................................................................... 26
- **6.2.4 Congest Volumes** .................................................................................... 26
- **6.2.5 Populations** ............................................................................................... 28
APPENDICES

RISK ACCEPTANCE CRITERIA........................................................................................................................................... 86
INTRODUCTION................................................................................................................................................................. 86
BASIS FOR CRITERIA............................................................................................................................................................... 86
    Need for Criteria.............................................................................................................................................................. 86
    Principles for Setting Risk Criteria ................................................................................................................................ 86
    Framework........................................................................................................................................................................ 87
PROPOSED RISK CRITERIA..................................................................................................................................................... 89
    Individual Risk................................................................................................................................................................. 89
    Societal Risk.................................................................................................................................................................... 92
EMERGENCY RESPONSE PLAN........................................................................................................................................... 94
NEED FOR AN EMERGENCY RESPONSE PLAN.................................................................................................................. 94
OBJECTIVES OF AN EMERGENCY MANAGEMENT PLAN.................................................................................................... 95
SCOPE.................................................................................................................................................................................. 96
EMERGENCY MANAGEMENT PLAN: KEY ELEMENTS.......................................................................................................... 96
    Basis of the Plan............................................................................................................................................................... 97
    Accidents Prevention Procedures/Measures....................................................................................................................... 97
        General........................................................................................................................................................................ 97
        Operation & Maintenance......................................................................................................................................... 98
        Protecting the Pipeline from External Interference................................................................................................. 99
        Protecting the Pipeline against Corrosion.................................................................................................................. 99
    Emergency Reporting...................................................................................................................................................... 99
        Within the Field.......................................................................................................................................................... 100
        Field to Emergency Control Center.......................................................................................................................... 100
        Incident Report........................................................................................................................................................ 100
        Incident Situation Report Form (SITREP).................................................................................................................. 101
        Medical Evacuation Report...................................................................................................................................... 101
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Distribution</td>
<td>101</td>
</tr>
<tr>
<td>Notification to Authorities</td>
<td>101</td>
</tr>
<tr>
<td>EMERGENCY RESPONSE STRATEGIES</td>
<td>101</td>
</tr>
<tr>
<td>Introduction</td>
<td>101</td>
</tr>
<tr>
<td>Alert Phase</td>
<td>102</td>
</tr>
<tr>
<td>Declaration of Emergency</td>
<td>103</td>
</tr>
<tr>
<td>Emergency Alarm (Siren)</td>
<td>104</td>
</tr>
<tr>
<td>Preparation for Emergencies</td>
<td>104</td>
</tr>
<tr>
<td>Command by Competent Persons</td>
<td>104</td>
</tr>
<tr>
<td>Number of Persons for Emergency Duties</td>
<td>104</td>
</tr>
<tr>
<td>List of Persons for Emergency Duties</td>
<td>104</td>
</tr>
<tr>
<td>Control of Emergencies</td>
<td>104</td>
</tr>
<tr>
<td>Assembly Procedures</td>
<td>104</td>
</tr>
<tr>
<td>Post Emergency</td>
<td>105</td>
</tr>
<tr>
<td>EMERGENCY RESPONSE ORGANIZATION</td>
<td>105</td>
</tr>
<tr>
<td>Incident Response</td>
<td>105</td>
</tr>
<tr>
<td>Emergency Response Group</td>
<td>106</td>
</tr>
<tr>
<td>Crisis Response Team</td>
<td>106</td>
</tr>
<tr>
<td>Incident Site Roles and Responsibilities</td>
<td>107</td>
</tr>
<tr>
<td>HSE Engineer</td>
<td>107</td>
</tr>
<tr>
<td>Sr. Administration Officer</td>
<td>108</td>
</tr>
<tr>
<td>PIC-onshore</td>
<td>110</td>
</tr>
<tr>
<td>Site Doctor</td>
<td>111</td>
</tr>
<tr>
<td>Fire Chief</td>
<td>112</td>
</tr>
<tr>
<td>Production Superintendent</td>
<td>113</td>
</tr>
<tr>
<td>Maintenance Superintendent</td>
<td>114</td>
</tr>
<tr>
<td>Scribe</td>
<td>115</td>
</tr>
<tr>
<td>Person Taking Calls</td>
<td>116</td>
</tr>
<tr>
<td>Control Room Operator</td>
<td>117</td>
</tr>
<tr>
<td>EMERGENCY RESPONSE ACTION</td>
<td>117</td>
</tr>
<tr>
<td>Emergency Response Centers</td>
<td>117</td>
</tr>
<tr>
<td>Incident Control Center (ICC)</td>
<td>117</td>
</tr>
<tr>
<td>Emergency Control Center (ECC)</td>
<td>118</td>
</tr>
<tr>
<td>ACCIDENT / EMERGENCY RESPONSE PROCEDURES</td>
<td>119</td>
</tr>
<tr>
<td>Fire / Explosion (General)</td>
<td>120</td>
</tr>
<tr>
<td>PROCEDURES FOR DEALING WITH REPORTED GAS/ VAPOR ESCAPES</td>
<td>121</td>
</tr>
<tr>
<td>FIRE PREVENTION PLANNING AND MEASURES</td>
<td>121</td>
</tr>
<tr>
<td>COMMUNICATION</td>
<td>122</td>
</tr>
<tr>
<td>EMERGENCY CONTROL CENTER</td>
<td>122</td>
</tr>
<tr>
<td>RECOVERY PROCEDURE</td>
<td>123</td>
</tr>
<tr>
<td>Pressure Reduction in Pipeline or Flow Restriction</td>
<td>123</td>
</tr>
<tr>
<td>Complete Shut-down of Pipeline</td>
<td>124</td>
</tr>
<tr>
<td>EMERGENCY MANAGEMENT PLAN: ONSITE CRISIS</td>
<td>124</td>
</tr>
<tr>
<td>Role of Incident Controller</td>
<td>124</td>
</tr>
<tr>
<td>COMMUNICATION SYSTEMS NETWORK</td>
<td>125</td>
</tr>
<tr>
<td>TRANSPORTATION</td>
<td>126</td>
</tr>
<tr>
<td>PUBLIC INFORMATION SYSTEM</td>
<td>126</td>
</tr>
<tr>
<td>Before the Crisis</td>
<td>126</td>
</tr>
<tr>
<td>During the Crisis</td>
<td>126</td>
</tr>
<tr>
<td>After the Crisis</td>
<td>126</td>
</tr>
</tbody>
</table>
FIRE FIGHTING SYSTEM ................................................................. 126
Before the Crisis ........................................................................ 127
During the Crisis ........................................................................ 127
CHECKLIST FOR CAPABILITY ASSESSMENT ...................... 127
EMERGENCY MANAGEMENT PLAN: OFFSITE ....................... 129
WARNING SYSTEM ..................................................................... 129
SERVICES SUPPORT SYSTEM .................................................. 130
LIST OF FIGURES

FIGURE 2-1: LOCATION OF NORTH GIZA POWER STATION ............................................................................................................. 3
FIGURE 2-2: AGRICULTURAL LAND AT THE LOCATION OF THE POWER PLANT STATION ................................................................. 4
FIGURE 2-3: ROAD THAT PASSES ADJACENT TO THE POWER PLANT STATION AND CONNECTS MANSHET RADWAN WITH AL KHATATBA 4
FIGURE 2-4: AL RAYAH AL BEHERY CLEAN WATER CANAL AT THE LOCATION OF THE POWER STATION ............................................. 5
FIGURE 2-5: A GOOGLE EARTH IMAGE SHOWING THE AGRICULTURAL LAND TO THE IMMEDIATE VICINITY OF THE NORTH GIZA POWER STATION .......................................................................................................................................................... 6
FIGURE 2-6: WIND ROSE OF NORTH GIZA (WIND SPEED IN KNOTS) ................................................................................................. 1
FIGURE 3-1: PROPOSED LAYOUT OF THE NORTH GIZA POWER STATION (PREPARED BY PGESCO) ..................................................... 11
FIGURE 3-2: PROCESS FLOW DIAGRAM FOR THE NORTH GIZA POWER STATION .................................................................................. 12
FIGURE 5-1: QRA METHODOLOGY .......................................................................................................................................................... 20
FIGURE 6-1: WIND ROSE (PROBABILITY OF WIND DIRECTION) .............................................................................................................. 25
FIGURE 6-2: EVENT TREE FOR VAPOR AND FLASHING LIQUID RELEASE TYPES ........................................................................ 44
FIGURE 6-3: EVENT TREE FOR LIQUID RELEASE TYPE ......................................................................................................................... 45
FIGURE 6-4: EVENT TREE FOR VAPORIZING LIQUID RELEASE TYPE .................................................................................................... 45
FIGURE 9-1: ALOHA OUTPUT FOR CASE 82-1 POOL FIRE ................................................................................................................................. 67
FIGURE 9-2: ALOHA OUTPUT FOR CASE 61-1 JET FIRE ................................................................................................................................. 68
FIGURE 9-3: ALOHA OUTPUT FOR CASE 64-2 TANK TOP FIRE ............................................................................................................................... 69
FIGURE 9-4: EXAMPLE OF OVERPRESSURE CONTOURS FOR CASE 61-2 OBTAINED BY ALOHA ........................................................................ 70
FIGURE 9-5: HEAT FLUX CONTOURS DUE TO POOL FIRES ............................................................................................................................. 72
FIGURE 9-6: HEAT FLUX CONTOURS DUE TO JET FIRES ............................................................................................................................. 73
FIGURE 9-7: HEAT FLUX CONTOURS DUE TO TANK TOP FIRES ....................................................................................................................... 74
FIGURE 9-8: OVERPRESSURE CONTOURS DUE TO VAPOR CLOUD EXPLOSIONS .......................................................................................... 75
FIGURE 9-9: OVERPRESSURE CONTOURS DUE TO EXPLOSIONS OF HIGH PRESSURE STREAM DRUMS ......................................................... 76
FIGURE 10-1: INDIVIDUAL RISK CONTOURS ON A GOOGLE EARTH IMAGE ..................................................................................... 82
FIGURE 10-2: INDIVIDUAL RISK CONTOURS INSIDE THE LIMITS OF THE POWER STATION ........................................................................ 83
FIGURE 10-3: SOCIETAL RISK REPRESENTED AS F/N CURVE .................................................................................................................. 84

FIGURE A-1: "ALARP" FRAMEWORK FOR RISK CRITERIA ......................................................................................................................... 89
FIGURE A-2: AN INTERPRETATION OF UK HSE SOCIETAL RISK CRITERIA (F-N CURVE) ........................................................................ 93
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2-1</td>
<td>TEMPERATURE, HUMIDITY AND RAINFALL FOR THE PROPOSED SITE (35-YEAR AVERAGE)</td>
<td>7</td>
</tr>
<tr>
<td>Table 6-1</td>
<td>ATMOSPHERIC PARAMETERS</td>
<td>26</td>
</tr>
<tr>
<td>Table 6-2</td>
<td>HUMAN IMPACT CRITERIA</td>
<td>30</td>
</tr>
<tr>
<td>Table 6-3</td>
<td>GENERIC PROCESS LEAK FREQUENCIES</td>
<td>39</td>
</tr>
<tr>
<td>Table 6-4</td>
<td>SUMMARY OF IGNITED RELEASE OUTCOMES, OR HAZARD TYPES</td>
<td>41</td>
</tr>
<tr>
<td>Table 6-5</td>
<td>VARIATION OF PROBABILITY OF EXPLOSION WITH INTERSECTION VOLUME</td>
<td>47</td>
</tr>
<tr>
<td>Table 7-1</td>
<td>HAZARD CAUSES, CONSEQUENCES AND PROPOSED OR INHERENT SAFEGUARDS</td>
<td>49</td>
</tr>
<tr>
<td>Table 7-2</td>
<td>HAZARDOUS MATERIALS STORED AND USED ON SITE</td>
<td>54</td>
</tr>
<tr>
<td>Table 8-1</td>
<td>COMBUSTION TURBINE GENERATORS (UNIT 14) FAILURE CASES</td>
<td>62</td>
</tr>
<tr>
<td>Table 8-2</td>
<td>FUEL GAS REDUCING STATION AND THE FUEL GAS COMPRESSOR (UNIT 61) FAILURE CASES</td>
<td>63</td>
</tr>
<tr>
<td>Table 8-3</td>
<td>FUEL OIL TANKS (UNIT 64) FAILURE CASES</td>
<td>63</td>
</tr>
<tr>
<td>Table 8-4</td>
<td>FUEL OIL TRANSFER PUMPS (UNIT 65) FAILURE CASES</td>
<td>63</td>
</tr>
<tr>
<td>Table 8-5</td>
<td>LUBE OIL STORAGE (UNIT 82-9C) FAILURE CASES</td>
<td>63</td>
</tr>
<tr>
<td>Table 8-6</td>
<td>HYDROGEN GENERATION (UNIT 92) FAILURE CASES</td>
<td>63</td>
</tr>
<tr>
<td>Table 8-7</td>
<td>STEAM GENERATOR FAILURE (UNIT 11) FAILURE CASES</td>
<td>64</td>
</tr>
<tr>
<td>Table 8-8</td>
<td>LOCATION OF FIRE ACCIDENTS</td>
<td>64</td>
</tr>
<tr>
<td>Table 8-9</td>
<td>LOCATION OF EXPLOSION ACCIDENTS</td>
<td>65</td>
</tr>
<tr>
<td>Table 9-1</td>
<td>ALOHA POOL FIRE DATA</td>
<td>66</td>
</tr>
<tr>
<td>Table 9-2</td>
<td>ALOHA JET FIRE DATA</td>
<td>67</td>
</tr>
<tr>
<td>Table 9-3</td>
<td>ALOHA TANK TOP FIRE DATA</td>
<td>68</td>
</tr>
<tr>
<td>Table 9-4</td>
<td>MODELS USED FOR THE DIFFERENT EXPLOSION CASES</td>
<td>69</td>
</tr>
<tr>
<td>Table 10-1</td>
<td>FREQUENCIES USED FOR THE DIFFERENT CASES</td>
<td>77</td>
</tr>
<tr>
<td>Table A-1</td>
<td>COMPARISON OF SELECTED INDIVIDUAL RISK CRITERIA FOR NEW PLANTS</td>
<td>91</td>
</tr>
<tr>
<td>Table A-7</td>
<td>ROLES AND RESPONSIBILITIES OF VARIOUS EMERGENCY RESPONSE TEAM MEMBERS</td>
<td>128</td>
</tr>
</tbody>
</table>
## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIChe</td>
<td>American Institute of Chemical Engineers</td>
</tr>
<tr>
<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
</tr>
<tr>
<td>ALOHA</td>
<td>Areal Locations of Hazardous Atmospheres</td>
</tr>
<tr>
<td>API</td>
<td>American Petroleum Institute</td>
</tr>
<tr>
<td>BFW</td>
<td>Boiler Feed Water</td>
</tr>
<tr>
<td>BLEVE</td>
<td>Boiling Liquid Expanding Vapor Explosion</td>
</tr>
<tr>
<td>BP</td>
<td>British Petroleum</td>
</tr>
<tr>
<td>CCPA</td>
<td>Center for Chemical Process Safety</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed Circuit Television</td>
</tr>
<tr>
<td>CIA</td>
<td>Central Intelligence Agency</td>
</tr>
<tr>
<td>CTG</td>
<td>Combustion Turbine Generator</td>
</tr>
<tr>
<td>DNV</td>
<td>Det Norske Veritas</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>ESD</td>
<td>Electrostatic Discharge</td>
</tr>
<tr>
<td>F/N</td>
<td>Frequency – Number of Fatalities Curve</td>
</tr>
<tr>
<td>FM200</td>
<td>Dupont waterless fire suppression system</td>
</tr>
<tr>
<td>FRED</td>
<td>Fire, Release, Explosion and Dispersion</td>
</tr>
<tr>
<td>HAZID</td>
<td>Hazard Identification</td>
</tr>
<tr>
<td>HAZOP</td>
<td>Hazard and Operability Study</td>
</tr>
<tr>
<td>HCRD</td>
<td>Hydrocarbon Release Database</td>
</tr>
<tr>
<td>HP</td>
<td>High Pressure</td>
</tr>
<tr>
<td>HSE</td>
<td>Health and Safety Executive</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air Conditioning</td>
</tr>
<tr>
<td>IP</td>
<td>Intermediate Pressure</td>
</tr>
<tr>
<td>LFL</td>
<td>Lower Flammability Limit</td>
</tr>
<tr>
<td>LP</td>
<td>Low Pressure</td>
</tr>
<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
</tr>
<tr>
<td>NFR</td>
<td>Normal Flow Rate</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>OEM</td>
<td>Office of Emergency Management</td>
</tr>
<tr>
<td>P&amp;ID</td>
<td>Piping and Instrumentation Drawing</td>
</tr>
<tr>
<td>PFD</td>
<td>Process Flow Diagram</td>
</tr>
<tr>
<td>PGESCo</td>
<td>Power Generation Engineering and Services Company</td>
</tr>
<tr>
<td>QRA</td>
<td>Quantitative Risk Assessment</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>VCE</td>
<td>Vapor Cloud Explosion</td>
</tr>
</tbody>
</table>
1 INTRODUCTION

1.1 BACKGROUND
Cairo Electricity Production Company is planning to build a 3 x 750 MW power plant in North Giza. The Power Station is planned to be constructed 35 km to the north west of Cairo. The station will utilize the best available combined cycle technology. The design of the project is performed by the Power Generation Engineering and Services Company (PGESCo). The total power plant area is 290,600 m².

EcoConServ was assigned by Cairo Electricity Generation Company to prepare a Quantitative Risk Assessment (QRA) study for the proposed North Giza Power Station. This report is the main deliverable of this assignment and depends on Engineering Research and Consulting Co. in-house program.

1.2 OBJECTIVES AND SCOPE
The main objectives of this Quantitative Risk Assessment (QRA) study are:

- To identify and quantify the major process hazards associated with the proposed power plant facilities in North Giza.
- Assess the acceptability of the risks to people (primarily plant workers and any nearby residential areas), against internationally recognized criteria.
- Identify the main risk contributors in order to identify potential risk reduction measures and to demonstrate to the relevant stakeholders that the key risks are understood, and are being managed throughout the design process.

The scope covered is for a QRA, which is focused on the worst-case hazards, and associated risks, in order to assess the key risks.

1.3 LAYOUT OF STUDY
The layout of the remainder of this document consists of the following sections:

- Section 2 and Section 3 describe the site of the plant and the give details about the project.
- Section 4 sets out the risk criteria proposed for this study, on which the determination of acceptability will be based. This is covered in detail by Appendix 0.
- Section 5 summarizes the methodology, noting that this is covered in detail by Appendix A2. (detailed assumptions / methodology / failure case definition).
- Section 6 and Section 8 summarize the outcome of the Hazard Identification step and enumerate the failure cases.

- Section 9 describes the Consequence Assessment step and presents its results.

- Section 10 details the risk results, which are primarily based around the individual risk contours. These are discussed separately with respect to the potential off-site risks to the public and to the on-site risks to workers. It also presents the Conclusions and Recommendations of the analysis.
2 SITE DESCRIPTION

2.1 LOCATION
The North Giza Power Plant is to be located in an agricultural area in the north of Giza, 35 km to the north west of Cairo. Figure 2-1 shows the location of the power station in comparison with Cairo and Alexandria.

![Figure 2-1: Location of North Giza Power Station](image)

2.2 LAND USE
The total power plant area is 290,600 m². Currently, the land allotted for the power station is an agricultural land. Figure 2-2 shows a photograph of the agricultural land around the power plant. There is a low traffic road that passes to the south west of the land, which separates the power station from Al Rayah Al Behery. This road, shown in Figure 2-3, connects Manshet Radwan to the south-east with Al Khatatba to the north-west.

Al Rayah Al Behery is a clean water canal that branches off the Nile of Cairo and flows to the north-west direction. Figure 2-4 shows a photograph of this canal at the location of the site, while Figure 2-5 shows a Google Earth image of the land allotted for the North Giza Power Station and the agricultural land in its immediate neighborhood.
The closest residential area to the North Giza Power Station is the village of Abu Ghalib, which is located about 2 km to the north of the station. The location of the village is upwind with respect to the power station. The residential area of Abu Ghalib village comprises about 0.7 km$^2$.

Figure 2-2: Agricultural land at the location of the power plant station

Figure 2-3: Road that passes adjacent to the power plant station and connects Manshet Radwan with Al Khatatba
Figure 2-4: Al Rayah Al Behery clean water canal at the location of the power station
Figure 2-5: A Google Earth image showing the agricultural land to the immediate vicinity of the North Giza Power Station
2.3 **Meteorological Conditions**

The meteorological conditions for the site of North Giza Power Plant were obtained from the Giza Meteorological Station. The data cover the area of 50 km around the station, which includes the site of the plant.

Table 2-1 shows the temperature, humidity and rainfall. The wind rose for the area is shown in Figure 2-6. The wind rose shows that wind blows from the north within a 60 degree angle for the majority of the time and that the wind speed seldom increases over 10 knots.

<table>
<thead>
<tr>
<th>Month</th>
<th>Av. Temperature (°C)</th>
<th>Humidity</th>
<th>Rainfall (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>19.8</td>
<td>6.9</td>
<td>31.5</td>
</tr>
<tr>
<td>February</td>
<td>21.2</td>
<td>7.6</td>
<td>36.2</td>
</tr>
<tr>
<td>March</td>
<td>24.1</td>
<td>9.8</td>
<td>39.0</td>
</tr>
<tr>
<td>April</td>
<td>28.7</td>
<td>13.1</td>
<td>43.5</td>
</tr>
<tr>
<td>May</td>
<td>32.5</td>
<td>16.7</td>
<td>48.0</td>
</tr>
<tr>
<td>June</td>
<td>34.8</td>
<td>19.8</td>
<td>48.0</td>
</tr>
<tr>
<td>July</td>
<td>35.3</td>
<td>21.5</td>
<td>45.5</td>
</tr>
<tr>
<td>August</td>
<td>34.8</td>
<td>21.6</td>
<td>42.9</td>
</tr>
<tr>
<td>September</td>
<td>33.0</td>
<td>19.6</td>
<td>44.0</td>
</tr>
<tr>
<td>October</td>
<td>30.6</td>
<td>17.0</td>
<td>44.5</td>
</tr>
<tr>
<td>November</td>
<td>25.7</td>
<td>12.7</td>
<td>38.8</td>
</tr>
<tr>
<td>December</td>
<td>21.1</td>
<td>8.6</td>
<td>36.3</td>
</tr>
<tr>
<td>Annual-average</td>
<td>28.46</td>
<td>14.58</td>
<td>59.5</td>
</tr>
</tbody>
</table>
Figure 2-6: Wind rose of North Giza (wind speed in Knots)
3 PROJECT DESCRIPTION

3.1 POWER STATION

3.1.1 PLANT LAYOUT
The layout of the plant is shown in Figure 3-1. The process area contains dedicated open spaces for steam generators, pumps, combustion turbine generators, and transformers. There are also standalone buildings such as the control building, the switchgear building and the electrical building.

The units and equipment are laid out in such a way that allows for appropriate safety distances and easy movement between the units.

The site also contains a water treatment unit to treat the incoming water before flowing to the boilers. In addition to the process area, the plant also includes the following non-process related facilities:

- Office building
- Warehouse / workshop building
- Main / secondary security office
- Fire fighting station
- Clinic
- Mosque
- Hydrogen generation building and storage area
- Bottled gas area
- Foam equipment

3.1.2 PROCESS DESCRIPTION
The North Giza Power Station is a combined cycle power plant. In general usage the term "combined cycle power plant" describes the combination of gas turbine generators (Brayton cycle) with turbine exhaust waste heat boilers and steam turbine generators (Rankine cycle) for the production of electric power.

The flow sheet for the process is given in Figure 3-2 and its description follows.

The steam generator is divided into many sections according to operating pressure. The pressure increases inside the steam generator towards the combustor. The steam generator has three pressure sections: low, intermediate and high pressure section.
Condensate from low pressure steam condenser is pumped to condensate preheating section in order to use the smallest portion of heat inside steam generator.

The condensate water passes through deaerator for two reasons:

1. Heating of condensate water by direct injection of steam.

2. Removal of non-condensable gases like $N_2$, $O_2$ and $CO_2$ and venting them to atmosphere.

Boiler Feed Water (BFW) from deaerator is pumped to the economizer sections where BFW exposes to hot gases leaving the evaporator sections to increase the temperature of BFW.

Due to this exposure, BFW changes from subcooled liquid to saturated liquid. Thus BFW is ready to enter the evaporators sections.

Since the pressure differs inside the steam generator, the BFW from the deaerator is pumped to the pressure of each section (low, intermediate and high) using:

1. Low pressure boiler feed water pump

2. High pressure / intermediate pressure boiler water feed pump

Saturated BFW form economizers passes through evaporators to produce saturated steam, which is routed to the superheater to finally produce steam at the required pressure.

The procedure described above is the same for LP, IP and HP BFW except that HP BFW passes through three HP economizers and three HP superheaters.

- HP steam is expanded in HP turbine then the exhausted HP steam is preheated, desuperheated and expanded in IP turbine.

- Desuperheating is done in order to control the turbine inlet temperature to protect turbine seals and glands.

LP steam from LP steam superheater is mixed with the exhausted steam from IP turbine then routed to LP turbine. After that, the exhausted LP steam is condensed, mixed with make-up BFW and pumped again to the condensate preheating section.
Figure 3-1: Proposed Layout of the North Giza Power Station (Prepared by PGESCo)
Figure 3-2: Process Flow Diagram for the North Giza Power Station
3.2 FIRE FIGHTING SYSTEMS

The Fire Fighting Systems, designed by PGESCo for the North Giza Power Station will follow the internationally-recognized standards of the National Fire Protection Association (NFPA) standards and will have the following characteristics.

A fire water system is provided for the plant. The fire water supply will be from the fire water pumps. The main underground fire loop will serve strategically placed yard hydrants and will supply water to sprinkler and spray systems for plant equipment.

The main underground fire water loop will incorporate sectionalizing valves so that a failure in any part of the system can be isolated while allowing the remainder of the system to function properly. Single-branch service mains will be provided from the loop to remote facilities, as needed, to satisfy fire water demands. The main loop sectionalizing valves will be located to minimize impact to fire water service within practical limits (e.g., every fourth branch).

Each branch will be provided with an isolation valve to allow facility isolation without system interruption.

A single fire pump will supply maximum water demand for any automatic sprinkler system plus water for fire hydrants and hose stations. The fire water system will be sized to meet the demand of the largest single fixed automatic fire suppression system plus 113.5 m³/hr (500 gpm) for yard hydrants. The fire water system will be based on 2 hours of service.

The system pressure and flow requirements will be provided by one 100-percent-capacity electric-motor-driven fire pump, backed up by one 100-percent-capacity diesel-engine-driven fire pump. A common jockey pump will maintain water pressure in the fire water distribution loops.

During a fire event, the electric-motor-driven fire pump will start automatically, with an alarm indicator in the control room. Once started, the pump will continue to run until manually stopped.

If the electric pump fails to start or drops to a lower set pressure, the diesel-engine-driven fire pump will start. Discharge from the pump will connect to the underground yard loop. The fire pump will be installed in accordance with National Fire Protection Association (NFPA) 20.

The electric and diesel pumps will be connected to the fire loop in at least two sections so that if there is a failure in one section of the fire loop, they can supply water to the remainder of the loop.
The fire protection system will include:

- CO₂ extinguishing system for each CTG (supplied by the combustion turbine supplier)
- Wet pipe automatic sprinkler system to envelop, as required, oil piping and equipment associated with the steam turbines lubricating oil and hydraulic system.
- Preaction system to protect the steam turbines bearings
- Foam system to protect the solar fuel oil storage tanks in accordance with NFPA 11.
- Full ring spray cooling for fuel oil tanks
- Main control room and main electrical/switchgear buildings:
  - FM200 clean agent suppression system for the main control room with smoke detectors
  - Manual suppression hose station with smoke detectors system for the main switchgear area
- Water spray deluge system for each of the main and auxiliary transformers
- A protective signaling system with main panel in the control room, including:
  - Operating status of electric and diesel fire water pumps
  - One central supervisory control panel to monitor the status of zones, with visual indications, audible alarm, and test provisions.
- HVAC duct smoke detectors
- Area fire/smoke detectors where required for automatic suppression system actuation
- Area fire/smoke detectors where required for alarm only
- Fire alarm horns (audible throughout the site), bells and strobe lights.
- Manual pull stations
- Interconnecting cabling
- Manual suppression equipment, including extinguishers, hose racks
- hose reels, hose houses, and hydrants
A standpipe and hose system will be provided in accordance with NFPA 14, in the power block. The main control room and will have portable CO₂ extinguishers in addition to the automatic fire suppression system.

Extinguishers will be sized, rated, and spaced in accordance with NFPA 10. Local building fire alarms, automatic fire detectors, and the fire signaling panel will be in accordance with NFPA 72. System design will essentially follow NFPA 850.
4 RISK ACCEPTANCE CRITERIA

In the absence of Egyptian legislation, the risks evaluated within this study were referenced against internationally-accepted criteria, in order to determine the acceptability of the risks and any need for risk reduction measures to be implemented within the design process.

The risk criteria proposed to be used are drawn from the widely used framework set out by the UK's HSE, using the As Low As Reasonably Practicable (ALARP) principle, and proposes risk acceptance criteria to be used as guidance for this study.

The derived criteria, and the ALARP framework, are described in full in Appendix I and summarized in the following sections.

4.1 RISK ASSESSMENT FRAMEWORK

The following measures of acceptability should be evaluated in assessing the risks from any hazardous activity:

- Individual risk criteria should be used to limit risks to individual workers and members of the public.

- Societal risk criteria should also be used to limit risks to the affected population as a whole.

- Cost-benefit analysis should be used to ensure that, once the above criteria are satisfied, an optimum level of safety measures is chosen for the activity, taking costs as well as risks into account. (Note that this is outside the scope of this study.)

The simplest framework for risk criteria is a single risk level which divides tolerable risks from intolerable ones. Such criteria give attractively simple results, but they need to be used very carefully, because they do not reflect the uncertainties both in estimating risks and in assessing what is tolerable. For instance, if applied rigidly, they could indicate that an activity which just exceeded the criteria would become acceptable as a result of some minor remedial measure which in fact scarcely changed the risk levels.

A more flexible framework specifies a level, usually known as the maximum tolerable criterion, above which the risk is regarded as intolerable whatever the benefit may be, and must be reduced. Below this level, the risks should also be made As Low As Reasonably Practicable (ALARP). This means that when deciding whether or not to implement risk reduction measures, their cost may be taken into account, using cost-benefit analysis. In this region, the higher the risks, the more it is worth spending to
reduce them. If the risks are low enough, it may not be worth spending anything, and the risks are then regarded as negligible.

This approach can be interpreted as dividing risks into three tiers (as is illustrated in Appendix 0):

- An upper band where risks are intolerable whatever the benefit the activity may bring. Risk reduction measures or design changes are considered essential.

- A middle band (or ALARP region) where the risk is considered to be tolerable only when it has been made ALARP. This requires risk reduction measures to be implemented if they are reasonably practicable, as evaluated by cost-benefit analysis.

- A negligible region where the risks are negligible and no risk reduction measures are needed.

4.2 INDIVIDUAL RISK CRITERIA

Individual risk is widely defined as the risk of fatality (or serious injury) experienced by an individual, noting that the acceptability of individual risks should be based on that experienced by the most exposed (i.e. 'worst-case') individual.

The most widely-used criteria for individual risks are the ones proposed by the UK HSE, noting that these have also been interpreted for projects in Egypt.

These criteria are:

- The maximum tolerable individual risk for workers is taken as $10^{-3}$ per year (i.e. 1 in 1,000 years).

- The maximum tolerable individual risk for members of the public is $10^{-4}$ per year (i.e. 1 in 10,000 years).

- The acceptable criterion, for both workers and public, corresponding to the level below which individual risks can be treated as effectively negligible, is $10^{-6}$ per year (i.e. 1 in 1,000,000 years).

- Between these criteria the risks are in the 'ALARP' or tolerability region. In this region the risks are acceptable only if demonstrated to be As Low As Reasonably Practicable (ALARP).

In terms of the acceptability of individual risks, it should be noted that:
• Individual risks are typically presented as contours that correspond to the risk experienced by a person continuously present, outdoors, at each location.

• While people are unlikely to remain "continuously present, outdoors" at a given point, the individual risk levels used to assess residential developments are not modified to account for any presence factor or the proportion of time spent indoors. That is, it should be conservatively assumed that dwellings are occupied at all times and that domestic properties offer no real protection against the potential hazards.

• Hence, the individual risks contours can be used directly with respect to the public, while for workers it is more appropriate to consider the most exposed individual (accounting for the time they spend in different areas, indoors, away from the hazards, etc).

• It should also be noted that lower criteria are often adopted with respect to vulnerable populations, such that schools and hospitals, for example, should be located such that the individual risks are well below $10^{-6}$ per year.

• The maximum criterion for the public of $10^{-4}$ per year is maintained in this study as a representative maximum. However, it should be emphasized that this is a maximum value and it would be extremely rare for this level to be considered acceptable for a new facility / development. That is, there is unlikely to be sufficient justification that there are no practicable methods of reducing this level of risk. In fact, it is considered to be best practice to treat $10^{-6}$ per year as the target criterion, while risks of up to $10^{-5}$ per year would require strong justification and risks above $10^{-5}$ per year should be avoided with respect to the public.

• It should, in any case, be emphasized that risks above $10^{-6}$ per year are acceptable only if shown to be ALARP.

• Conversely, for most workers (particularly those in a refinery) it is accepted that $10^{-6}$ per year risk levels are not practical to achieve and the target typically adopted is to achieve individual risks to workers of between $10^{-5}$ and $5 \times 10^{-5}$ per year.

In summary, it is proposed that:

• Risks to the public can be considered to be broadly acceptable if below $10^{-6}$ per year, although noting that societal risk factors should also be considered (including the type of population potentially exposed). Although risks of up to $10^{-4}$ per year may be considered acceptable if shown to be ALARP, it is
recommended that $10^{-5}$ per year is adopted for this study as the maximum tolerable criterion.

- Risks to workers can be considered to be broadly acceptable if below $10^{-5}$ per year and where risks of up to $10^{-3}$ per year may be considered acceptable if ALARP, which will be used in this study.

4.3 Societal Risk Criteria

A proposed criterion for Societal Risk is set out in Appendix 0 in the form of an F-N curve, which gives the cumulative frequency ($F$) of exceeding a number of fatalities ($N$).

It is, however, important to note that the acceptability of societal risks can be subjective and depends on a number of factors (such as the benefits versus the risks that a facility provides). There is not a single established indicator in terms of societal risk.

The proposed societal (F-N) criteria are considered to provide useful guidance on the acceptability of the societal risk, although it should be emphasized that the criteria are not as widely accepted as individual risk and should be used as guidance only.
5 METHODOLOGY

QRA is a well established methodology to assess the risks of industrial activities and to compare them with risks of normal activities. EcoConServ has used a QRA methodology as shown in Figure 5-1.

![QRA Methodology Diagram]

Figure 5-1: QRA Methodology

5.1 DATA COLLECTION

This study is based on the following documents, which were obtained from PGESCo:

- Process Flow Diagrams (PFDs)
- Heat and Material Balance
- Process and Instrument Diagrams (P&IDs)
5.2 HAZARD IDENTIFICATION (HAZID)

The hazard identification process is important for any risk analysis. A HAZID was performed in the course of preparing the QRA. The HAZID study for the main plant has enabled us to identify and enumerate the failure cases that require further analysis.

5.3 FREQUENCY ANALYSIS

Failure frequencies were determined for each event in order to perform a probabilistic risk assessment. Generally, a number of techniques are available to determine such frequencies. The approach relies on generic data. This provides failure frequencies for equipment items where data has been obtained from failure reports from a range of facilities.

5.4 CONSEQUENCE ANALYSIS

For each identified hazard scenario, consequence analysis tools were used to determine consequence effect zones for each hazard. The different possible outcomes could be:

- Dispersing of Hydrocarbon Vapor Cloud
- Explosion
- Fireball
- BLEVE
- Flash Fire
- Jet Fire
- Pool Fire.

The particular outcomes modeled depend on source terms (conditions like fluid, temperature, pressure etc.) and release phenomenology. The current understanding of the mechanisms occurring during and after the release is included in our consequence analysis models and tools. These models and tools are explained in Section 5.6.

5.5 RISK CALCULATIONS

The outcome of the risk analysis is risk terms presented in form of risk contours and FN curves, where the former is a form of location specific individual risk measurement while the latter is a measure for societal (group) risk.
The individual risk is the risk for a hypothetical individual assumed to be continuously present at a specific location. The individual at that particular location is expected to sustain a given level of harm from the realization of specified hazards. It is usually expressed in risk of death per year. Individual risk is presented in form of risk contours.

Societal Risk is the risk posed to a local community or to the society as a whole from the hazardous activity. In particular it is used to measure the risk to every exposed person, even if they are exposed on one brief occasion. It links the relationship between the frequency and the number of people suffering a given level of harm from the realization of a specified hazard. It is usually referred to a risk of death per year.

Risk contours were generated using the tools described in Section 5.6

5.6 RISK SOFTWARE TOOLS
Consequence modeling and risk estimation software are available from Shell, BP, DNV and Dyadem. The products produced by Shell and BP are used internally within those companies and are currently not available commercially. Shell products include FRED for consequence modeling and Shepherd for risk estimation, while BP products include Cirrus for consequence modeling. The acquisition of licensed software from DNV or Dyadem is cost prohibitive.

EcoConServ uses a collection of freely available software and ERCC in-house developed programs to estimate the risk. This approach has enabled EcoConServ engineers to have a deep understanding of the risk calculations methodology. The use of this risk software tools enables the users to have control over the modeling and hence the majority of the assumptions are covered in the inputs to, rather than within, the software.

EcoConServ tools include the use of ALOHA for consequence modeling. ALOHA is one of the tools developed by EPA's Office of Emergency Management (OEM) and the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA), to assist front-line chemical emergency planners and responders. ALOHA is an atmospheric dispersion model used for evaluating releases of hazardous chemical vapors. ALOHA allows the user to estimate the downwind dispersion of a chemical cloud based on the toxicological/physical characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release. ALOHA can estimate threat zones associated with several types of hazardous chemical releases, including toxic gas clouds, fires, and explosions.

The basic principles of ERCC in house program are:

- Dispersion results are drawn in from ALOHA software, taking flammable and toxic hazard ranges separately. These are used for delayed ignition hazards, such as toxic impacts, flash fires and Vapor Cloud Explosions (VCEs).
• The consequences of other fires (jet, pool, fireball / BLEVE) are specified in the form of downwind and crosswind distances (together with an offset) to specified impact levels. These can be derived from any source. Two impact levels are used for each fire type, for example jet fire radiation levels of 12.5 and 37.5 kW/m².

• The flammable vapor clouds are superimposed on the defined grid using one of the in-house developed programs, according to the wind rose, in order to determine:

  o The probability of ignition, according to the defined ignition sources and cloud duration (noting that this is in addition to a specific background ignition probability)

  o The probability and extent of any explosion that will occur, according to whether the specified cloud will reach any congested volumes (or groups of congested volumes) and ignition sources, in the respective weather conditions and wind direction.

• The resulting consequences, together with those specified directly (i.e. toxics, jet fires, etc.), are compared against the populations that are reached, and the defined vulnerabilities, to determine the appropriate risk (i.e. individual / societal, indoor / outdoor).

• The explosion modeling is conducted according to the ALOHA model requirements. Hence, the vast majority of assumptions in ERCC in-house programs are those specified within this document, as inputs.

Similarly, the way the risks are calculated, via event trees, is part of the user-defined input. The inputs to ERCC in house programs are consequences in the form specified above, where each will have an event frequency together with an immediate ignition probability or a background delayed ignition probability. The probability of weather category and wind direction is determined as per Assumptions of Appendix A2, as are the ignition and explosion probabilities (as discussed further in Appendix A2. All other variations on the outcome frequency are defined before input, e.g. the probability of isolation failure or variation in release orientation.
6 ASSUMPTIONS

6.1 INTRODUCTION
The basic aim of this Assumptions appendix is to document the details underpinning this Quantitative Risk Assessment (QRA) study.

Background data:

- The site-specific aspects that apply (or potentially apply) to each of the release scenarios (failure cases) modeled are referred to as 'background data'. This covers the meteorological conditions, as well as potential ignition sources and congested volumes that are specific to the site (and to the proposed layout), and the potentially exposed populations.

- These aspects are modeled as realistically as possible to represent the proposed layout / design of the new power station facility.

General assumptions:

The basic methodology adopted by ERCC for studies of this kind is set out in the following sections, in order to describe the basis for the defined scenarios and modeling approach. It should be emphasized that elements of these sections are generic and are intended to define the broad approach only, where specific assumptions may vary from failure case to failure case.

References are given at the end of the QRA main report.

6.2 BACKGROUND ASSUMPTIONS

6.2.1 WEATHER CATEGORIES
As well as the wind direction, the actual weather conditions, in terms of the wind speed and the stability (a measure of atmospheric turbulence), determine how quickly the flammable plume disperses to lower non-hazardous concentrations.

In the absence of detailed meteorological data (i.e. covering the stability categories), two representative weather conditions are applied to model the dispersion of each release scenario. These are D5 and F2 conditions, which are widely adopted (such as by NFPA and the UK HSE) as broadly representative of 'typical' and 'worst-case' dispersion conditions, respectively:

- D5 - neutral stability (D) and 5 m/s wind speed.
- F2 - stable (F) conditions and 2 m/s wind speed.
UK HSE guidance suggests that good practice for QRA studies is to assume that D5 conditions apply for 80% of the time and F2 for the remaining 20% - again, in the absence of detailed data only.

Although based on the experience of conducting QRA worldwide suggests that this provides a reasonably representative (and slightly conservative) basis when compared against local weather conditions.

The weather conditions can have a significant influence on flammable (and toxic) vapor cloud dispersion, which will be of most relevance with respect to the largest release scenarios and their potential off-site impacts. Typically (but not always) F2 conditions will represent the maximum hazard ranges, noting that they are unlikely to occur for as much as 20% of the time in practice. The risks will, therefore, be sensitive to the above assumption, although it should be noted that the above is widely used for this kind of study and considered to be sufficiently representative for this assessment.

6.2.2 Wind Direction
The wind rose for the region where the power station will be constructed is given below.

Please note that the above figure is based on the True North. The data provided is based on annual averages and, hence, is applied to the risk model as being the same for all time periods (e.g. day and night).
6.2.3 **Atmospheric Parameters**

The representative atmospheric parameters that are applied to the consequence modeling are summarized in Table 6-1, below. These are largely based on the data provided by our client.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>30</td>
<td>°C</td>
<td>The range of min/max temperatures is 2 to 41 °C, where 20 °C is taken as a representative base value.</td>
</tr>
<tr>
<td>Surface temperature</td>
<td>30</td>
<td>°C</td>
<td>Taken as the same as air temperature, above.</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>60</td>
<td>%</td>
<td>Assumed. Note that its influence on dispersion / consequences is minor.</td>
</tr>
<tr>
<td>Surface roughness</td>
<td>1</td>
<td>m</td>
<td>Representative parameter for regular large obstacles based on TNO Purple Book guidance.</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>1</td>
<td>kW/m²</td>
<td>Assumed. Note that its influence on dispersion / consequences is negligible.</td>
</tr>
<tr>
<td>Atmospheric pressure</td>
<td>1.013</td>
<td>bar</td>
<td>Negligible influence on dispersion / consequences.</td>
</tr>
</tbody>
</table>

As indicated in the above table, assumptions such as surface roughness can significantly affect the hazard ranges predicted for the worst-case release scenarios. However, the influence on most releases is minor and the purpose of the risk study is to determine the frequency of the most representative outcomes. Hence, the overall risks will be reasonable robust to the above assumptions.

6.2.4 **Congest Volumes**

The explosion assessment is based on the Multi Energy Model (TNO, 1997) and is based around definition of congested volumes that have the potential to be explosion sources. The broad rule-set used to define the congested volumes within each of the units is set out below.

- All air coolers are assumed to provide a 'roof' under which gas may potentially accumulate, where the pipe-rack / pipework underneath would typically provide sufficient congestion for an explosion source. Where the height of the air coolers is not clear, a default height of either 10 or 15 m is assumed (drawing on experience of similar facilities).
• Where platforms are indicated on a plot plan it is assumed that they are there to provide access to equipment and taken to indicate a degree of congestion. The height of the congestion is generally taken as that of the platform, although a degree of judgment is applied according to the specific equipment/platform.

• Compressor (and other) shelters are to be included as appropriate, taken as the shelter volume less the equipment volume.

• Other congestions are more judgmental, but can include:
  • The volume around reactors and columns, where the plot plan indicates a likelihood of congestion, up to a fraction of the height – usually taken as that of the nearest piperack.
  • The volume associated with banks of vessels or heat exchangers where the gap between the equipment is small enough that flame propagation will occur.
  • Linked volumes will form a single explosion source in the event of a vapor cloud covering some or all of the respective volumes; volumes that are not linked will lead to separate explosions occurring. Very broadly, the largest width or ‘diameter’ is used to estimate the likelihood of flame propagation between volumes, and hence to determine whether they are linked.

Each congested region is assessed against TNO guidance (TNO, 1997; Eggen, 1995) to determine the peak overpressure that may arise following an explosion. For example, a 2-dimensional confinement, low obstacle density obstructed region is assigned a peak explosion overpressure of 0.5 barg (Multi-Energy explosion strength 6). The majority of volumes have higher obstacle density, which results in a Multi-Energy explosion strength of 7 being used in most cases. Note that the peak explosion overpressure assigned to any congested volume is capped at a maximum (default) value of 1 barg.

Furthermore, the effect of flame reactivity is taken into consideration, where by default all flammable materials are assigned a conservative explosion strength of 7, while higher reactivity materials (e.g. ethylene and hydrogen) would be assigned higher explosion strengths (default value = 8).

It should be emphasized that the identification of congested volumes involves a high degree of judgment. However, the approach adopted is consistent with that used internationally for a number of similar, recent studies and is intended to provide an indication of the likely explosion impacts.
The on-site impacts (such as the overpressure loads to specific buildings) will be sensitive to these assumptions, while the off-site effects are considered to be reasonably robust, given that the extent of each volume is broadly representative.

6.2.5 **POPULATIONS**
The on-site populations will be consistent with a typical facility and would not affect any decisions at this pre-construction stage in the development. The information sent to EcoConServ does not include any data about the on-site population. It was assumed that the maximum population will be around 280 workers during the day shift.

The off-site populations are to be considered semi-quantitatively on the basis of the populated areas potentially affected (i.e. once the individual risk contours have been derived).

The following population density estimates will be used:

- Urban, high density - 5000 people per km²
- Urban, medium density - 2000 people per km²
- Urban, low density - 750 people per km²

The above should be recognized as coarse estimates. The aim will be to use the upper and lower values to provide a realistic range of potential societal risks that may apply.

The uncertainty in this assumption should be recognized, although the importance will depend on the initial off-site risk results (and hence the maximum hazard ranges).

6.3 **IMPACT CRITERIA ASSUMPTION**

6.3.1 **SUMMARY**
Risks to people are based on defined fatality / impact probabilities for given exposures. These are summarized in

---

*EcoConServ*

*Environmental Solutions*
Table 6-2, below, for personnel outdoors, and within the following building types:

- ‘typical’ on-site buildings
- reinforced concrete buildings (assumed to be representative of a typical control building).

The values given for each are a summary only – see the following sections for justification of the fire and explosion impact criteria, which includes discussion of the API (API, 1995) building type assigned to each. Toxic impacts are assessed on a different basis, using a probit function, as described later.

Note that the outdoor values are used in the derivation of the general individual risks, which is of particular relevance to off-site populations. As discussed in Appendix 0, the criteria used for residential populations is based on the assumption that all personnel are effectively outdoors (i.e. no credit is claimed for protection by residential buildings).
Table 6-2: Human Impact Criteria

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Impact Level</th>
<th>Fatality rate for defined impact</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Outdoors</td>
<td>Indoors - Typical (API B1, B2, B4)</td>
</tr>
<tr>
<td>Jet Fire</td>
<td>Flame (&gt;37.5 kW/m²)</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Radiation (&gt;12.5 kW/m²)</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Pool Fire</td>
<td>Flame (&gt;37.5 kW/m²)</td>
<td>0.7</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Radiation (&gt;12.5 kW/m²)</td>
<td>0.35</td>
<td>0.1</td>
</tr>
<tr>
<td>Flash Fire</td>
<td>Flame (to LFL)</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Fireball</td>
<td>Flame (&gt;37.5 kW/m²)</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Radiation (&gt;12.5 kW/m²)</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Overpressure</td>
<td>P1 (30-70 mbar)</td>
<td>0</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>P2 (70-110 mbar)</td>
<td>0</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>P3 (110-160 mbar)</td>
<td>0</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>P4 (160-300 mbar)</td>
<td>0.01</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>P5 (300-500 mbar)</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>P1 (&gt; 500 mbar)</td>
<td>0.25</td>
<td>1</td>
</tr>
</tbody>
</table>

6.3.2 Vulnerability / Impact Criteria - Fires and Explosions

The basis for the fire impact levels and criteria is summarized below.

- The levels at which impairment from fires occurs are defined for two radiation levels, of greater than 37.5 kW/m² and 12.5 kW/m², which are referenced within the risk model as 'flame' and 'radiation' impacts, respectively.

- A fatality rate of 100% is assumed at radiation levels of 37.5 kW/m² or greater and 50% for 12.5 kW/m² or greater for personnel outdoors that are exposed to radiation effects from jet fires and fireballs / BLEVEs. These values involve a degree of judgment, but are consistent with standard practice (and slightly conservative).

- Although the radiation levels are the same, in order to recognize the greater potential for exposed personnel to escape from pool fires, a reduced vulnerability is applied for personnel outdoors for pool fires. A fatality rate of
70% is assumed at radiation levels of 37.5 kW/m² or greater for pool fires, and 35% for values of 12.5 kW/m² or greater.

- People outdoors exposed to flash fires are conservatively assumed to have a 100% probability of fatality, noting that the flash fire envelope is based on the concentration above the Lower Flammable Limit (LFL), while buildings are typically assumed to offer good protection to occupants from the potential impacts of flash fires. Based on international studies, and CIA guidance, a 10% fatality rate is assumed for each building.

The basis for the explosion impact levels and criteria is summarized below.

- The fatality rates applied for the (six) different explosion overpressures are based on guidance contained within API RP 752 (Reference 3). This defines different fatality rate curves, which are used to derive the values listed in Assumption II.3.1, for the following building categories:
  a) B1 - Wood-frame trailer or shack
  b) B2 - Steel-frame, metal-siding or pre-engineered building
  c) B3 - Unreinforced masonry bearing wall building
  d) B4 - Steel or concrete framed with reinforced masonry infill or cladding
  e) B5 - Reinforced concrete building

- The default for the on-site buildings is taken as 'B4'.

Note that residential populations are treated as - effectively - outdoors, as discussed above.

6.3.3 Vulnerability / Impact Criteria - Toxics
The vulnerability to toxic consequences is determined using probit functions that relate the concentration and exposure duration to the potential lethality. None of the studied failure cases included the release of toxic material and thus no further explanation is presented here.

6.4 Failure Case Definition Assumptions

6.4.1 Failure Cases - Definition
The key factors in selection of the representative sections (i.e. the generic failure cases) are:

- Material / phase released (gas, pressurized liquid, cryogenic liquid, etc.).
- Release condition (inventory driven, pumped flow, etc.).
• Process conditions (temperature and pressure).
• Release location (the area in which the release occurs, including the height).
• Isolation (by ESD).

For each of the sections containing process equipment or piping, up to five representative release sizes are considered:

• Full-bore rupture (based on the most representative line size within each section)
• Large leaks (e.g. due to connection failures) - 75 mm (3") equivalent diameter
• Medium, Small and Very Small leaks (e.g. due to corrosion, impact and other such cases) – 25, 12 and 2 mm (1", ½" and 1/10") equivalent diameter leaks respectively.

Storage tanks (catastrophic failure and large leaks) and catastrophic failure of pressure vessels are also typically defined as separate failure cases.

The development of the release is discussed within the following assumptions, noting that:

• A representative isolation time will apply in all cases (i.e. the small proportion of events where the detection / isolation systems fail will not have a significant influence on the overall risks).
• Blowdown is not modeled for any cases, on the basis that it is only effective at the later stages of any release, which has no real influence on the risks to personnel / buildings.

6.4.2 FAILURE CASES - PARAMETERS

For each of the release scenarios to be modeled, the key inputs to the derivation of release parameters are the phase, process conditions, flowrate, location and section volume / inventory, where the parameters are derived as follows:

• Phase: The phase of the material at the process conditions is the key factor. Hence, 2-phase releases are accounted for in the modeling, but are defined as liquid releases for the purposes of the initial discharge, to ensure that the corresponding release rate is derived on the maximum mass flow basis.
• Process conditions (temperature and pressure): Taken from the PFDs and Heat & Mass Balances. Where the conditions vary within a section, those associated with the main inventory are used, and where there is no 'main' inventory the stream with the highest pressure.
• Flow rate: Also taken from the PFDs and Heat & Mass Balances.

• Release location: The release location selected is necessarily representative, but is generally taken as that corresponding to the largest inventory within a section. The default height of all releases is taken as 1 m, with the exception of any sections where all of the components included are at height.

• Volume / inventory: The section volume is derived from the vessel volumes, together with estimates of line lengths associated with each section and the estimated fill fraction of each vessel. Note that at the input stage the volume of each section is defined. This is not necessarily the isolatable volume and the inventory available for release is derived from the representative density and the volume of all connected sections, including the flash fraction of connected liquid inventories.

Note also that the potential for impingement of the release is considered with respect to flammable clouds (in order to ensure a conservative basis for vapor cloud explosions). (Impingement is not considered with respect to ignited releases – e.g. jet fires - to ensure the analysis is conservative in this respect.)

6.4.3 FAILURE CASES - RELEASE TYPES
The outcome, and hence the way in which the discharge and subsequent dispersion parameters are modeled, for each release varies according to the type, where four basic release types are considered:

• Vapor releases. These are relatively straightforward scenarios where the process fluid is gas, and hence the discharge parameters applied to the model are based on the gas properties.

• Liquid releases. For the purposes of this analysis, note that this refers to releases of liquid, which remain as liquid. These are defined as all releases where the vapor fraction is less than 20% (by mole) and where the flash fraction upon release also remains below 20%. Hence, these are release scenarios where the dominant outcomes are potential pool fires, with a limited potential for vapor clouds and associated hazards. These are, generally, releases of stabilized crude oil or heavy hydrocarbon products.

• Vaporizing liquid releases. This release type aims to cover '2-phase' releases, where the fluid is primarily liquid that will not flash, but where some gas will vaporize from the pool that is formed (e.g. unstabilized crude oil). The liquid component and vapor cloud are, therefore, modeled separately.

• 'Flashing' liquid releases. These are releases where the process fluid is 2-phase or liquid, where a significant flash will occur upon release (i.e. 20% or greater). These releases are generally those due to lighter hydrocarbons.
They are modeled as 2-phase (or liquid) releases and tend to result in jet fires in the event of immediate ignition, or vapor clouds if not immediately ignited. Note that pool fires are also credible, but are usually minor in comparison to the other outcomes/hazard ranges.

The basic rule-set used in relation to determining a representative fluid for each section (release scenario) is summarized below.

- Noting that the consequences do not vary significantly for heavy hydrocarbons, fluids with more carbon content than decane (or equivalent) are defined in simple terms as either C10, C14 or C20.

- Streams are generally defined as a single equivalent component on the basis of the equivalent molecular weight where practicable. However, consideration is given to whether hydrogen or water content affects the average molecular weight, or whether the composition is such that the material should be modeled as a mixture.
6.4.4 FAILURE CASE PARAMETERS – RELEASE RATE / DURATION

The representative release rate and duration are derived according to whether the release is inventory driven or downstream of a pump:

<table>
<thead>
<tr>
<th>Type</th>
<th>Conditions</th>
<th>Release Rate, Q (kg/s)</th>
<th>Duration, T (s)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory Driven (Gas or Liquid)</td>
<td>Q&gt;NFR and T&lt;20 s</td>
<td>Instantaneous (flammable)</td>
<td>T = Ms/Q</td>
<td>Initial peak dominates for flammables – model as instantaneous release of section inventory (Ms). More conservative to model longer duration for toxics – use residual flowrate, NFR.</td>
</tr>
<tr>
<td></td>
<td>Q&lt;NFR or T&gt;120 s</td>
<td>Q=NFR (toxic)</td>
<td>T = Tiso + Miso/Q</td>
<td></td>
</tr>
<tr>
<td>Restricted (Pumped) Flow (Liquid)</td>
<td>Qo&gt;2NFR</td>
<td>Q = average release rate over 2 min</td>
<td>T = Miso/Q</td>
<td>Rapid release, depletes section inventory rapidly. Initial peak is reduced rapidly and not representative, hence average over first 2 minutes taken as representative. Residual release at NFR, once initial inventory depleted, will be negligible in comparison. The inventory in this case, Miso, is the isolatable inventory of the section.</td>
</tr>
<tr>
<td></td>
<td>Qo&lt;2NFR</td>
<td>Q = Qo (up to a max of f x NFR)</td>
<td>T = Tiso + Miso/Q</td>
<td>Initial release rate will continue until isolation occurs. The inventory in this case, Miso, is the isolatable inventory of the section.</td>
</tr>
</tbody>
</table>

Terms: Q – release rate used; Qo – initial (maximum) release rate; NFR – normal flow rate; f – factor to allow for centrifugal pump over-run (1.25); Tiso – time for isolation; T – time to deplete inventory available for release (M / Qo); Ms – section inventory; Miso – isolatable inventory (plus connected inventories where appropriate).
6.4.5 Failure Case Parameters - Inventory

The basic rule-set used in relation to determining the inventory of each section (release scenario) is summarized below.

- The length of piping in each section is estimated from the plot plans on the basis of the x, y and z distances between the main components, with a degree of judgment included for short distances. A simple default of 10 m is included for distances to components that are not indicated on the plot plans (such as to ESDs downstream of a vessel).

- The vessel inventory is based on the volumes derived from the available data, and the density of the respective stream, or streams. Note that the volume calculations include a factor of 1.1 to account for torisphoidal ends.

- The fill fraction of each vessel is an important factor, where the basic fill fraction is assumed to be:
  - 30% for vertical vessels, including columns;
  - 50% for horizontal vessels;
  - The exceptions to the above are vessels that are intended for vapor only (e.g. compressor suction drums) or liquid only (e.g. surge drums) service, in which case 0 or 100% fill is used as appropriate.

- An important additional factor is whether the vessel is likely to be packed or not, which is generally assumed to apply to reactors only. A default of 50% packing is assumed, such that the hydrocarbon volume is taken as half of the actual vessel volume.

6.4.6 Failure Case Parameters - Release Duration

The fire and gas detection philosophy adopted within the plant is assumed to be consistent with best-practice and detection of a major release (and most small releases) is likely to occur rapidly for the majority of release locations.

However, the key factor in determining whether and when isolation occurs is the human factor aspect of the operators' response to the alarms. This, of course, can only be quantified as a representative isolation time, where a simple rule set is proposed below, based on the size of the initial release rate relative to the normal flow rate.

The release rate is taken as an indication of the severity of the release in terms of the number of gas detection alarms that may be activated, and of the likelihood of process alarms being activated. This approach does not suggest that rapid isolation will only occur for certain sized releases, or via process alarms only, but it is assumed to be
reasonably representative of the significance of each release, which is likely to determine the delay between detection and action (i.e. isolation).

For the initial release rate, Qo, in relation to the Normal Flow Rate (NFR):

- If $Qo > 0.2 \times NFR$, an isolation time of 5 minutes is assumed.
- For smaller release rates (i.e. $Qo < 0.2 \times NFR$), an isolation time of 15 minutes is assumed.

The above isolation times are consistent with those used international studies, where:

- Detection is assumed to be rapid (or, specifically, is not reliant on visual detection due to the presence of adequate detectors and/or process alarms);
- Activation of ESDs is remotely actuated, such as from the Control Room, but requires manual control, i.e. there are no automatic isolation actions on detection of a hazardous release.

The release duration applied is determined from consideration of the inventory of the isolatable section, and the selected release rate, in relation to the isolation time.

6.4.7 Failure Case Parameters - Others

6.4.7.1 Release Inventory

The total inventory released is calculated simply as the product of the representative release rate and the duration for which it is applied, i.e. $M_{\text{released}} = Q \times T$.

6.4.7.2 Velocity (Release Momentum)

The discharge velocity is applied as a measure of the amount of momentum in the release, and determines the initial rate of air entrainment. This is a theoretical expansion velocity taking into account the velocity through the leak orifice and the expansion from the process pressure to atmospheric.

The velocity is calculated within the discharge model for each release. However, if $Qo$ is not used in the model, such as if the release rate is restricted by the pumping rate, the velocity used is decreased by the same proportion as the release rate (i.e. a factor of $Q/Qo$ is applied).

6.4.7.3 Discharge Temperature

The discharge temperature required for input to the dispersion model is the temperature of the material after expansion to atmospheric pressure and before the addition of any air for pre-dilution.

This is generally calculated within the discharge model, although it is noted that the approach used is theoretical and generally reduces the temperature of vapor releases to close to the boiling point. In many cases, the process temperature is significantly above
the material's boiling point and the maximum temperature drop that is considered credible, for vapor releases, is to 40 °C below the process temperature.

6.4.7.4 Additional Liquid Release Data
In addition to the parameters defined in the above sections, the droplet diameter and liquid fraction are required to define liquid releases. Together with the velocity, these parameters determine how far the droplets will travel in the release before raining out, or conversely whether they will evaporate before rain-out occurs. These parameters are derived from the initial discharge modeling.

The droplet diameter for non-flashing flows (i.e. fluids in the mechanical break-up regime) is set to a minimum of 0.2 mm, based on experimental data given in a UK HSE research project (Witlox & Bowen, 2001).

6.5 FREQUENCY ANALYSIS ASSUMPTIONS

6.5.1 GENERIC FAILURE DATA - PROCESS
The basis of the process and pipeline frequency analysis is EcoConServ and ERCC's interpretation of the Hydrocarbon Release Database (known as the "HCRD" database) (HSE, 1999). Although providing the most comprehensive available failure data, for a wide variety of equipment types, the HCRD, provides data on leak sizes that requires some interpretation to be used effectively. Experience shows that using the data directly, i.e. assuming that all releases occur at normal operating conditions, provides overly conservative inputs to a QRA study. A proportion of all leaks occur at conditions that produce releases with less serious consequences than would be modeled using standard QRA assumptions:

- Depressurized (maintenance)
- Rapid isolation (process trips)

Analysis has been conducted, which derives 'equivalent' hole sizes, based on the recorded release quantity (rather than the recorded hole size), hence making allowance for the proportion of incidents where limited releases occur. The resulting failure data is used as the basis for the frequency analysis in this study. The components, or parts, for which failure rates are derived and the generic failure rates applied to each are listed in Table 6-3.

Note that for interconnecting pipelines the Process data frequency for pipework is conservatively used.

Other failure rates that are typically utilized are:

- Catastrophic Pressure Vessel Failure: $4 \times 10^{-6}$ per year (applied to all pressure vessels)
• BLEVE of Pressure Vessel: $1 \times 10^{-6}$ per year (applied to pressure vessels with BLEVE potential – containing pressurized volatile liquid, such as LPG and light hydrocarbons)

### Table 6.3: Generic Process Leak Frequencies

<table>
<thead>
<tr>
<th>Equipment Item</th>
<th>Generic Leak Frequency (per year), by leak size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very Small (2mm)</td>
</tr>
<tr>
<td>Air cooler</td>
<td>3.60E-03</td>
</tr>
<tr>
<td>Block valve &lt;3in</td>
<td>7.20E-05</td>
</tr>
<tr>
<td>Block valve &gt;3in</td>
<td>2.10E-04</td>
</tr>
<tr>
<td>Centrifugal pump</td>
<td>4.70E-03</td>
</tr>
<tr>
<td>Centrifugal compressor</td>
<td>2.80E-03</td>
</tr>
<tr>
<td>Check valve &lt;3in</td>
<td>1.40E-04</td>
</tr>
<tr>
<td>Check valve &gt;3in</td>
<td>2.10E-04</td>
</tr>
<tr>
<td>Control valve &lt;3in</td>
<td>5.20E-04</td>
</tr>
<tr>
<td>Control valve &gt;3in</td>
<td>9.00E-04</td>
</tr>
<tr>
<td>Filter</td>
<td>1.80E-03</td>
</tr>
<tr>
<td>Fitting</td>
<td>4.10E-04</td>
</tr>
<tr>
<td>Flange &lt;3in</td>
<td>3.10E-05</td>
</tr>
<tr>
<td>Flange &gt;3in</td>
<td>4.70E-05</td>
</tr>
<tr>
<td>HX-s</td>
<td>1.70E-03</td>
</tr>
<tr>
<td>HX-t</td>
<td>2.00E-03</td>
</tr>
<tr>
<td>Piping &lt;3in</td>
<td>1.20E-04</td>
</tr>
<tr>
<td>Piping &gt;3in</td>
<td>4.80E-05</td>
</tr>
<tr>
<td>Plate &amp; Fin HX</td>
<td>5.90E-03</td>
</tr>
<tr>
<td>Relieve valve &lt;3in</td>
<td>6.10E-04</td>
</tr>
<tr>
<td>Relief valve &gt;3in</td>
<td>7.50E-04</td>
</tr>
<tr>
<td>Vessel/Column</td>
<td>2.40E-03</td>
</tr>
</tbody>
</table>

#### 6.5.2 Failure Data for Oil Tanks

##### 6.5.2.1 Full Surface Tank Fire

For the scenario of a full surface tank fire, insufficient data is available on the causation mechanisms to enable the fire frequency to be estimated directly based on the detailed tank design. Therefore, for the purposes of the QRA, generic frequency data must be used. In selecting an appropriate frequency to apply for a full surface tank fire in the...
QRA, two most applicable sources were the LASTFIRE Project (LASTFIRE, 1997) and Technica's "Singapore Study" (Technica, 1990).

The Singapore Study provided data taken from three studies covering storage tank operations in the Netherlands, USA and Scotland, as well as from oil and petrochemical companies operating terminals in Singapore from 1945. The full surface tank fire frequency derived from the USA/Europe and Singapore operations were $2.0 \times 10^{-4}$ per year and $9.3 \times 10^{-4}$ per year respectively.

The LASTFIRE Project involved the largest study to date undertaken to determine the fire frequency for large floating roof storage tanks. It involved data obtained from 16 companies, operating 2,420 tanks at 164 sites throughout 36 countries over a survey period from 1981 to 1996. The study derived a full surface tank fire frequency of $1.2 \times 10^{-4}$ per year.

The frequency considered most applicable for this study is $1.2 \times 10^{-4}$ per year, derived from the LASTFIRE project. This value has been selected because it has been derived from the widest sample set of events and tank locations. Statistically, this can be expected to provide a more appropriate representation of the true event frequency. In addition, both data sources reviewed suggested that there is a correlation between the frequency of storage tank fires and the number of thunderstorm days experienced in the area. When compared with Singapore, the number of thunderstorm days experienced in the project area is relatively low. This suggests that the expected frequency for a full surface tank fire in Singapore should be higher than at this project. The selected frequency is consistent in this respect, in that it is lower than the value determined solely for operations in the Singapore area.

### 6.5.2.2 Bund Fire

A bund fire is generated by the ignition of a major release of flammable liquid from a pipe or storage tank into a bunded area. The QRA assessed the frequency of a bund fire based on the release of product from a failure of the tanks or associated fittings in conjunction with the likelihood of ignition. The intervention measures implemented are also considered in the derivation of the consequence frequency values. The likelihood of ignition is dependent on the release rate of the product.

The failure frequencies were determined by identifying the various items associated with the tank that may fail. The failure rate for these items, in combination with the failure rate data for the tank itself were combined to determine the overall failure frequency.

The LASTFIRE Project estimated the frequency for a large bund fire resulting from a major spill to be $6 \times 10^{-5}$ per tank per year (LASTFIRE, 1997). Failure events that would lead to a major spill into the tank bund, would include large and catastrophic equipment failures. A bund fire would result if such a spill was subsequently ignited. Of the two
large bund fire events described in the LASTFIRE Project, one had a release rate of \( \sim 4.5 \text{ m}^3/\text{min} \) and the other had a pool fire surface area of 232 m\(^2\). The failure cases analyzed as part of the QRA with an equivalent hole size greater than 100 mm would result in spills of this magnitude. The total frequency of bund fires caused by these failures is 6.1 x 10\(^{-5}\) per year. This is comparable to the bund fire value determined by the LASTFIRE Project. This QRA uses the value of 6.1 x 10\(^{-5}\) per year for the bund fire frequency.

6.6 CONSEQUENCE ANALYSIS ASSUMPTIONS

6.6.1 GENERAL
For each release event defined, dispersion modeling and fire size calculations are conducted within ALOHA modeling software tool. These consequence results are used directly by ERCC in-house program (risk model).

The consequence fire input to the risk model in groups of hazard type, which depend upon the type of release and when ignition occurs, as summarized Table 6-4 below. Note that this table addresses flammable impacts only; toxic impacts will also apply for unignited releases depending on the composition.

<table>
<thead>
<tr>
<th>Release Type</th>
<th>Hazard Type (Consequence)</th>
<th>Immediate Ignition</th>
<th>Delayed Ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas release</td>
<td>Jet fire (or fireball for short duration release)</td>
<td>Flash fire/explosion</td>
<td></td>
</tr>
<tr>
<td>Liquid release</td>
<td>Pool fire</td>
<td>Pool fire</td>
<td></td>
</tr>
<tr>
<td>Flashing release</td>
<td>Jet fire (or fireball for short duration release)</td>
<td>Flash fire / explosion</td>
<td></td>
</tr>
<tr>
<td>Vaporizing release</td>
<td>Pool fire</td>
<td>Pool fire + flash fire / explosion of vaporized cloud</td>
<td></td>
</tr>
</tbody>
</table>

The different hazard types (fires, explosions, toxics) are discussed further in the following sections. However, the basic assumptions are dominated by the derivation of the representative release parameters, as discussed above.

6.6.2 DISPERSION MODELING
Dispersion of unignited gas releases is conducted within ALOHA to determine both flash fire and vapor cloud explosion (VCE) consequences. These impacts are applied if delayed ignition is determined to occur.
6.6.3 **Explosion Modeling**

The explosion modelling is carried out in ALOHA, using as input the area enclosed by the lower flammable Limit (LFL), and corresponding cloud depth and flammable mass, as predicted in the dispersion modeling.

Note that as a default, no unconfined vapor explosions are modeled. The ignition of flammable gas clouds in non-congested areas is covered by flash fires.

6.6.4 **Fire Modeling**

Based on the derivation of the release parameters described in Assumptions II.4.1 to II.4.7, the determination of the initial fire effects is handled by the ALOHA as follows.

- All immediately ignited releases are modeled as either jet or pool fires, unless the release is instantaneous or very rapid (less than 20 seconds) in which case a fireball is applied.

- All delayed ignition events are modeled as flash fires or VCEs, where pool fires will additionally apply for liquid spills.

- Flash fires are based on the LFL distance.

Note that pool fires are modeled assuming no drainage or containment, in order to determine the base case pool fire loads.

Note also that jet fires (and fireballs) are modeled on the basis of the theoretical (unobstructed) releases, as discussed above.

6.7 **Risk Analysis Assumptions**

6.7.1 **Software Used**

Consequence modeling and risk estimation software are available from Shell, BP, DNV and Dyadem. The products produced by Shell and BP are used internally within those companies and are currently not available commercially. Shell products include FRED for consequence modeling and Shepherd for risk estimation, while BP products include Cirrus for consequence modeling. The acquisition of licensed software from DNV or Dyadem is cost prohibitive.

EcoConServ uses a collection of freely available software and ERCC in-house developed programs to estimate the risk. These tools enable the users to have control over the modeling and hence the majority of the assumptions are covered in the inputs to, rather than within, the software.

The used tools include the use of ALOHA for consequence modeling. ALOHA is one of the tools developed by EPA's Office of Emergency Management (OEM) and the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA), to assist front-line chemical emergency planners and responders. ALOHA is an
atmospheric dispersion model used for evaluating releases of hazardous chemical vapors. ALOHA allows the user to estimate the downwind dispersion of a chemical cloud based on the toxicological/physical characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release. ALOHA can estimate threat zones associated with several types of hazardous chemical releases, including toxic gas clouds, fires, and explosions.

The basic principle the used tools are:

- Dispersion results are drawn in from ALOHA software, taking flammable and toxic hazard ranges separately. These are used for delayed ignition hazards, such as toxic impacts, flash fires and Vapor Cloud Explosions (VCEs).

- The consequences of other fires (jet, pool, fireball / BLEVE) are specified in the form of downwind and crosswind distances (together with an offset) to specified impact levels. These can be derived from any source. Two impact levels are used for each fire type, for example jet fire radiation levels of 12.5 and 37.5 kW/m².

- The flammable vapor clouds are superimposed on the defined grid using one of the in-house developed programs, according to the wind rose, in order to determine:
  
  - The probability of ignition, according to the defined ignition sources and cloud duration (noting that this is in addition to a specific background ignition probability)
  
  - The probability and extent of any explosion that will occur, according to whether the specified cloud will reach any congested volumes (or groups of congested volumes) and ignition sources, in the respective weather conditions and wind direction.

- The resulting consequences, together with those specified directly (i.e. toxics, jet fires, etc.), are compared against the populations that are reached, and the defined vulnerabilities, to determine the appropriate risk (i.e. individual / societal, indoor / outdoor).

- The explosion modeling is conducted according to the ALOHA model requirements. Hence, the vast majority of assumptions in ERCC in-house programs are those specified within this document, as inputs.

Similarly, the way the risks are calculated, via event trees, is part of the user-defined input. The inputs to ERCC programs are consequences in the form specified above, where each will have an event frequency together with an immediate ignition probability or a background delayed ignition probability. The probability of weather category and wind direction is determined, as are the ignition and explosion...
probabilities. All other variations on the outcome frequency are defined before input, e.g. the probability of isolation failure or variation in release orientation.

Example event trees by Release Type are given below.

![Event Tree Diagram]

Figure 6-2: Event Tree for Vapor and Flashing Liquid Release Types
6.7.2 IGNITION PROBABILITY MODEL

The overall, background probability of ignition is based on the release rate dependent model developed by Cox, Lees and Ang, CLA (Reference 8).

For liquid releases, the probability of ignition is derived as follows:

\[ P_{\text{ignition}} = \exp (0.392 \ln (m) - 4.333) \]

where: \( m \) = release rate (kg/s) - maximum probability of 0.3 applied

---

**Figure 6-3: Event Tree for Liquid Release Type**

**Figure 6-4: Event Tree for Vaporizing Liquid Release Type**
The overall ignition probability for gas releases is derived in the same way, where:

\[ P_{\text{ignition}} = \exp (0.642 \ln (m) - 4.16) \]

where: \( m \) = release rate (kg/s) - maximum probability of 0.3 applied

The corresponding ignition probability is split equally between immediate and delayed ignition. This results in a maximum immediate ignition probability of 0.15, which applies to the majority of the Rupture release cases. The approach adopted for determining the probability of delayed ignition is:

- Assign a 'background' ignition probability to each release. This is based on the release rate dependent CLA approach and results in the same values as for the immediate ignition probabilities derived in the previous section. Note that this 'background' ignition probability applies to each release irrespective of the location or direction.

- Additionally, strong ignition sources on the site are identified and applied to the risk model. These provide an additional delayed ignition probability (of up to 100%) to any releases that are of sufficient size and directionality to reach the defined ignition sources.

This results in a maximum 'background' delayed ignition probability of 0.15, while the maximum ignition probability for releases that come into contact with the above sources (at the appropriate height) is 1.

### 6.7.3 Explosion Probability Model

The values for 'explosion given ignition' are based on a framework dependent on the volume of the cloud within a region of congestion. Very small clouds of less than 213 m\(^3\) are not considered large enough for the flame to accelerate to the speeds required to generate a damaging overpressure (assumed based on API RP 753). For larger clouds the precise geometry of the congested volume, the tendency of the combusting gas to push uncombusted material ahead of it and potentially increase the run-up distance beyond that predicted by a simple dispersion model, and the location of the ignition source all will exert an influence on the overpressure developed. Assigning a variable probability of explosion given ignition with an increasing size of the intersection volume (i.e. the volume of congestion intersecting with the flammable cloud), is essentially a surrogate for these effects. Note that 6000 m\(^3\) is approximately half a ton of flammable material.

In accordance with the Multi Energy model explosion framework, if the cloud does not cover a region of congestion, then the explosion probability is assigned to a value of 0. Hence, the above equation gives the probability that an explosion occurs given that ignition occurs, and that the cloud is contact with a region of congestion.
Table 6-5: Variation of probability of explosion with intersection volume

<table>
<thead>
<tr>
<th>Intersection (Congestion &amp; Cloud) Volume (m$^3$)</th>
<th>Probability of Explosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;213</td>
<td>0</td>
</tr>
<tr>
<td>214-3000</td>
<td>0.3</td>
</tr>
<tr>
<td>3001-6000</td>
<td>0.6</td>
</tr>
<tr>
<td>&gt;6001</td>
<td>0.9</td>
</tr>
</tbody>
</table>
7 HAZARD IDENTIFICATION

7.1 GENERAL HAZARDS
The first step in any risk assessment is to identify all hazards. The merits of including the hazard for further investigation are subsequently determined by its significance, normally using a cut-off or threshold quantity.

Once a hazard has been identified, it is necessary to evaluate it in terms of the risk it presents to the employees and the neighboring community. In principle, both probability and consequence should be considered, but there are occasions where if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made on just one factor.

During the hazard identification component, the following considerations are taken into account:

- Chemical identities;
- Location of facilities that use, produce, process, transport or store hazardous materials;
- The type and design of containers, vessels or pipelines;
- The quantity of material that could be involved in an airborne release; and,
- The nature of the hazard (e.g. airborne toxic vapors or mists, fire, explosion, large quantities stored or processed handling conditions) most likely to accompany hazardous materials spills or releases.

Table 7-1 shows the general hazards that were found for the power station, along with possible causes, expected consequences and proposed or inherent safeguards.
### Table 7-1: Hazard causes, consequences and proposed or inherent safeguards

<table>
<thead>
<tr>
<th>Site Area</th>
<th>Hazard Cause</th>
<th>Hazard Consequence</th>
<th>Proposed / Inherent Safeguard</th>
</tr>
</thead>
</table>
| Gas line           | External interference, Construction error, corrosion, earthquake, subsidence | Leak/rupture, ignition, jet fire, flash, explosion | - pipeline marker signs to be installed at regular intervals  
|                    |                                                                              |                                             | - pressure testing of fitting line after construction  
|                    |                                                                              |                                             | - external paint system corrosion protection  
|                    |                                                                              |                                             | - land is flat with no subsidence potential  
|                    |                                                                              |                                             | - fitting line is installed in a pipe rack of substantial construction  
|                    |                                                                              |                                             | - and remote from through traffic  
|                    |                                                                              |                                             | - site work using mechanical equipment will be subject to a  
|                    |                                                                              |                                             | - permit system and supervision.  
| Turbine Enclosure  | Gas fitting line joint or pipe failure                                       | Leak/rupture, ignition, jet fire, explosion | gas detection within the enclosure  
|                    |                                                                              |                                             | - automatic isolation valve located at gas entry point to the  
|                    |                                                                              |                                             | - enclosure (linked to gas detection to operate at 50% LEL)  
|                    |                                                                              |                                             | - enclosure is vented with fans  
|                    |                                                                              |                                             | - alarms linked to gas detection  
|                    |                                                                              |                                             | - fire detection installed in the enclosure (linked to fire fighting  
|                    |                                                                              |                                             | - system)  
|                    |                                                                              |                                             | - fire hydrants, hose reels and extinguishers available on site  
|                    |                                                                              |                                             | - inert gas fire suppression installed in the gas turbine enclosure  
|                    |                                                                              |                                             | - site is fully staffed during all operational periods (i.e. no fuel in  
|                    |                                                                              |                                             | - the turbine when site is unstaffed)  
| Turbine Enclosure  | Oil tank corrosion, valve failure, oil pipe failure                         | Leak of oil into the enclosure Spray of oil onto hot components resulting in spray fire | enclosure is bunded to contain oil spillage  
|                    |                                                                              |                                             | - oil pump is fitted with pressure relief valve  
|                    |                                                                              |                                             | - oil lines are separated from hot parts of the gas turbine  
|                    |                                                                              |                                             | - oil lines are stronger than maximum pressure of the system  
|                    |                                                                              |                                             | - fire detection installed in the enclosure (linked to fire fighting  
|                    |                                                                              |                                             | - system)  

EcoConserv
<table>
<thead>
<tr>
<th>Site Area</th>
<th>Hazard Cause</th>
<th>Hazard Consequence</th>
<th>Proposed / Inherent Safeguard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine Enclosure</td>
<td>Diesel fuel pipeline joint or pipe failure</td>
<td>Leak of diesel into the enclosure&lt;br&gt;Spray of diesel onto hot components resulting in spray fire</td>
<td>site is fully staffed during all operational periods (i.e. oil system will not be in operation when site is unstaffed)&lt;br&gt;inert gas fire suppression installed in the gas turbine enclosure&lt;br&gt;fire hydrants, hose reels and extinguishers available on site&lt;br&gt;enclosure is bunded to contain diesel spillage&lt;br&gt;pipelines are separated from hot sections of the turbine&lt;br&gt;pipelines are stronger than maximum pressure of the system&lt;br&gt;fire detection installed in the enclosure (linked to fire fighting system)&lt;br&gt;inert gas fire suppression installed in the gas turbine enclosure&lt;br&gt;site is fully staffed during all operational periods (i.e. no fuel in the turbine)</td>
</tr>
<tr>
<td>Fuel oil storage</td>
<td>Tank, pipeline, pump leak</td>
<td>Spill of fuel oil in the area surrounding the tank, pump or pipework, ignition, pool fire&lt;br&gt;Release of fuel oil directly to ground from underground pipeline</td>
<td>Fuel oil tank is bunded to contain 100% of stored liquid&lt;br&gt;pumps are installed in bunded area&lt;br&gt;fuel oil tank is separated from the remaining site buildings&lt;br&gt;fuel system is pressure tested prior to use (virtually eliminating leak potential)&lt;br&gt;underground pipeline is corrosion protected and regularly pressure tested&lt;br&gt;fire hydrants, hose reels and extinguishers are available throughout the site&lt;br&gt;fuel oil storage area is regularly inspected as part of the site PM</td>
</tr>
<tr>
<td>Fuel oil storage</td>
<td>Equipment failure (e.g. flexible hose) during</td>
<td>Spill of fuel oil in the area surrounding the fuel oil transfer area is bunded</td>
<td>fuel oil transfer area is bunded&lt;br&gt;operator/driver is in attendance during the full transfer</td>
</tr>
<tr>
<td>Site Area</td>
<td>Hazard Cause</td>
<td>Hazard Consequence</td>
<td>Proposed / Inherent Safeguard</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------------</td>
<td>----------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>fuel transfer to the tanker (i.e. tanker delivery)</td>
<td>tanker transfer point, ignition, pool fire</td>
<td>operation&lt;br&gt;fire hydrants, hose reels and extinguishers are available throughout the site&lt;br&gt;flexible hoses used for transfer are regularly inspected and pressure tested (6 monthly)&lt;br&gt;emergency shutdown valves installed on delivery tanker&lt;br&gt;driveaway protection provided on the tankers (i.e. pull down bar covering valve connection point applies truck brakes)</td>
</tr>
<tr>
<td>Transformers</td>
<td>Transformer component failure</td>
<td>Leak of oil from transformer joint or pipe, low oil level in transformer, winding failure, explosion, pool fire in oil spill under transformer</td>
<td>oil level alarm and transformer shut down system installed on all transformers&lt;br&gt;all transformers are bunded to contain full contents of oil in transformer&lt;br&gt;transformer oil is regularly inspected and tested to ensure oil characteristics are at optimum levels&lt;br&gt;transformer temperature is monitored during all operations&lt;br&gt;site is fully staffed during periods when transformers are in use (i.e. transformers are not used unless site is staffed)&lt;br&gt;fire hydrants, hose reels and extinguishers are available throughout the site</td>
</tr>
<tr>
<td>HV Switchyard</td>
<td>High voltage equipment failure</td>
<td>Release of SF6 gas, potential impact to people and the environment</td>
<td>SF6 is non-poisonous, non-toxic, non-flammable, non-reactive (chemically)&lt;br&gt;SF6 containing equipment will be regularly tested to monitor gas content&lt;br&gt;Relatively small quantities of SF6 gas held in equipment&lt;br&gt;Negligible impacts- Incident not carried forward for further analysis.</td>
</tr>
<tr>
<td>Site Area</td>
<td>Hazard Cause</td>
<td>Hazard Consequence</td>
<td>Proposed / Inherent Safeguard</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>--------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>HV Switchyard</td>
<td>Minor oil containing equipment (e.g. transformers)</td>
<td>Leak of oil from equipment joint or pipe, low oil level in equipment, winding failure, explosion, pool fire in oil spill under equipment</td>
<td>Note: minor equipment installed in the switchyard will have lower impact than scenarios carried forward for main transformers. Hence, scenarios and impact distances for main transformers also cover smaller equipment within the switchyard. Where no offsite impact is assessed for main transformers, there will be no offsite impact from incidents in smaller equipment. Incident not carried forward for further analysis.</td>
</tr>
<tr>
<td>HV Switchyard</td>
<td>Fault in high voltage equipment resulting in discharge to the environment</td>
<td>Potential for high voltage contact between equipment and people</td>
<td>Switchyard secured with 1.8m chainwire fence Separation distances between HV equipment and fence eliminated potential for HV arcs at the fence line Equipment is earthed, with earth leakage circuit breakers HV equipment will not operate without personnel in attendance at site (i.e. security) Negligible impact at site boundary, incident not carried forward for further analysis.</td>
</tr>
<tr>
<td>NG Pressure Reducing Station and Compressor</td>
<td>Equipment failure causing leaks due to corrosion or defects</td>
<td>Gas release Jet fire if ignited Vapor cloud explosion if ignition is delayed</td>
<td>Inherent flexibility and strength of gas transmission pipelines and equipment Permit to work system Security fencing QA, welding inspection Hydrostatic testing of equipment Radiography of circumferential welds – ultrasonics on pipes Equipment located entirely within station boundaries Maintenance/inspection</td>
</tr>
<tr>
<td>Site Area</td>
<td>Hazard Cause</td>
<td>Hazard Consequence</td>
<td>Proposed / Inherent Safeguard</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
<td>-------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hydrogen generation unit</td>
<td>Equipment failure causing leaks due to corrosion or defects</td>
<td>Gas release</td>
<td>Inherent flexibility and strength of gas transmission pipelines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jet fire if ignited</td>
<td>and equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vapor cloud explosion if</td>
<td>Permit to work system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ignition is delayed</td>
<td>Security fencing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>QA, welding inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hydrostatic testing of equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Radiography of circumferential welds – ultrasonics on pipes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Equipment located entirely within station boundaries</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maintenance/inspection</td>
</tr>
</tbody>
</table>
7.2 HAZARDOUS PROPERTIES OF MATERIALS STORED AND USED

Table 7-2 lists the type and classes of dangerous goods proposed for storage and used in large quantities at the North Giza Power Station.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Goods</th>
<th>Nature of material</th>
<th>Qty Proposed for storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Natural Gas</td>
<td>Flammable Gas</td>
<td>No storage</td>
</tr>
<tr>
<td>2</td>
<td>Fuel Oil</td>
<td>Combustible Liquid</td>
<td>2 tanks – 24,000 m³ each</td>
</tr>
<tr>
<td>3</td>
<td>Lube oil</td>
<td>Combustible liquid</td>
<td>400 m³ tank</td>
</tr>
<tr>
<td>4</td>
<td>Hydrogen</td>
<td>Flammable Gas</td>
<td>2 tanks – 700 Nm³ each</td>
</tr>
</tbody>
</table>

Potential hazards associated with each storage and handling operation are detailed below.

7.2.1 NATURAL GAS

The inherent hazards of the fitting line arise from the flammability of the natural gas, and the pressure at which it is transmitted and processed in the station. The types of hazardous incident which may occur, in theory at least, would all require a leak in the fitting line or associated equipment (e.g. valves, meters, flanges, etc.). They are:

- fire;
- flash fire; and/or
- explosion.

However, it is noted that natural gas is lighter than air (i.e. a buoyant gas) and if released tends to rise and disperse rather than accumulate forming a flammable cloud.

A hazard identification table has been developed in Table 7-1, which has been used as the basis for the hazard analysis below.

7.2.2 FUEL OIL

Fuel oil is a combustible liquid, which will burn if the temperature of the liquid exceeds the flash point and the vapor generated at the liquid surface is ignited. The resultant incident is a pool fire that radiates heat to the surrounding area resulting in potential equipment damage and or injury/fatality.

Fuel oil is also a contaminant to the biophysical environment and releases can damage sensitive environmental areas surrounding storages in the event a leak occurs and escapes to the environment. Fuel will also float on water and be carried a significant distance from a leak point by a water course.
7.2.3 Hydrogen
Like all fuels, hydrogen has inherent hazards and must be handled carefully. Hydrogen is the simplest element. Hydrogen is very abundant, being one of the atoms composing water. In normal conditions (20°C, 0.1 MPa) hydrogen is a colorless, tasteless, non-poisonous, and flammable gas.

Hydrogen gas has the smallest molecule and has a greater propensity to escape through small openings than liquid fuels or other gaseous fuels. For transfer through a membrane the relative rate is governed by the relative diffusion coefficients of the materials. For subsonic releases through openings the rate is dependent on whether the flow is laminar or turbulent.

The high pressure systems of hydrogen storage the flow from any leaks is likely to be sonic. Therefore hydrogen would leak approximately 3 times faster than natural gas and 5 times faster than propane on a volumetric basis. However the energy density of hydrogen is lower than that of methane or propane such that for sonic flow its energy leakage rate would be 0.34 times that of methane and 0.2 times that of propane.

Hydrogen leaks are dangerous in that they pose a risk of fire where they mix with air. However, the small molecule size that increases the likelihood of a leak also results in very high buoyancy and diffusivity, so leaked hydrogen rises and becomes diluted quickly, especially outdoors. This results in a localized region of flammability that disperses quickly. As the hydrogen dilutes with distance from the leakage site, the buoyancy declines and the tendency for the hydrogen to continue to rise decreases (Alcock, 2001).

7.2.3.1 Hydrogen Embrittlement
Prolonged exposure to hydrogen of some high strength steels can cause them to lose their strength, eventually leading to failure. This effect is termed hydrogen embrittlement (HE).

7.2.3.2 Flammability and Ignition
Hydrogen has much wider limits of flammability in air than methane, propane or gasoline and the minimum ignition energy is about an order of magnitude lower than that of other combustibles. The wide range of flammability of hydrogen-air mixtures compared to other combustibles is in principle a disadvantage with respect to potential risks. A hydrogen vapor cloud could potentially have a greater volume within the flammable range than a methane cloud formed under similar release conditions. The minimum ignition energy tends to be for mixtures at around stoichiometric composition (29 vol.% for hydrogen). The minimum autoignition temperature of hydrogen is 585°C, higher than that of methane, propane or gasoline. However the autoignition temperature depends on the nature of the source. The minimum is usually measured in a heated glass vessel, however if a heated air jet or Ni-Chrome wire is used the autoignition temperature of hydrogen is lower than that of other fuels.
7.2.3.3 Deflagration and Detonation
Hydrogen gas can burn as a jet flame with combustion taking place along the edges of the jet where it mixes with sufficient air. In the open flammable mixtures undergo slow deflagration.

Where the flame speed is accelerated e.g. by extreme initial turbulence, turbulence from obstacles, or confinement, the result is an explosion. An extreme example is a detonation where the flame speed is supersonic.

An explosion is always accompanied by a fireball and a pressure wave (overpressure). The fireball can ignite combustible materials in the vicinity or fuel released by the explosion so that a fire may follow an explosion. If the flammable mixture is partially or totally confined the explosion may propel fragments of the enclosure material over great distances. A detonation explosion is more severe than a deflagration explosion, the overpressures generated are higher and hence much greater physical damage is possible. Direct detonation of a hydrogen gas cloud is less likely than a deflagration explosion as the ignition energy required is in the 10 kJ range, the minimum concentration is higher and the detonable range is narrower than the flammable range (Abdul Rosyid, 2006).

7.3 DETAILED HAZARDS IDENTIFICATION
The following section constitutes detailed qualitative hazard identification for those incidents listed in Table 7-1.

7.3.1 NATURAL GAS LINE
The following fitting line design and operational details, below, were assumed:

- Operating Pressure – 5,300kPa or 53bar (52.3 atmospheres);
- Diameter – 273mm;
- Wall thickness – 12.7mm; and
- Material – X42 Grade Steel.

There is historical evidence of gas transmission pipeline failure. Historical evidence (Bolt & Horalek, 2004) indicates that there are a number of factors that can lead to fitting line leak and subsequent release of gas. The details below summarize those incidents that have historically led to fitting line failure and gas release:

- **External Interference** – external interference accounts for the majority of release incidents in gas transmission fitting lines (Bolt & Horalek, 2004). Forklifts, excavators, front end loaders, and other mechanical equipment can strike fitting lines in pipe racks leading to gas release, ignition and jet fire. At this stage of development in the area there are few if any adjacent operations. Hence,
there is a low likelihood of external impact. However, as the area develops there is a higher likelihood that excavation or other contact will occur in the area and the pipeline may be affected. The fitting line is internal to the power station and of 12.7mm wall thickness that will withstand external interference. All work carried out at site will be controlled by a permit system and will be supervised. The pipe rack is of robust design and is clear of any through traffic. However, external impact has been carried forward for further analysis.

- **Flood Damage** – this may occur where the fitting line traverses river beds or water courses. The potential for fast running water could lead to scouring above the fitting line exposing the pipe to potential impact from rocks and debris moving in the water stream. In addition, surface flooding could lead to the fitting line floating from the trench, leading to fitting line damage. A review of the fitting line route indicates that the fitting line will be laid away from flood areas. Hence, this hazard has not been carried forward for further analysis.

- **Subsidence Damage** – where fitting lines are installed near or in banks and levees, wash away may expose the fitting line and uneven weight could cause severe fitting line damage. However, the fitting line is not installed in a bank or levee and therefore, incidents resulting from subsidence have not been carried forward for further analysis.

- **External Corrosion Damage** – many soils are acidic and fitting lines installed without external protection are susceptible to corrosion and eventual failure (leaks). The fitting line is not installed underground and hence is not exposed to acidic soils reducing the potential for external corrosion to negligible levels. Incidents involving external corrosion (excluding impact) have not been carried forward for further analysis.

- **Internal Corrosion Damage** – the introduction of corrosive gas to the fitting line could result in accelerated corrosion or moisture in the gas could lead to corrosion impact on the pipe internal surface. However, gas fed is dry and non-corrosive, having passed many kilometers through this line. Hence, the likelihood of corrosion from this source is considered negligible. Incidents as a result of corrosion have therefore not been carried forward for further analysis.

- **Faulty Material** – the use of faulty materials, such as fitting line with manufacturing defects, could lead to premature fitting line failure resulting in rupture. However, pipe material will be purchased from a quality assured organization (i.e. ISO9001), which minimizes the potential for faulty materials. Further, the fitting line will be fully tested in accordance with the appropriate requirements, including a pressure test to prove fitting line will operate safely and without failure at maximum allowable operating pressure (MAOP). The quality assurance testing regime minimizes the potential for fitting line failure as
a result of material defects. Hence, these potential incidents have not been carried forward for further analysis.

- **Faulty Construction** - like the faulty materials incidents detailed above, faulty construction can also lead to failure of the fitting line. For example, faulty welding can lead to premature failure and gas release. However, fitting line welds will be subjected to X-Ray inspection minimizing the potential for failure from this source. Further, the fitting line will be subjected to a testing regime, further minimizing the potential for faulty construction failure. Additional construction problems, such as poor support or alignment in the pipe rack will be minimized by strictly following the appropriate requirements. Hence, incidents as a result of faulty construction have not been carried forward for further analysis.

- **Ground Movement** - this may occur where fitting lines are installed in an earthquake zone. Earthquakes and excessive ground movement may lead to damaged pipe racks and buckled pipework or, in the worst case, rupture. However, the fitting line would not be installed in an earthquake zone. The North Giza area is relatively stable and earthquakes of the magnitude that could result in fitting line rupture are rare and, hence, the risk is considered negligible. Incidents as a result of earthquake of excessive ground movement have not been carried forward for further analysis.

- **"Hot Tap" by Error** - "hot tap" is the connection to a live gas line during operation. When this is conducted by expert personnel the risk is negligible. However, failure to identify a live gas fitting line and attempts, by error, to connect to this fitting line could lead to fitting line breach and gas release. To identify gas fitting line, marker signs will be installed on the fitting line in accordance with the appropriate requirements. This incident has, therefore, not been carried forward for further analysis.

The above analysis is supported by the results of studies conducted by the European Gas Pipeline Incident Data Base (Bolt & Horalek, 2004), which conducts research into gas pipeline incidents both in Europe and overseas. The results of these studies indicate that the majority of pipeline incidents (50%) occur as a result of external interference.

### 7.3.2 Gas Release in the Gas Turbine Enclosure

Natural gas fuel, supplied by a fitting line from the main supply line, is used to supply the gas turbines. The fuel is piped internally within the turbine enclosure and, hence, any leaks of gas would have the potential to accumulate within the enclosure resulting in the formation of a flammable gas cloud. Ignition of such a cloud could result in explosion and significant damage to the enclosure as well as offsite impact from explosion overpressure and/or "missiles" projected from the destruction of parts of the enclosure.
To minimize the potential for such an incident, the gas turbine enclosure will be fitted with ventilation, which will continually provide air exchange within the enclosure. Hence, any leaks will be diluted to below lower flammable limits (LFL) and discharged from the enclosure. Further, the enclosure will be fitted with a hydrocarbon detector, which will activate level alarms and initiate gas turbine fuel supply shut down (from outside the enclosure). Hence, any leaks will either be diluted and or isolated before reaching potentially hazardous levels.

Notwithstanding the fact that detection and protection measures have been installed, in the event such measures fail, there is a potential for an explosion within the enclosure and jet fire at the leak source. Hence, explosion and fire incidents at the gas turbine enclosure have been carried forward for further analysis.

7.3.3 **TRANSFORMERS**

Transformers are used to convert electrical power from one volt/amp value to another to facilitate power matching with the national grid and for power supply to specific electrical components on and offsite. Transformers generate significant amounts of heat and require insulation between winding circuits. Insulation between circuits and heat removal is performed by an oil circuit, which passes fluid (oil) around the transformer internal components and then cools the oil externally. Leaks and spills of oil can escape beyond the immediate area of the transformer and, in the worst case reach the environment. However, at the proposed gas turbine site all transformers will be fully bunded to contain the full oil contents of the transformer. Hence, any leaks or spills will be contained on site and there will be no environmental release as a result of leaks in this area.

In the event of continued release from a transformer, the oil level in the transformer will fall, exposing the transformer windings and removing the insulating/cooling properties of the oil. This would eventually lead to overheating and potential ignition of the oil and oil vapor inside the transformer resulting in explosion and fire. The explosion would cause damage to the transformer casing and release of burning oil to the bund, resulting in bund fire and potential heat radiation impact offsite. The proposed transformer design will incorporate blast walls between each transformer unit preventing damage to adjacent areas on site; however the blast walls may not mitigate heat radiation beyond the site boundary.

It is recognized that low oil level switches will be installed on all transformers, and a spray/deluge system will be installed over each transformer. The quantity of the transformer oil is insignificant when compared with the lube oil or the fuel oil available on the site. Hence, incidents involving the ignition of leaked transformer oil have not been carried forward for further analysis.
7.3.4 *Lube Oil (Storage and Turbine Enclosure)*
Lubricating oil will be stored in a 400-m³ tank adjacent to the turbine enclosure and will be circulated through the engine by a turbine oil pump. The lube oil storage will be bunded and therefore, in the event of an oil line failure or leak, the oil would collect in the bund and be contained on site. No leaks would escape beyond the immediate bund area. It would be necessary to clean up spills as soon as possible, hence, it is recommended that spill kits be installed adjacent to the turbine enclosures to assist in clean up of any spillages of fluids in the enclosure.

Notwithstanding the fact that oil spills would be contained within the bunded areas, in the unlikely event of oil ignition, the oil would burn in the bund resulting in a pool fire in the bund. This may result in the heat radiation impacting the surrounding areas. Hence, this incident has been carried forward for further analysis.

7.3.5 *Electrical Fires*
Electrical faults can cause overheating, sparking and a fire. However, electrical fires are only likely to have minor, localized impact. Smoke/fire detection and active fire protection should be effective in controlling such incidents.

Escalation of electrical fires to process areas is unlikely, because the electrical equipment are segregated by enclosures from other areas and hence the risk from electrical fires is assessed as insignificant and does not warrant further assessment within the QRA study. However, electrical faults will be considered as a potential cause of ignition of hydrocarbon releases.
8 FAILURE CASE DEFINITIONS

8.1 INTRODUCTION
The basic aim of the Failure Case Definition stage is to identify the failure cases, or major accident hazards, that will have the potential to result in risks to people, in particular to external populations, and hence will be inputs to the risk modeling.

The basic approach adopted is summarized in Section 8.2, with the derived failure cases listed in Section 8.3.

Note that the failure case definition presented in this section is underpinned by the methodology set out in Section 5.

8.2 METHODOLOGY
For the purposes of this risk assessment it is not necessary (or practical) to attempt to model all of the potential hazards associated with the different units. The basic approach adopted instead is summarized below:

- All significant risk contributors at locations a moderate distance outside of each unit are then defined as failure cases for this study, on the basis of having potential off-site impacts.
- In each case, brief review of the representative scenarios against the plant PFDs is undertaken to ensure that the key sections of each unit have been covered by using this approach.
- These failure cases are then superimposed upon the appropriate location of the latest plot plan for the plant.

Note that the general methodology adopted in deriving the initial failure cases, and the subsequent development of each, is detailed in Section 5. Note also that the subsequent modeling approach, using the ALOHA and ERCC in-house software is also described in Section 5.

The failure cases derived for each unit are presented in the following section. The tables given include a basic description of the failure case, as well as the representative process conditions and the primary hazard outcome(s) of each release.

This exercise identified that some units did not contribute significantly to the 'far-field' risk picture; hence no failure cases associated with those units have been included in the model.

Consistent with the focus of this study, only the larger, Rupture and Large leak (75 mm equivalent diameter hole) leak sizes are modeled for each of the failure cases identified.
8.3 FAILURE CASES
The list of representative failure cases is presented in Table 8-1 to Table 8-7. A total of 24 cases were considered as follows:

- Table 8-1: Combustion Turbine Generators (Unit 14) Failure Cases – 10 cases
- Table 8-2: Fuel Gas Reducing Station and the Fuel Gas Compressor (Unit 61) Failure Cases – 4 cases
- Table 8-3: Fuel Oil Tanks (Unit 64) Failure Cases – 4 cases
- Table 8-4: Fuel Oil Transfer Pumps (Unit 65) Failure Cases – 1 case
- Table 8-5: Lube Oil Storage (Unit 82-9C) Failure Cases – 1 case
- Table 8-6: Hydrogen Generation (Unit 92) Failure Cases – 2 case
- Table 8-7: Steam Generator Failure (Unit 11) Failure Cases – 6 cases

**Table 8-1: Combustion Turbine Generators (Unit 14) Failure Cases**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Description</th>
<th>Pressure (bar)</th>
<th>Temperature (°C)</th>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-1</td>
<td>Natural gas leak followed by ignition (14-1A)</td>
<td>40</td>
<td>150</td>
<td>Jet fire</td>
</tr>
<tr>
<td>14-2</td>
<td>Natural gas leak followed by delayed ignition (14-1A)</td>
<td>40</td>
<td>150</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
<tr>
<td>14-3</td>
<td>Natural gas leak followed by ignition (14-1B)</td>
<td>40</td>
<td>150</td>
<td>Jet fire</td>
</tr>
<tr>
<td>14-4</td>
<td>Natural gas leak followed by delayed ignition (14-1B)</td>
<td>40</td>
<td>150</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
<tr>
<td>14-5</td>
<td>Natural gas leak followed by ignition (14-2A)</td>
<td>40</td>
<td>150</td>
<td>Jet fire</td>
</tr>
<tr>
<td>14-6</td>
<td>Natural gas leak followed by delayed ignition (14-2A)</td>
<td>40</td>
<td>150</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
<tr>
<td>14-7</td>
<td>Natural gas leak followed by ignition (14-2B)</td>
<td>40</td>
<td>150</td>
<td>Jet fire</td>
</tr>
<tr>
<td>14-8</td>
<td>Natural gas leak followed by delayed ignition (14-2B)</td>
<td>40</td>
<td>150</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
<tr>
<td>14-9</td>
<td>Natural gas leak followed by ignition (14-1n)</td>
<td>40</td>
<td>150</td>
<td>Jet fire</td>
</tr>
<tr>
<td>14-10</td>
<td>Natural gas leak followed by delayed ignition (14-1n)</td>
<td>40</td>
<td>150</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
<tr>
<td>14-11</td>
<td>Natural gas leak followed by ignition (14-2n)</td>
<td>40</td>
<td>150</td>
<td>Jet fire</td>
</tr>
<tr>
<td>14-12</td>
<td>Natural gas leak followed by delayed ignition (14-2n)</td>
<td>40</td>
<td>150</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
</tbody>
</table>
Table 8-2: Fuel Gas Reducing Station and the Fuel Gas Compressor (Unit 61) Failure Cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Description</th>
<th>Pressure (bar)</th>
<th>Temperature (C)</th>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>61-1</td>
<td>Natural gas leak followed by ignition from reducing station (61-9A)</td>
<td>50</td>
<td>30</td>
<td>Jet fire</td>
</tr>
<tr>
<td>61-2</td>
<td>Natural gas leak followed by delayed ignition from reducing station (61-9A)</td>
<td>50</td>
<td>30</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
<tr>
<td>61-3</td>
<td>Natural gas leak followed by ignition from compressor (61-9B)</td>
<td>40</td>
<td>150</td>
<td>Jet fire</td>
</tr>
<tr>
<td>61-4</td>
<td>Natural gas leak followed by delayed ignition from compressor (61-9B)</td>
<td>40</td>
<td>150</td>
<td>Flammable Gas Cloud (Flash Fire, VCE)</td>
</tr>
</tbody>
</table>

Table 8-3: Fuel Oil Tanks (Unit 64) Failure Cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Description</th>
<th>Pressure (bar)</th>
<th>Temperature (C)</th>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-1</td>
<td>Leak from Tank (64-9A) followed by ignition</td>
<td>1</td>
<td>30</td>
<td>Pool fire</td>
</tr>
<tr>
<td>64-2</td>
<td>Tank fire (64-9A)</td>
<td>1</td>
<td>30</td>
<td>Tank top fire</td>
</tr>
<tr>
<td>64-3</td>
<td>Leak from Tank (64-9B) followed by ignition</td>
<td>1</td>
<td>30</td>
<td>Pool fire</td>
</tr>
<tr>
<td>64-4</td>
<td>Tank fire (64-9B)</td>
<td>1</td>
<td>30</td>
<td>Tank top fire</td>
</tr>
</tbody>
</table>

Table 8-4: Fuel Oil Transfer Pumps (Unit 65) Failure Cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Description</th>
<th>Pressure (bar)</th>
<th>Temperature (C)</th>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>65-1</td>
<td>Leak from pump outlet followed by ignition</td>
<td>15</td>
<td>30</td>
<td>Pool fire</td>
</tr>
</tbody>
</table>

Table 8-5: Lube Oil Storage (Unit 82-9C) Failure Cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Description</th>
<th>Pressure (bar)</th>
<th>Temperature (C)</th>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>82-1</td>
<td>Leak from pump outlet followed by ignition</td>
<td>15</td>
<td>30</td>
<td>Pool fire</td>
</tr>
</tbody>
</table>

Table 8-6: Hydrogen Generation (Unit 92) Failure Cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Description</th>
<th>Pressure (bar)</th>
<th>Temperature (C)</th>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>92-1</td>
<td>Leak from the hydrogen tank</td>
<td>150</td>
<td>30</td>
<td>Jet fire</td>
</tr>
<tr>
<td>92-2</td>
<td>Leak from the hydrogen tank followed by delayed ignition</td>
<td>150</td>
<td>30</td>
<td>VCE</td>
</tr>
</tbody>
</table>
Table 8-7: Steam Generator Failure (Unit 11) Failure Cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Description</th>
<th>Pressure (bar)</th>
<th>Temperature (°C)</th>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-1</td>
<td>Explosion from HP steam drum (11-1A)</td>
<td>160</td>
<td>570</td>
<td>Explosion</td>
</tr>
<tr>
<td>11-2</td>
<td>Explosion from HP steam drum (11-1B)</td>
<td>160</td>
<td>570</td>
<td>Explosion</td>
</tr>
<tr>
<td>11-3</td>
<td>Explosion from HP steam drum (11-2A)</td>
<td>160</td>
<td>570</td>
<td>Explosion</td>
</tr>
<tr>
<td>11-4</td>
<td>Explosion from HP steam drum (11-2B)</td>
<td>160</td>
<td>570</td>
<td>Explosion</td>
</tr>
<tr>
<td>11-5</td>
<td>Explosion from HP steam drum (11-1n)</td>
<td>160</td>
<td>570</td>
<td>Explosion</td>
</tr>
<tr>
<td>11-6</td>
<td>Explosion from HP steam drum (11-2n)</td>
<td>160</td>
<td>570</td>
<td>Explosion</td>
</tr>
</tbody>
</table>

8.4 LOCATION OF CASES

The locations of cases are needed for the risk calculations. Table 8-8 lists the location of the fire accidents with respect to the plant's coordinates shown in Figure 3-1, while Table 8-9 the explosion accidents.

Table 8-8: Location of Fire Accidents

<table>
<thead>
<tr>
<th>Fire accident type</th>
<th>Case</th>
<th>Case and Unit</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool Fire</td>
<td>64-1</td>
<td>Fuel Oil Tank (64-9A)</td>
<td>4830</td>
<td>9950</td>
</tr>
<tr>
<td></td>
<td>64-3</td>
<td>Fuel Oil Tank (64-9B)</td>
<td>4920</td>
<td>9950</td>
</tr>
<tr>
<td></td>
<td>65-1</td>
<td>Fuel Oil Transfer Pump (65)</td>
<td>4945</td>
<td>9985</td>
</tr>
<tr>
<td></td>
<td>82-1</td>
<td>Lube oil storage (82-9C)</td>
<td>4960</td>
<td>10070</td>
</tr>
<tr>
<td>Jet Fire</td>
<td>14-1</td>
<td>CTG (14-1A)</td>
<td>5080</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-3</td>
<td>CTG (14-1B)</td>
<td>5115</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-5</td>
<td>CTG (14-2A)</td>
<td>5215</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-7</td>
<td>CTG (14-2B)</td>
<td>5255</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-9</td>
<td>CTG (14-1n)</td>
<td>5371</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-11</td>
<td>CTG (14-2n)</td>
<td>5410</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>61-1</td>
<td>Reducing Station (61-9A)</td>
<td>4775</td>
<td>10030</td>
</tr>
<tr>
<td></td>
<td>61-3</td>
<td>NG Compressor (61-9B)</td>
<td>4850</td>
<td>10040</td>
</tr>
<tr>
<td></td>
<td>92-1</td>
<td>H2 Tank (92)</td>
<td>5290</td>
<td>9940</td>
</tr>
<tr>
<td>Tank Top Fire</td>
<td>64-2</td>
<td>Fuel Oil Tank (64-9A)</td>
<td>4830</td>
<td>9950</td>
</tr>
<tr>
<td></td>
<td>64-4</td>
<td>Fuel Oil Tank (64-9B)</td>
<td>4920</td>
<td>9950</td>
</tr>
</tbody>
</table>
Table 8-9: Location of Explosion Accidents

<table>
<thead>
<tr>
<th>Fire accident type</th>
<th>Case</th>
<th>Case and Unit</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor Cloud Explosion</td>
<td>14-2</td>
<td>CTG (14-1A)</td>
<td>5080</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-4</td>
<td>CTG (14-1B)</td>
<td>5115</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-6</td>
<td>CTG (14-2A)</td>
<td>5215</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-8</td>
<td>CTG (14-2B)</td>
<td>5255</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-10</td>
<td>CTG (14-1n)</td>
<td>5371</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>14-12</td>
<td>CTG (14-2n)</td>
<td>5410</td>
<td>10010</td>
</tr>
<tr>
<td></td>
<td>61-2</td>
<td>Reducing Station (61-9A)</td>
<td>4775</td>
<td>10030</td>
</tr>
<tr>
<td></td>
<td>61-4</td>
<td>NG Compressor (61-9B)</td>
<td>4850</td>
<td>10040</td>
</tr>
<tr>
<td></td>
<td>92-2</td>
<td>H₂ Tank (92)</td>
<td>5290</td>
<td>9940</td>
</tr>
<tr>
<td>Boiler Explosion</td>
<td>11-1</td>
<td>HP Drum (11-1A)</td>
<td>5080</td>
<td>9960</td>
</tr>
<tr>
<td></td>
<td>11-2</td>
<td>HP Drum (11-1B)</td>
<td>5115</td>
<td>9960</td>
</tr>
<tr>
<td></td>
<td>11-3</td>
<td>HP Drum (11-2A)</td>
<td>5215</td>
<td>9960</td>
</tr>
<tr>
<td></td>
<td>11-4</td>
<td>HP Drum (11-2B)</td>
<td>5255</td>
<td>9960</td>
</tr>
<tr>
<td></td>
<td>11-5</td>
<td>HP Drum (11-1n)</td>
<td>5374</td>
<td>9960</td>
</tr>
<tr>
<td></td>
<td>11-6</td>
<td>HP Drum (11-2n)</td>
<td>5408</td>
<td>9960</td>
</tr>
</tbody>
</table>
9 CONSEQUENCE ASSESSMENT

The consequence of the failure cases were estimated using the methodology of Section 5 and the assumptions detailed in Appendix A2. Consequences are presented here in two sections, one for the fire accidents and one the explosion accidents.

9.1 CONSEQUENCE OF FIRE ACCIDENTS

The failure cases that result in fire can be divided into three types: pool fires, tank top fires and jet fires. We present our calculation data and results in the next sections.

9.1.1 POOL FIRES

Table 9-1 summarizes the pool fire case data that were given to or calculated by ALOHA for the various pool fire scenarios.

Table 9-1: ALOHA Pool fire data

<table>
<thead>
<tr>
<th>Case</th>
<th>Case and Unit</th>
<th>Tank Volume (m³)</th>
<th>Bund Area</th>
<th>Total Amount Burned in 1 hr (kg)</th>
<th>Pool diameter (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-1</td>
<td>Fuel Oil Tank (64-9A)</td>
<td>24,000</td>
<td>85 x 70 m</td>
<td>115,572</td>
<td>25</td>
</tr>
<tr>
<td>64-3</td>
<td>Fuel Oil Tank (64-9B)</td>
<td>24,000</td>
<td>85 x 70 m</td>
<td>115,572</td>
<td>25</td>
</tr>
<tr>
<td>65-1</td>
<td>Fuel Oil Transfer Pump (65)</td>
<td>-</td>
<td>-</td>
<td>5,884</td>
<td>5.6</td>
</tr>
<tr>
<td>82-1</td>
<td>Lube oil storage (82-9C)</td>
<td>20</td>
<td>22.7 x 22.7 m</td>
<td>20,885</td>
<td>10.7</td>
</tr>
</tbody>
</table>

A sample pool fire output is shown in Figure 9-1. Note that ALOHA figures assume that the wind blows towards the positive x-axis. Figure 9-5 shows radiation contours of 12.5 and 37.5 kW/m² for all pool fire scenarios in the facility.
JET FIRES

Table 9-2 summarizes the jet fire accident data that were given to or calculated by ALOHA for the various jet fire scenarios. The hole diameter was selected to be 75 mm as discussed in details in Appendix A2.

Table 9-2: ALOHA jet fire data

<table>
<thead>
<tr>
<th>Case</th>
<th>Case and Unit</th>
<th>Pipe Length (m)</th>
<th>Pipe Diameter (cm)</th>
<th>Total Amount Burned in 1 hr (kg)</th>
<th>Flame Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-1</td>
<td>CTG (14-1A)</td>
<td>20</td>
<td>10</td>
<td>86.540</td>
<td>9</td>
</tr>
<tr>
<td>14-3</td>
<td>CTG (14-1B)</td>
<td>20</td>
<td>10</td>
<td>86.540</td>
<td>9</td>
</tr>
<tr>
<td>14-5</td>
<td>CTG (14-2A)</td>
<td>20</td>
<td>10</td>
<td>86.540</td>
<td>9</td>
</tr>
<tr>
<td>14-7</td>
<td>CTG (14-2B)</td>
<td>20</td>
<td>10</td>
<td>86.540</td>
<td>9</td>
</tr>
<tr>
<td>14-9</td>
<td>CTG (14-1n)</td>
<td>20</td>
<td>10</td>
<td>86.540</td>
<td>9</td>
</tr>
<tr>
<td>14-11</td>
<td>CTG (14-2n)</td>
<td>20</td>
<td>10</td>
<td>86.540</td>
<td>9</td>
</tr>
<tr>
<td>61-1</td>
<td>Reducing Station (61-9A)</td>
<td>20</td>
<td>10</td>
<td>127,730</td>
<td>11</td>
</tr>
<tr>
<td>61-3</td>
<td>NG Compressor (61-9B)</td>
<td>20</td>
<td>10</td>
<td>86,540</td>
<td>9</td>
</tr>
<tr>
<td>92-1</td>
<td>H2 Tank (92)</td>
<td>tank</td>
<td>Hole in tank</td>
<td>53.4</td>
<td>4</td>
</tr>
</tbody>
</table>

A sample jet fire output is shown in Figure 9-2, while Figure 9-6 shows radiation contours of 12.5 and 37.5 kW/m² for all jet fire scenarios in the facility.
For the case of hydrogen jet fire (92-1), note that the amount of hydrogen in the tank was calculated to be about 56 kg resulting in a jet fire that lasts for only 27 seconds.

9.1.3 TANK TOP FIRES
Table 9-3 summarizes the tank top fire accident data that were given to or calculated by ALOHA for the various tank top fire scenarios.

Table 9-3: ALOHA tank top fire data

<table>
<thead>
<tr>
<th>Case</th>
<th>Case and Unit</th>
<th>Tank Volume (m³)</th>
<th>Total Amount Burned in 1 hr (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-2</td>
<td>Fuel Oil Tank (64-9A)</td>
<td>24,000</td>
<td>295,767</td>
</tr>
<tr>
<td>64-4</td>
<td>Fuel Oil Tank (64-9B)</td>
<td>24,000</td>
<td>295,767</td>
</tr>
</tbody>
</table>

A sample tank top fire output is shown in Figure 9-3, while Figure 9-7 shows radiation contours of 12.5 and 37.5 kW/m² for the two tank top fire scenarios in the facility.
9.2 CONSEQUENCE OF EXPLOSION ACCIDENTS

Explosions can occur due to the ignition of a cloud of flammable vapor in a congested area. Explosions in this QRA study were modeled using the industry-standard TNO Multi Energy Model and with ALOHA. The explosion cases that were modeled in this study are shown in Table 9-4.

Table 9-4: Models used for the different explosion cases

<table>
<thead>
<tr>
<th>Fire accident type</th>
<th>Case</th>
<th>Case and Unit</th>
<th>Model Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor Cloud Explosion</td>
<td>14-2</td>
<td>CTG (14-1A)</td>
<td>ALOHA</td>
</tr>
<tr>
<td></td>
<td>14-4</td>
<td>CTG (14-1B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-6</td>
<td>CTG (14-2A)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-8</td>
<td>CTG (14-2B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-10</td>
<td>CTG (14-1n)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-11</td>
<td>CTG (14-2n)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>61-2</td>
<td>Reducing Station (61-9A)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>61-4</td>
<td>NG Compressor (61-9B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>92-2</td>
<td>H₂ Tank (92)</td>
<td></td>
</tr>
<tr>
<td>Boiler Explosion</td>
<td>11-1</td>
<td>HP Drum (11-1A)</td>
<td>TNO Multi Energy Model (CCPS, 1999)</td>
</tr>
<tr>
<td></td>
<td>11-2</td>
<td>HP Drum (11-1B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-3</td>
<td>HP Drum (11-2A)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-4</td>
<td>HP Drum (11-2B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-5</td>
<td>HP Drum (11-1n)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-6</td>
<td>HP Drum (11-2n)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9-4 shows the results of a typical case obtained by ALOHA, while Figure 9-8 shows the overpressure contours resulting of all cases of vapor cloud explosions.
Figure 9-9 shows the overpressure contours due to the explosion of the high pressure steam drums.

Figure 9-4: Example of overpressure contours for case 61-2 obtained by ALOHA
Figure 9-5: Heat flux contours due to pool fires
Figure 9-6: Heat flux contours due to jet fires
Figure 9-7: Heat flux contours due to tank top fires
Figure 9-8: Overpressure contours due to vapor cloud explosions
Figure 9-9: Overpressure contours due to explosions of high pressure stream drums
10 RISK RESULTS

The risks were calculated from the results of the consequence analysis of the failure cases and the estimation of the frequencies of those cases. The frequencies were estimated based on the assumptions, data and practices explained in Section A2 and are presented in Section 10.1.

Individual risks are the key measure of risk acceptability for this type of study, where it is proposed that:

- Risks to the public can be considered to be broadly acceptable if below $10^{-6}$ per year, although noting that societal risk factors should also be considered (including the type of population potentially exposed). Although risks of up to $10^{-4}$ per year may be considered acceptable if shown to be ALARP, it is recommended that $10^{-5}$ per year is adopted for this study as the maximum tolerable criterion.

- Risks to workers can be considered to be broadly acceptable if below $10^{-5}$ per year and where risks of up to $10^{-3}$ per year may be considered acceptable if ALARP.

Individual risks are presented in Sections 10.2 through 10.4, while societal risks are presented in Section 10.5.

10.1 FREQUENCY ESTIMATION

Table 10-1 shows the frequencies calculated for each of the cases identified during the hazards identification phase.

<table>
<thead>
<tr>
<th>Fire accident type</th>
<th>Case</th>
<th>Case and Unit</th>
<th>Basis for Frequency Calculations</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>64-1</td>
<td>Fuel Oil Tank (64-9A)</td>
<td>LASTFIRE Project. See Section A2.5.2</td>
<td>$6.1 \times 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>64-3</td>
<td>Fuel Oil Tank (64-9B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pool Fire</td>
<td>65-1</td>
<td>Fuel Oil Transfer Pump (65)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>82-1</td>
<td>Lube oil storage (82-9C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jet Fire</td>
<td>14-1</td>
<td>CTG (14-1A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-3</td>
<td>CTG (14-1B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-5</td>
<td>CTG (14-2A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-7</td>
<td>CTG (14-2B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-9</td>
<td>CTG (14-1n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire accident type</td>
<td>Case</td>
<td>Case and Unit</td>
<td>Basis for Frequency Calculations</td>
<td>Frequency</td>
</tr>
<tr>
<td>--------------------</td>
<td>------</td>
<td>---------------</td>
<td>----------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td>14-10</td>
<td>CTG (14-2n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>61-1</td>
<td>Reducing Station (61-9A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>61-3</td>
<td>NG Compressor (61-9B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>92-1</td>
<td>H2 Tank (92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tank Top Fire</td>
<td>64-2</td>
<td>Fuel Oil Tank (64-9A)</td>
<td>LASTFIRE Project. See Section A2.5.2</td>
<td>1.2 x 10^4</td>
</tr>
<tr>
<td></td>
<td>64-4</td>
<td>Fuel Oil Tank (64-9B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vapor Cloud Explosion</td>
<td>14-2</td>
<td>CTG (14-1A)</td>
<td>7.1 x 10^4 from Section A2.5.1 0.15 probability of delayed ignition</td>
<td>1.1 x 10^4</td>
</tr>
<tr>
<td></td>
<td>14-4</td>
<td>CTG (14-1B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-6</td>
<td>CTG (14-2A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-8</td>
<td>CTG (14-2B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-10</td>
<td>CTG (14-1n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-12</td>
<td>CTG (14-2n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>61-2</td>
<td>Reducing Station (61-9A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>61-4</td>
<td>NG Compressor (61-9B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>92-2</td>
<td>H2 Tank (92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiler Explosion</td>
<td>11-1</td>
<td>HP Drum (11-1A)</td>
<td>Explosion of pressure vessels. See Section A2.5.1</td>
<td>4 x 10^-6</td>
</tr>
<tr>
<td></td>
<td>11-2</td>
<td>HP Drum (11-1B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-3</td>
<td>HP Drum (11-2A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-4</td>
<td>HP Drum (11-2B)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-5</td>
<td>HP Drum (11-1n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-6</td>
<td>HP Drum (11-2n)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10.2 **INDIVIDUAL RISK CONTOURS**

At this stage in the risk assessment process the most useful measure of risk is individual risk, which is presented in the form of contours. The individual risk contours for the risk assessment are shown in Figure 10-1 and Figure 10-2. The individual risk contours give the risk of fatality (or serious injury) experienced by a person continuously present, outdoors.

It should be emphasized when interpreting the results shown in Figure 10-1 and Figure 10-2 that:

- These results are based only on the major accident hazards identified as having the key hazard ranges (as discussed in Appendix A2) and hence are focused on the off-site risks.

- The on-site risks will not be accurately predicted by neglecting the smaller hazard range events that do not affect the off-site populations but will have relatively high frequencies and, hence, will be significant in terms of on-site risk.
Although based on the risks to people outdoors, the contours are considered to be directly applicable to the risks to residential populations. That is, no risk benefit (i.e., protection) is claimed for being indoors for residential buildings. Thus, the $10^{-6}$ per year individual risk contour can be taken as the target risk level for the public in terms of individual risk (see Appendix 0 for derivation of the proposed risk criteria).

The contours shown in Figure 10-1 and Figure 10-2 are discussed in the following sections in terms of the risks to the off-site / public and on-site / worker populations in Sections 10.3 and 10.4, respectively.

The potential societal risks are discussed in Section 10.5.

10.3 RISKS TO THE PUBLIC (OFF-SITE)

As discussed above, Figure 10-1 is focused on the off-site risk, where it can be seen that:

- The maximum extent of individual risk contours does not cross the canal to the West, and is far from reaching the populated areas to the South of the facility.

- The $10^{-7}$ individual risk contour almost traces the North and West facility boundary. Hence any future settlements beyond those two facility boundaries would still be safe. However, a buffer zone of agricultural low-population land needs to be maintained to the East of the facility since the individual risk in that vicinity is around $10^{-5}$.

- The risks in all directions outside the facility do not reach any residential areas. The QRA results suggest that the risk to the nearby populations would be well within the proposed risk criteria and hence would be acceptable.

10.4 RISKS TO WORKERS (ON-SITE)

In addition to the overall individual risk contours shown in Figure 10-1, Figure 10-2 shows a ‘zoomed-in’ version of the same curve overlaid onto the layout plot.

It should, again, be emphasized that the on-site risks are coarse and that below $10^{-4}$ per year the contours are not accurate. However, the $10^{-4}$ and $10^{-5}$ per year contours are broadly representative.

10.5 SOCIETAL RISKS

As discussed in Appendix 0, it is important that risk acceptability considerations account for both individual and societal risk, as well as the cost of mitigating against the identified risks.

However, at this stage of the analysis it should be noted that:
• The base case risk results suggest that the societal risk to the public will be limited, based on the maximum (representative) hazard ranges not reaching the residential areas.

• The risk to onsite workers should not be neglected. In fact, the only societal risk associated with the power plant is the societal risk to onsite workers.

Figure 10-3 shows the F/N curve for the North Giza Power Station in comparison with the ALARP zone. At low-fatality high-frequency zone, it is noted that the F/N curve goes inside the ALARP region. These are the incidents that mainly affect the onsite workers. The rest of the F/N curve demonstrates negligible societal risk as no incident from the station can impact the public.

The low risk to the public demonstrates that a lot of thoughtful consideration was put into the site selection process.

10.6 KEY HAZARDS
Significant overpressure levels of around 0.3 barg will not extend any significant distance offsite, but are likely to affect the key admin / office. This suggests that with the current layout these two key buildings should have blast protection of the order of 0.3 barg. The explosion frequency contours suggest that all buildings on-site should have protection against blast loads of at least 0.1 barg.

10.7 RECOMMENDATIONS
The emphasis on risk reduction should be on preventative measures, i.e. to minimize the potential for leaks to occur. This would chiefly be achieved through appropriate design (to recognized standards) and through effective inspection, testing and maintenance plans / procedures.

Rapid isolation of significant leaks will not eliminate the risks but will help to minimize the hazards and, particularly, the ignition probability (by limiting the total mass of flammable vapor released). For isolation to be effective, first requires detection to occur and hence best practice fire and gas detection systems, with associated shutdown systems and procedures, will be important mitigation measures.

It should be recognized that it is not necessarily practical for power plants to have automatic shutdown systems and there will inevitably be a tendency for operators to establish the exact nature of a release before isolation occurs. This is reasonably well accepted, and it is unusual to rely on isolation occurring in less than 5 minutes for a typical QRA study.

However, two alternative approaches, or philosophies, that should be considered in this respect are to:
• Specify automatic shutdown on confirmed gas detection (or appropriate process alarms) for identified key inventories. This is not typically done, but may be considered either for inventories over a certain size of volatile liquid, or for certain sections of the plant that are identified as "higher risk" by detailed risk analysis.

• Ensure that the systems, procedures and training are in place to enable operators to rapidly determine the scale of any release that occurs, with particular regard to the potential for off-site effects. This may include CCTV, best-practice control systems, wind direction information, etc, where the key aspect will be to ensure that isolation can be rapidly activated when significant off-site risk potential is likely (noting that releases of this magnitude will inevitably have significant on-site and asset risk issues).
Figure 10-1: Individual risk contours on a Google Earth image

EcoCon Serv
ENVIRONMENTAL SOLUTIONS
Figure 10-2: Individual risk contours inside the limits of the power station
Figure 10-3: Societal risk represented as F/N curve
11 BIBLIOGRAPHY


RISK ACCEPTANCE CRITERIA

INTRODUCTION
This appendix introduces the concept of risk acceptance criteria and the As Low As Reasonably Practicable (ALARP) principle, and proposes risk acceptance criteria to be used as guidance for this study. It should be emphasized that the selection of criteria is open to interpretation, in the absence of any formal local regulations, but where the intention of this study is to use criteria that are consistent with internationally accepted practice.

- Section 0 describes the basis for the risk criteria, introducing the widely accepted As Low As Reasonably Practicable (ALARP) concept.
- Section 0 sets out the criteria that are proposed for this study, covering both individual and societal risk criteria.

BASIS FOR CRITERIA

NEED FOR CRITERIA
A risk analysis provides measures of the risk resulting from a particular facility or activity. However, the assessment of the acceptability (or otherwise) of that risk is left to the judgment and experience of the people undertaking and/or using the risk analysis work. The normal approach adopted is to relate the risk measures obtained to acceptable risk criteria.

A quantitative risk analysis produces only numbers, which in themselves provide no inherent use. It is the assessment of those numbers that allows conclusions to be drawn and recommendations to be developed. The assessment phase of a study is therefore of prime importance in providing value from a risk assessment study.

PRINCIPLES FOR SETTING RISK CRITERIA
Given that society accepts hazardous activities in principle, and does not have limitless resources to devote to their safety, the following set of principles is considered by some to be appropriate when making decisions about their acceptability in specific cases:

1. The activity should not impose any risks which can reasonably be avoided.
2. The risks should not be disproportionate to the benefits (in terms of jobs, tax revenues and finished products) which the activity produces.
3. The risks should be equitably distributed throughout the society in proportion to the benefits received.
4. The risks should be revealed in minor accidents which the emergency services can cope with, rather than in catastrophes.

In reality, principles such as these are impossible to achieve. In fact, when resources are limited, such principles may be in conflict with each other. For example, reducing catastrophic risks may require expenditure that could have saved more lives from low-fatality accidents.

The following approach is proposed for assessing the risks from any hazardous activity, being the nearest practical approach to the ideal situation:

- **Individual risk criteria** should be used to limit risks to individual workers and members of the public. These address the equity requirement (3) above insofar as it applies to individuals.

- **Societal risk criteria** should be used to limit risks to the affected population as a whole. These attempt to address requirement (2) above, although in a necessarily crude fashion since the benefits of hazardous activities are even more difficult to quantify than their risks. They also address the equity requirement (3) above insofar as it applies to communities. By expressing societal risk criteria on a frequency-fatality (FN) curve, they can also address the catastrophe risk in requirement (4) above.

- **Cost-benefit analysis** should be used to ensure that, once the above criteria are satisfied, an optimum level of safety measures is chosen for the activity, taking costs as well as risks into account. This addresses requirement (1) above.

An activity is said to have tolerable risks if it satisfies all three aspects of this approach, and intolerable risks if it fails to meet any of them.

Leaving aside other inputs to the decision, an activity with tolerable risks would generally be regarded as acceptable to the company, the regulatory authority and the public, while an activity with intolerable risks would generally be regarded as unacceptable.

**FRAMEWORK**

The simplest framework for risk criteria is a single risk level which divides tolerable risks from intolerable ones (i.e. acceptable activities from unacceptable ones). Such criteria give attractively simple results, but they need to be used very carefully, because they do not reflect the uncertainties both in estimating risks and in assessing what is tolerable. For instance, if applied rigidly, they could indicate that an activity which just exceeded the criteria would become acceptable as a result of some minor remedial measure which in fact scarcely changed the risk levels.
A more flexible framework specifies a level, usually known as the maximum tolerable criterion, above which the risk is regarded as intolerable whatever the benefit may be, and must be reduced. Below this level, the risks should also be made as low as reasonably practicable (ALARP). This means that when deciding whether or not to implement risk reduction measures, their cost may be taken into account, using cost-benefit analysis. In this region, the higher the risks, the more it is worth spending to reduce them. If the risks are low enough, it may not be worth spending anything, and the risks are then regarded as negligible.

This approach can be interpreted as dividing risks into three tiers as is illustrated in Figure A-1.

- An upper band where risks are intolerable whatever the benefit the activity may bring. Risk reduction measures or design changes are considered essential.

- A middle band (or ALARP region) where the risk is considered to be tolerable only when it has been made ALARP. This requires risk reduction measures to be implemented if they are reasonably practicable, as evaluated by cost-benefit analysis.

- A negligible region where the risks are negligible and no risk reduction measures are needed.

There is some consensus on this three-band approach, and versions are used by the UK, Dutch, Swiss and US Santa Barbara criteria.
PROPOSED RISK CRITERIA

**INDIVIDUAL RISK**

Individual risk is widely defined as the risk of fatality (or serious injury) experienced by an individual, noting that the acceptability of individual risks should be based on that experienced by the most exposed (i.e. ‘worst-case’) individual.

The most widely-used criteria for individual risks are the ones proposed by the UK HSE (Reference 1), noting that these can also be used for projects in Egypt.

These criteria are:

- The maximum tolerable individual risk for workers is taken as 10^-3 per year (i.e. 1 in 1,000 years).
- The maximum tolerable individual risk for members of the public is 10^-4 per year (i.e. 1 in 10,000 years).
- The acceptable criterion, for both workers and public, corresponding to the level below which individual risks can be treated as effectively negligible, is 10^-6 per year (i.e. 1 in 1,000,000 years).
• Between these criteria the risks are in the 'ALARP' or tolerability region. In this region the risks are acceptable only if demonstrated to be As Low As Reasonably Practicable (ALARP).

In terms of the acceptability of individual risks, it should be noted that:

• Individual risks are typically presented as contours that correspond to the risk experienced by a person continuously present, outdoors, at each location.

• While people are unlikely to remain “continuously present, outdoors” at a given point, the individual risk levels used to assess residential developments are not modified to account for any presence factor or the proportion of time spent indoors. That is, it should be conservatively assumed that dwellings are occupied at all times and that domestic properties offer no real protection against the potential hazards. Hence, the individual risks contours can be used directly with respect to the public, while for workers it is more appropriate to consider the most exposed individual (accounting for the time they spend in different areas, indoors, away from the hazards, etc).

• The individual risk criteria proposed for the public correspond to an individual having a chance of death or serious injury (due to the hazards assessed) of between 1 in 10,000 and 1,000,000 years. To put these risks into context, note that the risk of death in the UK due to road accidents is just over 1 in 10,000 years, while the risk of an individual being struck by lightning is widely quoted as being 1 in 10,000,000 years.

• For risks approaching the maximum tolerable individual risk level for the public of 10^{-4} per year (1 in 10,000 years) to be considered to be acceptable, it should be demonstrated that all reasonably practicable measures to minimize the risks have been, or will be, taken. The same applies for risks closer to the acceptable criterion of 10^{-6} per year, but where the degree of effort (and expenditure) that would be considered to be practicable would be less.

It should be emphasized that a variety of individual risk criteria are used worldwide, as shown by selected examples given in Table A-1, below:

For risks to the public a lower / tolerable criterion of 10^{-6} per year is widely accepted. However, lower values are adopted by some companies and legislators. For example, Statoil have a lower criterion of 10^{-7} per year and where for new facilities the Dutch authorities use 10^{-6} per year as the upper / maximum criterion.
It should also be noted that lower criteria are often adopted with respect to vulnerable populations, such that schools and hospitals, for example, should be located such that the individual risks are well below $10^{-6}$ per year.

The maximum criterion for the public varies between $10^{-3}$ and $10^{-5}$ per year (or lower in some cases - as indicated above). The UK HSE value of $10^{-4}$ per year is maintained in this study as a representative maximum. However, it should be emphasized that this is a maximum value and it would be extremely rare for this level to be considered acceptable for a new facility / development. That is, there is unlikely to be sufficient justification that there are no practicable methods of reducing this level of risk. In fact, it is considered to be best practice to treat $10^{-6}$ per year as the target criterion, while risks of up to $10^{-5}$ per year would require strong justification and risks above $10^{-5}$ per year should be avoided with respect to the public.

It should, in any case, be emphasized that risks above $10^{-6}$ per year are acceptable only if shown to be ALARP.

The converse applies to some extent to for risks to workers. Table A-1 shows that, although the maximum criterion does vary, the ALARP / tolerable region is generally between $10^{-3}$ and $10^{-6}$ per year, as per the UK HSE approach. However, for most workers (particularly those in a power plant) it is accepted that $10^{-6}$ per year risks levels are not practical to achieve and the target typically adopted is to achieve individual risks to workers of between $10^{-5}$ and $5 \times 10^{-5}$ per year.

Table A-1: Comparison of Selected Individual Risk Criteria for New Plants

<table>
<thead>
<tr>
<th>Body / Company</th>
<th>Public Max</th>
<th>Public Tolerable</th>
<th>Workers Max</th>
<th>Workers Tolerable</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK / HSE</td>
<td>$10^{-5}$</td>
<td>$10^{-6}$</td>
<td>$10^{-3}$</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Qatar Petroleum</td>
<td>$10^{-4}$</td>
<td>$10^{-6}$</td>
<td>$10^{-4}$</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>ADNOC / KOC</td>
<td>$10^{-4}$</td>
<td>$10^{-6}$</td>
<td>$10^{-3}$</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>BG Corporate</td>
<td>$10^{-5}$</td>
<td>-</td>
<td>$10^{-3}$</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Chevron</td>
<td>$10^{-5}$</td>
<td>$10^{-6}$</td>
<td>$5 \times 10^{-4}$</td>
<td>$10^{-6}$</td>
</tr>
</tbody>
</table>

In summary, it is proposed that:

- Risks to the public can be considered to be broadly acceptable if below $10^{-6}$ per year, although noting that societal risk factors should also be considered (including the type of population potentially exposed). Although risks of up to $10^{-4}$ per year may be considered acceptable if shown to be ALARP, it is recommended that $10^{-5}$ per year is adopted for this study as the maximum tolerable criterion.
• Risks to workers can be considered to be broadly acceptable if below $10^{-5}$ per year and where risks of up to $10^{-3}$ per year may be considered acceptable if ALARP.

**Societal Risk**

A proposed criterion for Societal Risk is set out in Figure A-2 in the form of an F-N curve, which gives the cumulative frequency (F) of exceeding a number of fatalities (N).

It is important to note that the acceptability of societal risks can be subjective and depends on a number of factors (such as the benefits versus the risks that a facility provides). There is not a single established indicator in terms of societal risk. For example, the UK HSE does not apply specific societal risk criteria in general, although they are applied to particular sites such as ports. Instead, the emphasis is placed on demonstrating that the risks are ALARP, where judgment on the ultimate acceptability of the risks is determined on a case by case basis.

However, the UK HSE do quote a single point risk criterion which has been interpreted to form a F-N criterion, as shown in Figure A-2. The maximum tolerable risk line is based on a standard 1:1 slope through the UK HSE's quoted intolerable societal risk level of "50 or more fatalities occurring with a frequency of 1 in 5000 years" (N=50 and $F=2 \times 10^{-4}$ per year). The minimum (broadly acceptable) risk line is simply assumed to be two orders of magnitude lower.

This is considered to provide a useful guidance on the acceptability of societal risk, although it should be emphasized that the criteria are not as widely accepted as individual risk and should be used as guidance only.
Figure A-2: An interpretation of UK HSE Societal Risk Criteria (F-N Curve)
EMERGENCY RESPONSE PLAN

NEED FOR AN EMERGENCY RESPONSE PLAN
Hydrocarbons occupy an important segment of our economy and are also the source of large benefits to the society. In recent years, there has been a rapid increase in the use of natural gas in industries and at the domestic front. Use of cleaner fuels has resulted in increased use of natural gas as fuel in electricity generation and transportation. However, natural gas is highly flammable and ignition results in flash fire, as well as confinement of vapors may lead to explosion. Thus, extreme care is essential while handling natural gas at all stages of transportation and handling.

The hazardous substances could be the source of potential danger to life, property and environment, if not stored or handled properly. Some of the major disasters occurred at Bhopal, Mexico and other parts of the world in the last few decades have made people all over the world concerned about the dangers of chemical accidents. Thus, it is mandatory for each industrial establishment, isolated storage installations and transporters to notify the persons working therein, the public and the Government, regarding the details of the chemical being used or stored and the on-site emergency preparedness in case of any such event. Occurrence of such accidents makes it essential for the Central and State Government agencies as well as the local authorities to be prepared to help mitigate and assist during such eventualities.

In order to achieve the highest levels of safety, the Company’s policy should be to maintain and continuously improve the capability for a rapid and effective response to all emergencies, which may affect its operations. In pursuit of this policy, the Company must recognize that emergencies can occur in spite of rigorous and ongoing preventive measures. It shall, therefore, prepare and revise an Emergency Management Plan (EMP) including emergency procedures, establish an Emergency Response Group (ERG) to implement them, train the personnel for an emergency, liaise with external organizations, verify and update emergency procedures etc.

An onsite preparedness plan should indicate details of in-built safety measures, role of key persons during such emergency situation, measures relating to declaration of emergency, disaster combating procedures, evacuation of non-essential persons, rescue of affected persons, information system, mutual aid, post emergency rehabilitation, long term clean up measures, to keep all concerned abreast of socio-technical requirements.

If the effects of a chemical hazard are not restricted within the plant boundaries and are felt beyond the premises, the situation warrants off-site emergency planning. In such scenarios, the action plan no longer remains in control of the factory management alone, but also becomes a concern for the general public living outside the commuters in the affected zone. To control such a situation, involvement of local and district
administration and law and order authorities becomes essential. Therefore, the district magistrates of each district are given the responsibilities of preparation of off-site emergency plan for their districts in command, based on the data submitted by the identified hazardous installation in the area in their on-site emergency plan.

OBJECTIVES OF AN EMERGENCY MANAGEMENT PLAN
A major emergency is one, which has the potential to cause serious injury or loss of life. It may cause extensive damage to property and serious disruption, both inside and outside a plant. Sometimes, it requires the assistance of outside emergency services to handle it effectively. Although the emergency may be caused by a number of factors, e.g. plant failure, human error, earthquake, vehicle crash or sabotage, it normally manifests itself in three basic forms, viz. Fire, Explosion or Toxic release.

The purpose of this EMP is to detail organizational responsibilities, actions, reporting requirements and support resources available to ensure effective and timely management of emergencies at, or affecting the plant’s operations. The overall objectives of EMP are to:

- Ensure safety of people, protect the environment and safeguard commercial considerations
- Immediate response to emergency scene with effective communication network and organized procedures.
- Obtain early warning of emergency conditions so as to prevent impact on personnel, assets and environment;
- Safeguard personnel to prevent injuries or loss of life by protecting personnel from the hazard and evacuating personnel from an installation when necessary
- Minimize the impact of the event on the installation and the environment, by:
  - Minimizing the hazard as far as possible
  - Minimizing the potential for escalation
  - Containing any release.

This is achieved by:

- Describing procedures to deal with emergencies affecting personnel, equipment, third party contractors, local communities or the environment
- Defining the roles and responsibilities of supervisory personnel, (at the plant site and site-base office) and Emergency Response Group (ERG) and Crisis Response Team (CRT) personnel.
• Describing the external resources available to the ERG for use in an emergency and how these resources will be coordinated.

SCOPE
The scope of this document is to identify all emergency scenarios, set out the basic principles of emergency response for each of these scenarios, and to present the organization and the arrangements, which are in place for the emergencies.

It is intended to act as an emergency support tool to the standard operating policies of the company; it is acknowledged that variations may be necessary subject to the knowledge of supervisory personnel and the particular circumstances of emergency situations as they unfold.

While these procedures would be followed to the greatest possible extent during an incident response, based upon sound management and/or engineering judgment and operational experience variations may be granted by the ERG Leader.

This manual will apply to all emergency situations related to the onshore oil and gas handling and transportation operations associated with the plant operation. This Plan recognizes that the Incident Controller is authorized to initially control and contains any and all emergency situations at the identified field incident site. The Emergency Response Group Leader (ERG Leader) is authorized to control all emergencies associated with the plant operations.

The results of the Risk Assessment (RA) study were used in the preparation of this EMP.

The following hazards as applicable to the pipelines and power plant processing facilities have been considered in the RA study:

• Oil and gas release due to leaks in the pipelines
• Leaks in the outlets of oil/gas processing equipment like Separator and Compressor
• Fire caused by ignition of leaked flammable products
• Explosions caused by ignition of leaked flammable products in the congested areas.

EMERGENCY MANAGEMENT PLAN: KEY ELEMENTS
Following are the key elements of the Emergency Management Plan:

• Basis of the plan
• Accident prevention procedures/measures
• Accident/emergency response planning procedures
• Recovery procedure

• Onsite & offsite crisis management, communication, contact information etc.

**Basis of the Plan**

Identification and assessment of hazards is crucial for on-site emergency planning and it is therefore necessary to identify what emergencies could arise during transportation of the natural gas through pipeline, compression and combustion of gas and combustion of fuel oil for production of high pressure steam. Hazard analysis or consequence analysis (in case of catastrophic release of hazardous chemicals) is therefore considered as the basis of EMP.

Major hazards/accidents are categorised into the following events involving flammable materials:

• Hazards from spread of fire, explosion or release of flammable substances from the wells

• Fire threatening items of pipeline/equipment section containing hazardous / flammable substances

• Hazards from high levels of thermal radiation for limited duration

• External interference such as excavation resulting in blow out of wells or large holes or ruptures of the pipeline. Ignition of the released gas/vapor from pipe rupture can cause heat radiation at some distance from the pipeline

• At valve stations, gas/vapor release due to failure of small-bore over-ground pipe work is a credible event. Gas/vapor fires, on ignition of releases, can occur

• Controlled releases of gas through vents also occur at the valve stations during pipeline depressurization and pigging operations. If such operations are not properly carried out, accidents can occur

• Risk mitigation measures based on consequence analysis also form an integral part of an organized Disaster Management Plan

**Accidents Prevention Procedures/Measures**

**General**

The American Society of Mechanical Engineers first published the ASME B31.8 code in the US in 1935. It was adopted by the Government's Department of Transportation in the United States as the minimum Federal Standard (192) for Gas Transportation Safety.

ASME B31.8 explicitly requires that each operating company having gas transmission or distribution facilities within the scope of ASME B31.8 shall:
• Have a written plan covering operating and maintenance procedures in accordance with the scope of code
• Have a written emergency plan covering facility failure or other emergencies
• Operate and maintain its facilities in accordance with these plans
• Modify the plans from time to time as experience dictates and as exposure of the public to the facilities and changes in operating conditions require
• Provide training to employees in the procedures established for their operating and maintenance functions. The training shall be comprehensive and shall be designed to prepare employees for service in their area of responsibility
• Keep records to administer the plans and training properly

Operation & Maintenance
The oil and gas handling system will be fit for purpose after testing and commissioning. The power industry experiences throughout the world have shown that the main physical dangers a pipeline faces during operation are mechanical damages caused by excavation works adjacent to them and corrosion resulting from breaks in the coating system, which leave the pipe wall steel exposed.

To guard the pipeline against damage, a system of regular surveillance and inspection to warn of mechanical or corrosion damage is employed.

Repairs will have to be made to any mechanical and corrosion damage on the pipeline, which the inspection program discovers.

Following are the main factors, which determine whether the pipeline will stay free of significant defects:

• Changes in the pipeline environment
• Adequate pipeline markers
• The effectiveness of the pipeline’s corrosion protection
• The pipeline’s protection against external interference such as caused by nearby excavations
• The influence of ground movement from natural or man-made causes such as settlement geological faults, washouts or mining

Preservation of pipeline integrity in accordance with ASME B31.8 during modification, maintenance and repairs
Protecting the Pipeline from External Interference

The pipelines should be laid 100 meters away from the habitated area. In the event of pipeline incident, it may affect the population living in proximity to the pipeline and the environment. An action plan is needed to handle any emergency smoothly with minimum effect on lives and property.

It is essential to protect the pipelines from being struck or damaged by third parties. The primary defense against this occurrence will be:

- Liaisons with third parties likely to excavate near the pipelines. The company shall identify, then make them aware of the well and the gas and oil pipelines and gather advance notifications of their activities

- Regular patrolling of the pipeline routes to monitor third party activities on the ground. The patrolman should be instructed to report on the following activities taking place in the vicinity of the wells and pipelines:
  - Ground movement
  - Removal of surface soil, tipping or stacking of materials etc
  - Any building or civil engineering works
  - Any other activity which may affect pipelines or any other equipment

Protecting the Pipeline against Corrosion

To prevent the buried steel pipeline from corroding over time, it should be coated with an electrically insulating coating such as Polyethylene or epoxy. The insulating properties of the coating prevent flow of the very small, naturally occurring electric currents between the pipe and the soil, which cause corrosion of the steel.

Sacrificial anodes may be placed. This applied current counteracts the induced current flow and will prevent the corrosion of the steel pipe where the coating is damaged or defective. The operation of the corrosion prevention system will be periodically monitored to ensure its effectiveness.

Regular monitoring of the cathodic protection system ensures that it is functioning correctly through the life of the pipeline. Cathodic protection (CP) is a well-established corrosion control process.

There are several techniques, which can be used to determine the condition of the pipeline coating from the ground surface above the pipeline.

Emergency Reporting

- When witnessing or receiving notification of an emergency, as much information as possible should be taken and/or conveyed to the relevant emergency
activation authority. Where possible, all information should be logged in written
form with time and date included and provided to the Incident Controller.

- Personnel working on the field may, at any time, be exposed to an emergency,
  which could take many forms, for example (but not limited to):
    - Injuries and/or fatalities
    - Exposures
    - Aggressive releases
    - Fires and/or explosions
    - Equipment hazards
    - Impacts
    - Extreme weather
    - Adverse environments

- When an emergency occurs, an appropriate and prompt response is required,
  providing precise action to control, correct and return the site to a safe condition.
  Timely action is also required to protect people, the environment and property
  from harm.

- Reporting Forms for actions to be considered, when witnessing an emergency or
  receiving a report of an emergency.

**WITHIN THE FIELD**
All near misses and unsafe acts will be written in logbooks / reported in the 'Near miss,
unsafe acts, hazards and sub-standard conditions report' and verbally communicated to
the concerned Supervisor / Superintendent / Installation Manager at an appropriate
opportunity. All accidents and incidents will be immediately reported to the Installation
Manager (Incident Controller), and appropriate forms completed.

**FIELD TO EMERGENCY CONTROL CENTER**
All accidents and incidents occurring within the Field facilities will be reported to the
Production Manager and Asset HSE Manager as per the company’s Incident Reporting
and Investigation Procedure. This includes both situations where there is actual damage
to health or equipment and also where there has been a threat of danger or a near miss.

**INCIDENT REPORT**
- One report form covers all accidents / incidents
• Incident report should be submitted regardless of the severity of the injury, or whether the injured party is a Cairn employee or a contractor

• Form should be completed and faxed to the Asset HSE Manager and Production Manager for review and distribution.

• All incident reports are to be followed up with the company's investigation report as per the procedure.

**INCIDENT SITUATION REPORT Form (SITREP)**

To be completed and endorsed by the site Incident Controller and faxed to the Emergency Response Group (ERG) at the commencement of any significant incident. The ERG may also fax copies of the SITREP to the CRT Leader as appropriate. The SITREP is continually used to further update the ERG on incident activity.

**MEDICAL EVACUATION REPORT**

• Completed by the Site Doctor to accompany any person being moved due to medical evacuation.

• Purpose is to provide full information on the patient's condition to the destination hospital.

**INTERNAL DISTRIBUTION**

The Asset HSE Manager will distribute copies of reports to all Senior Managers. In the event of a major incident, distribution of various reports (i.e. Incident SITREP / Medevac etc.) will be authorized by the ERG Leader.

**NOTIFICATION TO AUTHORITIES**

The ERG Leader is responsible to ensure that the respective agencies are informed of any serious incident such as damage to equipment, environment or to people.

**EMERGENCY RESPONSE STRATEGIES**

**INTRODUCTION**

Whenever there is an emergency, the managers/response team is required to swing into action without losing time. Time is the essence of the immediate relief and rescue operations to save human life, to mitigate the impact on the environment and to safeguard commercial consideration. The same is true while dealing with any emergency during the proposed production operations in the plant.

This EMP has been prepared keeping in mind the above fact and it is conceptually based on the Trigger Mechanism.

The Trigger Mechanism envisages that on receiving signals of a disaster happening or likely to happen, all activities required for the mitigation process are energised and
activated simultaneously without loss of any time. The primary objective of this mechanism is to undertake immediate rescue and relief operations and stabilise the mitigation process as quickly as possible.

The main parameters of such a response plan include:

- Signal/Warning Mechanism
- Activities and their Levels
- Sub-Activities
- Command and Control Structure
- Individual roles and responsibilities of each specified authority to achieve the activation as per response time
- Response teams for each specified authority
- Emergency procedures
- Alternate plans & contingency measures.

**Alert Phase**

It will be the duty of all site personnel at the site to remain alert at all times for hazardous situations that have the potential to escalate into an emergency incident. All the members of the ERG and CRT will be on a standby and will be activated as required. All members of the response will be familiar with the company's Disaster Management Plan.

Emergencies on site can be initiated in a number of ways depending upon the severity of the incident by the site fire alarm siren which any personnel in the field can activate. The site siren will sound in an intermittent mode. Also, the individual fire alarms will sound in the area of the incident.

This procedure initiates the Site Fire and Rescue Department and Site Security into their standard procedures and the Site Fire and Rescue Department to attend the incident. This has the advantage of permitting the earliest possible action to be taken to control the immediate situation, which may avoid the development of a major emergency.

The Incident Controller will attend the scene of the incident and the ERG Leader will be notified. Depending upon the severity of the emergency, the ERG Leader will activate the ERG and notify the CRT Leader as appropriate. Only if it's a major disaster, the CRT will be activated. The Incident Controller will assess the situation from the edge of the incident scene to reduce the probability of personal injury. The Emergency Support Team members will be on standby ready to go to the Emergency Control Center.
Evacuation of employees to the nearest assembly point or refuge may be required, if not hindered by fire.

**DECLARATION OF EMERGENCY**
To enable the appropriate level of response to be implemented, emergency incidents are to be categorized according to three levels as follows:

**Tier 1**
- The incident can be effectively and safely managed, and contained within the facility by operations staff
- The incident has no effect outside the site.
- There is unlikely to be serious danger to life, the environment or to company assets or reputation.

**Tier 2**
- The incident cannot be effectively and safely managed and contained at the installation or facility by operational staff and some form of additional assistance is required
- The incident may be “on site”, have some effect beyond the “site” and an external emergency services will be involved
- There is likely to be danger to life, to the environment or to company assets or reputation.

**Tier 3**
- The incident has ESCALATED to a level where it begins, or has the potential to begin, to adversely affect the Company, its Joint Venture Partners, or the public on a broad front
- The incident will have technical, press, public affairs and personnel implications, which require immediate assistance
- There will be one or combination of the following:
  - Death and/or serious injury
  - Potential for significant pollution or environment damage
  - Substantial damage or property
Emergencies will initially be under the control of the Incident Controller whose main tasks are to locate the source and nature of the incident, to inform the ERG Leader, and activate the Site Security and Emergency Services.

During normal working hours the Incident Controller will keep the ERG Leader informed and jointly decide whether it's a Tier 1, Tier 2 or Tier 3 emergency. For a major emergency appropriate Emergency Control Centers will be set up, the site Emergency Support Team summoned and the ERG and CRT activated as required.

**EMERGENCY ALARM (SIREN)**
Personnel on site will know that a Major Emergency has been declared, if the site fire alarm siren and all local fire alarm systems are activated. The Emergency Siren Modes will be operated as per internationally accepted alarm codes.

**PREPARATION FOR EMERGENCIES**

**Command by Competent Persons**
Effective command and control starts with a clear definition of the overall command and control structure, and description of the duties of key personnel with specific responsibilities for emergency response.

**Number of Persons for Emergency Duties**
The command/control of emergencies must identify the minimum number of persons required to provide an adequate response to emergencies. This includes having staffed trained and competent to fulfill the roles of other members of staff if they are not available.

**List of Persons for Emergency Duties**
A list of the staff in the field having emergency duties is displayed in the Control Room. It is the responsibility of the Incident Controller to ensure that these lists are kept up to date.

**Control of Emergencies**
The major systems for controlling emergencies and preventing escalation are detailed in this EMP, which gives the emergency procedures to be followed in case of an impending / occurring disaster. It should be noted that during any emergency during the production operation, this document would be referred. This would result in the most efficient emergency response strategy to combat the impending/occurring disaster.

**Assembly Procedures**
When personnel arrive on site, they are assigned to an assembly station.

**Assembly Areas**

- Non-essential personnel assemble within the accommodation
• Fire Team at the Team Station
• Emergency Response Team in the office of Incident Controller.

Lists
Assembly lists should be kept up to date and are produced by a senior person. Copies are displayed at each Assembly Station.

Accounting for Personnel
The person in charge at each Assembly Station checks the personnel according to the assembly list and relays the information to the site HSE Support and the Incident Controller. The HSE Support person conducts the final headcount and notifies the Incident Controller of the results and discrepancies if any.

Co-ordination
The Senior person in the Control Room is charged with co-ordinating the information/response measures from the various Assembly Stations and ensuring that all personnel are accounted for. He must refer to the HSE Support or the Incident Controller if any personnel are not accounted for or if there are impediments to carry out the response strategy.

POST EMERGENCY
The post emergency phase is an important event in the long-term emergency response strategy for CEIL.

It is absolutely necessary for the Emergency Response Team (ERT) members (IRT, ERG and CRT) to review the ERP and the incident response events and provide their inputs for response improvements or ERP updates. All personnel involved in the emergency response actions during an incident will be debriefed by their superior officer.

It will be the responsibility of the designated ERT members to prepare a complete incident report collating incident reports/logs from the respondents and forward the same to higher authorities as appropriate or send notifications to the Government authorities as the case may be. It will be the responsibility of the ERG leader to develop a post emergency action plan with the assistance of Incident Controller.

EMERGENCY RESPONSE ORGANIZATION

INCIDENT RESPONSE
The Incident Controller (IC) is responsible for coordinating the on-site tactical response to any emergencies arising out of the operations in the facility and will activate and direct emergency response personnel as appropriate to the emergency. The Incident Controller will notify and correspond with the ERG Leader.
If required, the following personnel or teams are available to be activated at the site:

- Incident Controller
- HSE Support
- Site Medical Center
- Site Contractor Mgt. (as appropriate)
- Fire Team Leader
- Technical Support
- Control Room
- Scribe

**Emergency Response Group**

The Emergency Response Group (ERG) is responsible for coordinating the strategic response relative to any Tier 2 emergency arising out of the production activities in the facility. The ERG is activated and directed by the ERG Leader, and will assemble in the Emergency Coordination Center (ECC).

If additional support is required for the response, the following personnel should be mobilized as required:

- Operation & Technical Coordinator
- QHSE Coordinator
- Human Resources & Services Coordinator
- Public Affairs Coordinator
- Logistics Coordinator
- Recorder
- Security Coordinator
- Reception Coordinator
- Telecommunication Coordinator

**Crisis Response Team**

The Crisis Response Team (CRT) is responsible for coordinating the overall strategic response to any Tier 3 emergency arising out of any activity in the country. The CRT is activated and directed by the Crisis Response Team Leader (CRT Leader).
The CRT will initially assemble in the designated Emergency Management Center (EMC) and will be directed by the CRT Leader, or alternate.

If an incident requires additional support, the following personnel should be mobilized:

- Finance and Commercial Coordinator
- Operations / Technical Coordinator
- Risk, Health, Safety and Environment Coordinator
- Public Affairs Coordinator
- Human Resources and Services Coordinator
- Legal and Joint Venture Partner Coordinator
- Recorder

**INCIDENT SITE ROLES AND RESPONSIBILITIES**

The roles and responsibilities of the members of the Incident Response Team are outlined below:

**HSE Engineer**

**Pre-emergency**

Maintain familiarization with Field Emergency Response Plan, key respondents and appropriate emergency notification requirements.

**During Emergency**

- Liaise with Incident Controller for incident briefing and likely requirements
- Assist Incident Controller in co-ordination of emergency response personnel as appropriate
- Liaise with the site doctor for emergency medical/first aid as appropriate
- Coordinate support in areas of administration and information gathering
- Brief personnel regarding likely incident needs and safe working practices, monitor them for signs of trauma, fatigue and stress
- Continually refer to ERP procedures, role checklists and OSCP, use Emergency Response Log
- Filter flow of information and keep Incident Controller informed of situation
• Prepare/maintain supporting information flow between Incident Controller and ERG Leader

For Evacuation

• Ensure headcount of personnel at Fire station Muster Point and Main Gate (including Fire Teams) etc
• Ensure third party contractors, security personnel, transport drivers and cartage contractors are included in all headcount
• Check headcount results; notify Incident Controller of results and any discrepancies
• Follow Evacuation procedure

For HSE Incident

• Notify ERG HSE Coordinator of any likely HSE effects of incident on nearby environments and/or communities
• Liaise with ERG HSE Coordinator for incident updates and likely requirements
• Consider need for relief of personnel in your charge
• Consider relief/support for your role; prepare hand-over reports and plans
• As time permits, maintain log of events for collection at end of incident; provide to Incident Controller

Post-Emergency

• Debrief personnel in your charge before releasing them from duty
• Review incident response events; provide recommendations for response improvements or ERP updates
• At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller

Primary Role: To provide and coordinate support to responses designed to mitigate the impact of the incident and ensure efficient information flow between site and ERG.

Sr. Administration Officer

Pre-emergency

• Maintain familiarization with Field Emergency Response Plan, key respondents and appropriate emergency notification requirements
- Establish/maintain “goodwill” contact with all relevant community groups, their key contact persons and any relevant groups

**Emergency Actions**

- Liaise with HSE Engineer for incident briefing and likely requirements; maintain liaison
- Continually refer to ERP procedures and role checklists; use Emergency Response Log
- Brief personnel in your charge regarding likely incident needs and safe working practices, monitor them for signs of trauma, fatigue and stress
- Prepare an initial community impact assessment; provide to HSE Engineer
- Ensure community near incident site (residents, farmers etc.) are advised and regularly updated of incident status and any likely impact if applicable
- Assess requirement for post trauma counseling for affected site/community members
- Ensure Incident Controller is kept updated through HSE Engineer with all community liaison and media issues; maintain liaison as appropriate

**For Remote Spokesperson Role** (This role needs to be carried out only on confirmation with ERG Leader and Incident Controller).

- Liaise with Company Public Affairs Coordinator for media strategy and likely requirements
- Consult with ERG leader for most current incident information
- Review media conference material with ERG PA and Public Affairs Coordinator
- Rehearse with Public Affairs Coordinator before media conference / interview / release
- Ensure visual conference aid material (charts, maps, plans etc.) and relevant technical support personnel are available
- Assess effectiveness of each media conference with Public Affairs Coordinator
- Regular updating of ERG PA and Public Affairs Coordinator of all key media events
- Consider meeting with relevant community leaders/groups
• Consider need for relief of personnel

• Prepare hand-over reports and plans

• Maintain log of events for collection at end of incident; provide to Incident Controller

**Post-emergency**

• Debrief personnel in your charge before releasing them from duty

• Review incident response events; provide recommendations for response improvements or ERP updates

• At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller

Primary Role: To provide a link between the company and immediate community and to effectively assess the impact and implement appropriate responses and actions; to act as Remote Spokesperson, if asked to act in this role.

**PIC-onshore**

**Pre-emergency**

Maintain familiarization with Field Emergency Response Plan, key respondents and appropriate emergency notification requirements

**Emergency Actions**

• PIC - Onshore is the company's representative assuming control and liaison activities at an actual incident site (this role may be assumed by first person on the scene and then assumed by a more appropriate or senior Company person as an incident escalates)

• If not the first person at the scene, obtain all relevant incident information from person who raised the alarm or who initially assumed the role of PIC - Onshore

• Make early contact and maintain liaison with the Production Superintendent as emergency requires

• Evaluate and initiate immediate action to mitigate the effect of the emergency and request any additional resources likely to be required

• Assess the likely impact of incident to simultaneous operations, the local community or the environment

• Continually update Production Superintendent with ongoing incident response activities and requirements
• Advice Production Superintendent of any processes or systems that are threatened should be diverted or that should be closed etc.

• Brief personnel in your charge and constantly monitor them for safe working practices, stress, fatigue or trauma

For Fire and / or Explosion

• Immediately confirm location, extent and type of fire

• Confirm all personnel in the immediate area

• Assess likely cause of fire/explosion and undertake corrective action/damage control measures

• Provide incident information to Fire Chief

• Guide fire teams to incident site by safest route as required

• Monitor events; determine need for evacuation of personnel / equipment if situation warrants

• Consider need for relief of personnel in your charge

• Consider relief/support for your role; prepare hand-over reports and plans

• As time permits, maintain log of events for collection at end of incident; provide to Incident Controller

Post-emergency

• Debrief personnel in your charge before releasing them from duty

• Review incident response events; provide recommendations for response improvements or ERP updates

• At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller

Site Doctor

Pre-emergency

Maintain familiarization with Field Emergency Response Plan, key respondents and appropriate emergency notification requirements.

Emergency Actions

• Liaise with HSE Engineer for likely medical needs and requirements
• Consider the need to mobilize Medical Response Team (Trained First Aides)
• Prepare appropriate Medical Report to be sent along with patient
• Liaise with concerned hospitals for necessary treatment (follow up)
• Provide appropriate medical advice to the concerned

Post-emergency
• Review incident response events; provide recommendations for response improvements or ERP updates
• At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller
• Follow-up periodically on the recovery of the patient/medical treatment rendered

Fire Chief
Pre-emergency
• Maintain familiarization with Field Emergency Response Plan, key respondents and appropriate emergency notification requirements
• Establish / maintain “goodwill” contact with all relevant local response agencies, their key personnel and the respective notification/call-out requirements

Emergency Actions
• Liaise with Maintenance Superintendent for incident briefing and likely requirements, confirm nature, extent and location of emergency; maintain liaison
• Organize Fire Team from available, trained personnel assembled at muster point; ensure HSE Engineer receives list of Emergency Response Team member’s names (for headcount purposes)
• Proceed to incident site; develop and implement response strategy with Maintenance Superintendent and PIC-Onshore
• Continually assess situation and requirements for fire fighting materials and equipment
• Under direction of Maintenance Superintendent, conduct SAR if required, for missing personnel
• If incident (e.g. fire) is assessed as uncontrollable, inform Incident Controller and move back to Fire station muster point; liaise with Incident Controller and await instructions

Post-emergency
• Debrief personnel in your charge before releasing them from duty
• Review incident response events; provide recommendations for response improvements or ERP updates
• At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller

Production Superintendent
Pre-emergency
• Maintain familiarization with Emergency Response Plan, key respondents and appropriate emergency notification requirements
• Establish resource database of all relevant technical organizations, who are likely to be required for site incidents
• Maintain familiarization with the technical organizations key personnel and respective notification/call-out requirements

Emergency Actions
• When activated, liaise with Incident Controller for incident briefing and likely requirements, maintain liaison
• Continually refer to ERP procedures and role checklists; use Emergency Response Log
• Brief personnel regarding likely incident needs and safe working practices, monitor them for signs of trauma, fatigue and stress
• Assume responsibility for gathering technical information required for response strategies and technical assessment of incident; source engineering drawings, plans etc. as required
• Constantly monitor effectiveness of technical response strategy
• With ERG, consider forward planning issues; be pro-active in considering technical data needs etc.
• Arrange for safety induction of technical support contractors as appropriate
• Support ERG regarding technical issues that may be required by PA
• Consider need for relief of personnel
• Continually monitor/adapt requirement plans to suit escalation or reduction of incident needs

Post-emergency

• Review incident response events; provide recommendations for response improvements or ERP updates
• At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller

Maintenance Superintendent
Pre-emergency

• Maintain familiarization with Field Emergency Response Plan, key respondents and appropriate emergency notification requirements
• Establish resource database of all relevant technical organizations, who are likely to be required for site incidents
• Maintain familiarization with the technical organizations key personnel and respective notification/call-out requirements

Emergency Actions

• Coordinate with Fire Chief to direct Emergency Response Team
• When activated, liaise with Incident Controller for incident briefing and likely requirements; maintain liaison
• Liaise with Electrical/Mechanical/Instrumentation in charges and instruct appropriate actions relevant to their functions
• Coordinate through the company's project engineer for handling controls related emergency
• Continually refer to ERP procedures and role checklists; use Emergency Response Log
• Brief personnel regarding likely incident needs and safe working practices, monitor them for signs of trauma, fatigue and stress
• Consider need for relief of personnel
Post-emergency

- Review incident response events; provide recommendations for response improvements or ERP updates
- At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller

Primary Role: To organize, direct & guide Emergency Response Team including site doctor for initial incident response & liaise concerned department in charge for suitable emergency response.

Scribe

Pre-emergency

Maintain familiarization with Field Emergency Response Plan, key respondents and appropriate emergency notification requirements

Emergency Actions

- Liaise with Incident Controller for incident briefing and likely requirements
- Ensure that site Incident Control Center (ICC) is set-up and all appropriate emergency procedures, site plans etc. are available; have copies of the Contact Directory available and displayed
- Check that ICC communications equipment is working; verify with Site Radio Operator that all Radio Room communications systems are functioning and available
- Make early contact with ERG leader, maintain liaison as/when required
- Continually refer to ERP procedures and role checklists; use Emergency Response Log
- Coordinate display of known information on ICC wall charts
- Set up incident filing system
- Obtain copy of results of head counts from Incident Controller
- Maintain accurate master chronological log of activities and circumstances, record and file all information received from incident locations into incident filing system
- Ensure the incident information board(s) is accurate and kept updated
- Coordinate support in areas of administration and information gathering
• Filter flow of information and keep Incident Controller informed of any situation changes

• Forward completed incident SITREP, validated by Incident Controller, to ERG

• Prepare and maintain supporting information flow between Incident Controller and ERG Leader

• Consider relief/support for your role; prepare hand-over reports and plans

Post-emergency

• Review incident response, including any logs of events collected; provide recommendations for response improvements or ERP updates

• At the conclusion of any incident, prepare a complete incident report; provide to Incident Controller

Person Taking Calls

Emergency Actions

• Ensure all calls are taken away from site Incident Control Center

• For emergency calls, put the caller through to Incident Controller (or Alternate) or take a message for a return call

• If relatives call, refer them to the Incident Controller until a “Relatives Response” dedicated number is established

• If level of incoming calls becomes too great, contact HSE Engineer for additional resources

• Consider relief for your position for an extended incident response

• As time permits, maintain log of events for collection at end of incident; provide to Incident Controller

Post-emergency

• Pass “return call” requests to relevant persons for action

• Contribute to incident debrief

• Review incident response events; provide recommendations for response improvements or ERP updates

• At the conclusion of any incident/emergency, prepare a complete incident report; provide to Incident Controller
Primary Role: To filter incoming telephone calls, ensuring Incident Controller receives only relevant emergency calls while ensuring all other calls are handled appropriately.

Control Room Operator

Pre-emergency

Maintain familiarization with Field Emergency Response Plan, Key respondents and appropriate emergency notification requirements.

Emergency Actions

- Identify the caller and confirm the emergency.
- Get a description of exactly what has happened, confirm details such as
  - When, where, nearest location etc., as appropriate.
  - What risks continue to exist
  - What action has been initiated
  - Ascertain whether any medical assistance is required at the accident scene.
- Activate the Emergency Siren
- Notify Production Superintendent
- Start the main firewater pump immediately on remote if required
- Verify the incident details, escalation potential and actions already initiated
- Act according to the instructions from Production Superintendent
- Log all the events and actions.
- Consider relief / support for your role if required
- Prepare hand-over /status report if required.

EMERGENCY RESPONSE ACTION

EMERGENCY RESPONSE CENTERS

Incident Control Center (ICC)
The Incident Controller would set up the incident control center. It is suggested that best location for incident control center is the main control room. There will be radio, telephone or messenger contact with the Emergency Control Center.
The incident area will be taped off and warning notices posted. The in-house Fire Team will cordon off the incident area (Inner Cordon). Route markings from Emergency Control Center to the incident to aid the emergency services will be arranged.

**Emergency Control Center (ECC)**

The Emergency Control Center is to be set up at the oil and gas processing facility. The center is equipped to receive and transmit information and directions from and to the Incident Controller as well from outside. ECC shall contain equipment for logging the development of the incident to assist the controllers to determine any necessary action.

The Emergency Control Center should contain:

a) Adequate number of external telephones. At least one will be ex-directory or capable of use for outgoing calls only. This will avoid the telephone switchboard being overloaded with calls from anxious relatives, the press etc.;

b) Adequate number of internal telephones;

c) Radio equipment;

d) Plans of the works to show:

   i. Areas where there are large inventories of hazardous materials, including oil storage
   ii. Sources of safety equipment
   iii. The fire-water system and additional sources of water
   iv. Stocks of other fire extinguishing materials
   v. Assembly points, casualty treatment centers
   vi. Location of the works in relation to the surrounding community and
   vii. Lorry parks
   viii. Additional plans which may be marked up during the emergency to show:

   ix. Areas affected or endangered;
   x. Deployment of emergency vehicles and personnel;
   xi. Areas where particular problems arise;
   xii. Area evacuated; and
xiii. Other relevant information.

e) MSDS sheets for the various hazardous materials used on-site

f) Note-pads, pens, pencils to record all messages received and sent by whatever means;

g) Nominal roll of employees or access to this information;

h) List of key personnel, addresses and telephone numbers.

Emergency Control Center is located, designed and equipped to remain operational in an emergency.

**ACCIDENT / EMERGENCY RESPONSE PROCEDURES**

In order to deal with an emergency, a complete emergency procedure document will be prepared which identifies the key personnel involved with their specific duties and responsibilities.

This emergency plan will include all requirements for dealing with such a situation, so that all the equipments and personnel can be mobilized in the shortest possible time.

**Basic Features**

In the development of emergency procedures, following factors should be kept in view:

- Identification of situations i.e. what can happen and how it can happen
- Identification of problem/priority areas i.e. where it can happen
- Identification of individuals i.e. who is to take action
- Duties of individuals.
- System or equipment to be used and when to use it.
- Procedures for operating the system or equipment

**Basic Actions**

The basic actions required to handle any emergency are as follows:

- Operation of emergency shut down systems
- Maintenance of telephonic communication
- Persons to be nominated for evacuation
• Effective internal communication by public address system and walkie-talkie sets

The organizational chart identifying personnel who are to coordinate an emergency with assigned responsibilities and specific functions, is to be formulated for the Facility in an integrated manner. Communication links will be established with local authorities such as factory/section inspector, police station, fire brigade, hospital etc., State and Central authorities to meet the challenges of emergencies and ensure reliability of functioning of the communication system. Adequacy and efficiency of fire fighting and fire detection equipment, personal protective measures, medical services, safety and emergency training will be ensured.

The purpose of this section is to provide "all Hazards" emergency response procedures to previously identified hazards and threats to the plant's areas of operation and activities.

**FIRE/EXPLOSION (GENERAL)**

The following actions would be taken in case of the above emergency:

- Person first on the scene
- Rescue any personnel in danger (do not endanger yourself)
- Raise Alarm and evacuate the work area.
- Contain fire, close doors/windows to contain the fire
- Extinguish fire only if it is safe and you are trained to do so

**General**

- If fire is small and respondent is trained to do so, use nearest fire extinguisher and attempt to fight the fire/extinguish the source while calling for assistance
- If fire escalates or is bigger than first anticipated, immediately raise the alarm ensuring all contractor and company's personnel are informed
- Mobilize Fire Team if available
- Ensure the safety of all personnel when responding to the incident
- Request assistance from emergency services if available
- Confirm location, extent and type of fire/explosion and where possible eliminate the source
- Shut down and isolate electrical supply to affected area if safe to do so
• Consider suspension of operations and take actions to secure area
• Check for any exposures that are likely to escalate the incident (fuel drums, chemicals, oxy-acetylene bottles, petrol, kerosene, gas bottles, tyres etc.)
• If gas fire, do not try to extinguish unless gas flow can be turned off immediately. If gas cannot be turned off, concentrate on stopping spread of fire and cooling activities (e.g. cooling exposed vessels etc)
• Evacuate any personnel at risk to a safe distance upwind from the incident area and wait until advised otherwise
• When rescuing personnel in danger, ensure own escape route first; do not endanger yourself by entering an area containing smoke and/or noxious fumes
• Confirm all personnel are accounted for
• Monitor events and determine need for full evacuation of personnel/equipment
• Activate damage control procedures.

PROCEDURES FOR DEALING WITH REPORTED GAS/ VAPOR ESCAPES
The company is responsible for the organization and assignment of responsibility for:

• The setting up of a continuously manned Emergency Control Center for the receipt of telephone calls related to emergencies and gas/vapor escapes and/or from which, the employees are directed by telephone and/or radio
• The provision of adequate management, co-ordination and supervision of all administration and operations necessary to maintain disciplined progress and clearance of emergency work
• The organization of adequate staff and other resources in order to progress reported gas/vapor escapes within the specified times
• The organization of facilities for the monitoring of the receipt, issue, attendance at and clearance of emergency work so as to ensure that none are overlooked or unduly delayed

FIRE PREVENTION PLANNING AND MEASURES
Fire is one of the major hazards, related to natural gas and crude oil pipeline (ref. Chapter 3). Fire prevention and code enforcement is the area of responsibility of the fire service.
Safe operating practices reduce the probability of an accident fire in the facility. Personnel should understand their duties and responsibilities and be attentive to conditions that might lead to fire. Following procedures are recommended:

- There should be provision for safe handling and storage of dirty rags, trash and waste oil. Flammable liquids and chemicals if spilled, should be immediately cleaned.
- Containers of paints and hydrocarbon samples, gas cylinders for welding and cutting should be stored properly.
- Cutting and welding operations should be conducted in accordance with safe procedures.
- "No Smoking" areas should be clearly identified by warning signs.
- Equipments should be maintained in good operating conditions and kept free from external accumulation of hydrocarbons. Particular attention should be given to crude oil pump, seals, diesel and gas engines which could be potential source of ignition in the event of a failure.

The Emergency Management Plan will address the issue of a fire event and the procedure to be adopted in the very unlikely event of this occurring.

If a fire starts in any well or a pipeline section, that section of pipeline will be immediately isolated by closing the section (block) valves, as quickly as possible. Surrounding facilities will be cooled with water. The Public will be advised to move away from the fire and seek shelter to avoid exposure to heat radiation.

**COMMUNICATION**

An essential component of a EMP is the Communication Links necessary for gathering information needed for overall co-ordination. Emergency Control Center links with incident scene and with in-house as well as outside emergency services is necessary. Too much dependence on the Public Telephone system is insufficient, as it can soon be overloaded in an emergency situation. A multi-user wireless paging system with selective call facility is also useful for promptly locating key operating personnel in the plant, both during normal conditions and during emergencies. A public address (PA) system with loud speaker installed at vital installations can be extremely useful during emergencies. An additional location and transit communications can be addressed by using vehicle and well site installed VHF units.

**EMERGENCY CONTROL CENTER**

The establishment of a 'focal point' or 'EMERGENCY CONTROL CENTER' to coordinate emergency response activities within a relevant area is essential.
The emergency control center will be sited in an area of minimum risk (Operational Control Room of the Gas Processing Station) and will have easy and fast access to all major hazardous installations.

Emergency control centers will be equipped with the following:

- An adequate number of external telephones
- An adequate number of internal telephones (if required)
- Wireless communication system with adequate number of portable handsets
- Notepads, pens & pencils
- A list of external agencies likes Fire Brigade, Police, Hospitals, Port, neighboring Industries, Téléphone co. etc.
- Drawing of the Terminal and Pipeline network
- Source of safety and fire equipment
- List and location of 'LEAK' clamps
- A nominal role of employees
- First-aid kits

A list of KEY PERSONNEL with addresses, telephone numbers, etc. with their roles and responsibilities

**RECOVERY PROCEDURE**

Following an accident on the well, pipeline or equipment, there shall be a full recovery procedure as part of the Disaster Management Plan. The recovery procedure shall deal with two distinct situations described below.

**PRESSURE REDUCTION IN PIPELINE OR FLOW RESTRICTION**

The Operations Manager may have to restrict the pressure or reduce the flow in the pipeline, depending on the severity of the accident. Following the required repair or attention to any safety detail, the pipeline should be brought back into full service by manually attending the appropriate valves, along with full communication with the Control Engineer at the control station. When full operating conditions are established, any barriers or excavations should be removed and the incident site should be returned to its original condition. All members of the emergency response team should be kept in full contact throughout this exercise and should be informed when the pipeline gas flow/pressure situation is back to normal.
COMPLETE SHUT-DOWN OF PIPELINE
This would occur if the pipeline suffers a rupture from third party interference and gas escapes. At such instance, repair of the pipeline is necessary and a new section of pipeline is needed to be installed to replace the damaged section. For minor leaks, it may be acceptable to install a repair clamp and the Operations Manager will assess this. When any non-destructive testing requirements are completed on welds or repairs, then the pipeline anti-corrosion wrapping must be made properly. The excavations need to be reinstated and the pipeline can be brought back to service as documented in the appropriate maintenance manual. All members of the emergency response team should be kept informed at every stage of the operation.

EMERGENCY MANAGEMENT PLAN: ONSITE CRISIS
Identification of Personnel and Assessment of Responsibilities on specific functions of Coordinating Authority.

In order to effectively deal with emergencies, the organizational chart for on-site emergencies (Fig. 5.1) should be periodically reviewed and updated. Usually, for Oil and Gas facilities, following coordinators are required to coordinate for various activities during the emergency:

- Incident Controller (IC) : Installation Manager
- Operations Coordinator (IC) : Production Manager
- Fire Fighting & Safety Coordinator : Fire & Safety Incharge
- Medical Incharge : Medical Officer / Paramedic
- Communications Coordinator : Electrical/Instrumentation Incharge
- Services Coordinator : Maintenance Incharge
- Logistics Coordinator : Administrative Incharge

ROLE OF INCIDENT CONTROLLER
He shall be the main guiding force in directing the emergency operations and will be in charge of overall control of the disaster. The actions include:

- On hearing the fire siren or on receiving information about the disaster, he will immediately take charge of the emergency control center
- To declare the category of the emergency after discussing with other team members
- To instruct all the team members/ coordinators to make necessary arrangements
• To inform mutual aid partners about the disaster

• Instruct the safe shut down of system in consultation with emergency site incharge and key personnel

• If necessary, arrange for evacuation of population in the neighboring villages

• Carry out search for causalities within the affected area and arrange for first aid/hospitalization of victims, if required

• Ensure not to operate the plant/system unless it is declared safe by the competent person

• Provide local authorities, media and Govt. adequate factual information through in-company modalities.

**COMMUNICATION SYSTEMS NETWORK**

An efficient and reliable communication system is required for the success of the emergency plan. The efficient communication system is required to alert:

• Emergency Authorities and Services

• Neighboring area and public in the vulnerable zone

The communication system requires the following:

• Communication between Control Room to other units in the terminal

• Hotlines between Control Room to Emergency Services, Meteorological Station and the mutual aid members

• Paging system and alarm for with the Control Room for alerting the employees

• P&T Telephone lines

A communication flow chart is to be prepared and kept in the Control Room. An up-to-date Telephone Directory of key personnel concerned with the emergency should be available at all times. These matters should be documented and kept within the Disaster Management Plan manual.

The Emergency Management Plan Manual is required to maintain a record of police stations, hospitals and fire brigade stations in the area to seek assistance in dealing with emergency situations. The emergency team of the company should liaise with these agencies and with district officials and furnish them information on the possible hazards, extent of damage & actions to be taken by them during such emergencies.
TRANSPORTATION
In case of the Natural Gas/Crude Oil pipeline, the main criteria for transport vis-à-vis the emergency management are the accessibility and response time to reach a specific location along the pipeline.

Sectionalizing valves will be located at the Gas Pressure Reducing Station. Vehicles from the Gas Pressure Reducing Station are required to transport personnel as well as materials and equipments to the incident site. The transportation should include vehicles for transporting the public in emergency.

For efficient co-ordination, there should be a Communication team in the Control Room to ensure that all the modes of communication are functional round-the clock during an emergency. A log-book for the messages received in/out and actions taken should be maintained.

PUBLIC INFORMATION SYSTEM
During a crisis following an incident, the people of the area and a large number of media representatives would like to know about the situation from time to time and the response of the district authority to the crisis. It is important to give timely information to the public in order to prevent panic and rumors. The emergency public information could be carried out in three phases.

BEFORE THE CRISIS
This will include the safety procedure to be followed during an emergency through posters, talks and mass media in different languages including local language. Leaflets containing do's/don'ts should be circulated to educate the people in the vicinity

DURING THE CRISIS
Dissemination of information about the nature of the incidents, actions taken and instructions to the public about protective measures to be taken, evacuation etc. are the important steps during this phase

AFTER THE CRISIS
Attention should be focused on information concerning restoration of essential services, travel restrictions, etc.

FIRE FIGHTING SYSTEM
Release of gas/vapors can lead to fire. In order to deal with such possible situations, there is a need for constant preparedness to mobilize fire fighting and control resources in minimum time. There should be control of all fire fighting resources in the affected areas under the Fire & Safety Officer. The operational response will be coordinated from the Central Control Room. The planning for fire fighting should be as follows:
**BEFORE THE CRISIS**

- Proper road and means of escape should be identified
- Considering the possible hazards, there must be adequate water supply
- Training of the fire fighting personnel
- Provision of adequate availability of fire fighting facilities is important

**DURING THE CRISIS**

Immediate response to an incident should be coordinated by the Control Room by matching all the resources. In a major incident having wide off-site implications, more than one installation may be affected, necessitating concurrent fire fighting operations at a number of places. In this case, the whole area may be divided in different fire zones.

The task of the fire zone commanders is as under:

- Command and control of all fire fighting resources in the respective fire zones
- Deployment of additional fire resources allocated by Control Room
- Co-ordination of fire fighting teams

**CHECKLIST FOR CAPABILITY ASSESSMENT**

The checklist will help in assessing the preparedness, prevention and response resources capabilities. The points included in the checklist are only indicative and there is a need to closely examine the local requirements while preparing the checklist.

For good control and management of an incident, there are three important requisites.

- Defined Organization
- Effective means
- Trained people

The organization has to be properly structured for routine as well as emergency purposes with clear understanding of duties and responsibilities. The structure has to consider an execution and speedy implementation of the response plans; while at the same time, it should be flexible enough to tune itself to the fast changing situations. All plans and procedures for emergency handling should be established.

Means include equipment and materials, transport and communication. Identification, storage and upkeep of these means are essential for speedy implementation of the response plans.
People form the vital element in emergency response. Experience, education and training should help make this vital element effective.

In general, the duties, responsibilities and competence of the individual team are defined by the description of the function.

A broad outline of responsibilities and duties of different managers concerning the emergency management plan are given below:

Roles and Responsibilities of Various Emergency Response Team Members

Table A-2: Roles and responsibilities of various emergency response team members

<table>
<thead>
<tr>
<th>Role</th>
<th>Responsibility</th>
</tr>
</thead>
</table>
| Incident Controller (IC)      | • Responsible for overall control of emergency  
                               | • Liaise with external agencies for any additional help  
                               | • Reports to statutory agencies about the emergency  |
| Operations Coordinator (OC)   | • Responsible for control of emergency at site  
                               | • Liaise with fire and safety coordinator in effective control of emergency  |
| Services Coordinator (SC)     | • Responsible for upkeep of equipments and facilities  
                               | • Provides necessary support for identifying and rectifying the faults and bring the systems online |
| Communication Coordinator     | • Ensure proper working of the communication facilities during an emergency  
                               | • Responsible for internal and external communication as instructed  
                               | • Log the sequence of events and actions taken |
| Logistics Coordinator         | • Responsible for providing support for the transportation of men, material, food etc.  
                               | • Liaise with chief coordinator for mobilizing external emergency services |
| Medical Incharge              | • Responsible for treatment of casualties involved in the incident during emergency control operation |
EMERGENCY MANAGEMENT PLAN: OFFSITE
An unexpected emergency on site could also affect people, livestock and property in the area outside the boundary limits depending on the severity of the incident. This calls for the necessity of developing an offsite emergency preparedness program so as to address any such possible eventuality.

The scope of the offsite plan is to protect the people around and evacuate them if necessary. The district collector is responsible for preparation of an offsite disaster management plan and the company shall provide all the required information related to their operations for preparation of the plan.

WARNING SYSTEM
In an off-site management plan, one of the most important prerequisites is a good 'Warning System'. Efficient warning system will save lives, prevent injuries and reduce losses. The Emergency Coordinator - Onsite in consultation with Emergency Coordinator Offsite will decide the appropriate warning system and implement it.

The warning systems are of the following types:

- Disaster Warning (Maximum Credible Loss Scenario) High pitched continuous wailing siren
- Fire/Toxic Release
- Long siren followed by short siren
- All Clear

Depending upon the nature of hazards and the area affected, other methods of warning may be used as follows:

- Out-door warning sirens
- Public address system with police
- ARP sirens
- Mass media
- Door to door visit by Civil/Defense Personnel
- Telephone contact with schools and other organizations/public institutions
• Information to be provided at common gathering places such as village canteens, shops, etc.

SERVICES SUPPORT SYSTEM
A major off-site incident may affect a number of units and the surrounding colonies. Hence in addition to the communication, warning, public information, fire fighting system, following additional service support will be required:

• Health and medical services
• Transportation services
• Security and police
• Media
• Mutual aid services

A telephone directory containing the contact numbers of all these support services should be documented and be part of the offsite disaster management plan.