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Hazards of isopentane and procedures for isopentane handling Berlin Binary Cycle Power Plant

1. Introduction

Berlin Binary Cycle Power Plant uses isopentane as a work fluid. The principal hazard associated to isopentane handily is the high flammability of the fluid.

The present report includes a description of isopentane characteristics, hazards identification, the layout of fire protection systems, procedures concerning isopentane handling and training workshops.

2. Hazards

Due its physical and chemical characteristics, the main hazard associated to isopentane handling is the flammability of the fluid, therefore the more important safety measures includes the appropriate storage and handling of the product far away from ignition sources and open flame, in order to protect the equipment and the plant. Human hazards are minor if staff is not in direct contact with the fluid and avoid drinking it.

In the following items isopentane characteristics are described with more detail. The information is based on safety sheets (MSDS) made by different organizations for the isopentane.

2.1 Product identification

Product Name:	ISOPENTANE
Intended Use:	Working Fluid for Binary Cycle Berlín
Synonyms:	2-Methylbutane Isopentane
Chemical Formula:	C_5H_{12} $(CH_3)_2$-CH-CH_2-CH_3
CAS No.:	78-78-4
UN No.:	1265
Appearance:	Colorless
Physical Form:	Liquid
Odor:	Mild Gasoline-like

2.2 Composition / information on ingredients

Chemical Name:	Isopentane
Chemical Family:	Aliphatic hydrocarbons

Hazchem Warning: 33 Flammable liquid

HAZARDOUS COMPONENTS					
Component / CAS No:	***Percent (%)***	***ACGIH:***	***OSHA:***	***NIOSH:***	***Other:***
Isopentane / 78-78-4	>99	600 ppm TWA	1000 ppm TWA	NE	-

Note: State, local or other agencies or advisory groups may have established more stringent limits. Consult an industrial hygienist or similar professional, or your local agencies, for further information.
1%=10,000 PPM.
NE=Not Established

2.3 Hazards identification

Main Hazards: The main hazard is the flammability of the vapourised Isopentane. As the vapour is heavier than air it can also act as a simple asphyxiant by diluting the concentration of the oxygen in the air to a level below which it can support life.

Chemical Hazards: Under normal conditions of ambient temperature and pressure Isopentane does not pose any chemical hazards.

Biological hazards: The vapour can act as an anaesthetic at concentrations above 1000 ppm.

Potential Health Effects:

Eye: Contact may cause mild eye irritation including stinging, watering, and redness.

Skin: Contact may cause mild skin irritation including redness, and a burning sensation. Prolonged or repeated contact can worsen irritation by causing drying and cracking of the skin leading to dermatitis (inflammation). No information available on skin absorption.

Inhalation (Breathing): Low degree of toxicity by inhalation.

Ingestion (Swallowing): No information available on acute toxicity. ASPIRATION HAZARD - This material can enter lungs during wallowing or vomiting and cause lung inflammation and damage.

Signs and Symptoms: Effects of overexposure may include nausea, vomiting, diarrhea, abdominal pain, transient excitation followed by signs of nervous system depression (e.g., headache, drowsiness, dizziness, loss of coordination, disorientation and fatigue)., irritation of the digestive tract, irritation of the nose and throat.

Cancer: No data available.

Target organs: No data available for this material.

Developmental: No data available for this material.

Other Comments: Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage (sometimes referred to as Solvent or Painters' Syndrome). Intentional misuse by deliberately concentrating and inhaling this material may be harmful or fatal.

Pre-Existing medical: Conditions aggravated by exposure may include skin disorders, respiratory (asthma-like) disorders. Exposure to high concentrations of this material may increase the sensitivity of the heart to certain drugs. Persons with pre-existing heart disorders may be more susceptible to this effect (see Section 4).

2.4 First aid measures

Eye: If irritation or redness develops, move victim away from exposure and into fresh air. Flush eyes with clean water. If symptoms persist, seek medical attention.

Skin: Remove contaminated shoes and clothing and cleanse affected area(s) thoroughly by washing with mild soap and water. If irritation or redness develops and persists, seek medical attention.

Inhalation (Breathing): If respiratory symptoms develop, move victim away from source of exposure and into fresh air. If symptoms persist, seek medical attention. If victim is not breathing, clear airway and immediately begin artificial respiration. If breathing difficulties develop, oxygen should be administered by qualified personnel. Seek immediate medical attention.

Ingestion (Swallowing): Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. If victim is drowsy or unconscious and vomiting, place on the left side with the head down. If possible, do not leave victim unattended and observe closely for adequacy of breathing. Seek medical attention.

2.5 Fire-fighting measures

Flammable Properties:

Flash Point:	<-60°F/<-51°C (Estimate)
OSHA Flammability Class:	Flammable Liquid
NFPA Flammability Class:	1A Flammable Liquid
LEL%:	1.4
UEL%:	7.6
Autoignition Temperature:	800°F / 426°C

Unusual Fire & Explosion Hazards: This material is extremely flammable and can be ignited by heat, sparks, flames, or other sources of ignition (e.g., static electricity, pilot lights, mechanical/electrical equipment, and electronic devices such as cell phones, computers, calculators, and pagers which have not been certified as intrinsically safe). Vapors may travel

	considerable distances to a source of ignition where they can ignite, flash back, or explode. May create vapor/air explosion hazard indoors, in confined spaces, outdoors, or in sewers. Vapors are heavier than air and can accumulate in low areas. If container is not properly cooled, it can rupture in the heat of a fire.
Extinguishing media:	Dry chemical, carbon dioxide, or foam is recommended. Water spray is recommended to cool or protect exposed materials or structures. Carbon dioxide can displace oxygen. Use caution when applying carbon dioxide in confined spaces. Water may be ineffective for extinguishment, unless used under favorable conditions by experienced fire fighters.
Fire Fighting Instructions:	For fires beyond the incipient stage, emergency responders in the immediate hazard area should wear bunker gear. When the potential chemical hazard is unknown, in enclosed or confined spaces, or when explicitly required by DOT, a self contained breathing apparatus should be worn. In addition, wear other appropriate protective equipment as conditions warrant (see Section 8). Isolate immediate hazard area, keep unauthorized personnel out. Move undamaged containers from immediate hazard area if it can be done with minimal risk. Water spray may be useful in minimizing or dispersing vapors and to protect personnel. Cool equipment exposed to fire with water, if it can be done with minimal risk. Avoid spreading burning liquid with water used for cooling purposes.

2.6 Accidental release measures

Personal Precautions	Do not enter any areas where Isopentane has been released unless tests have shown that it is safe to do so.
Environmental precautions	The vapour does not pose a hazard to the environment. An explosive vapour/air mixture could be formed when leaks occur, so eliminate all forms of ignition.
Small spills	Small leaks should be contained by shutting off the source of supply. If unable to stop small leaks the containers should be moved into the open, well away from any source of ignition.
Large spills	Stop the source if it can be done without risk. Eliminate all sources of ignition and static discharges. Restrict access to the area until completion of the clean-up procedure. Post relevant warning signs. Wear adequate protective clothing when working near the source of the leak. Ventilate the area using forced-draught if necessary. Ensure that all equipment is flameproof.

2.7 Handling and storage

Handling:

Open container slowly to relieve any pressure. Bond and ground all equipment when transferring from one vessel to another. Can accumulate static charge by flow or agitation. Can be ignited by static discharge. The use of explosion-proof electrical equipment is recommended and may be required (see appropriate fire codes). Refer to NFPA-704 and/or API RP 2003 for specific bonding/grounding requirements.
Do not enter confined spaces such as tanks or pits without following proper entry procedures such as ASTM D-4276 and 29CFR 1910.146. The use of appropriate respiratory protection is advised when concentrations exceed any established exposure limits (see Sections 2 and 8).

Wash thoroughly after handling. Do not wear contaminated clothing or shoes. Keep contaminated clothing away from sources of ignition such as sparks or open flames. Use good personal hygiene practices.
"Empty" containers retain residue and may be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, or other sources of ignition. They may explode and cause injury or death. "Empty" drums should be completely drained, properly bunged, and promptly shipped to the supplier or a drum reconditioner. All containers should be disposed of in an environmentally safe manner and in accordance with governmental regulations.
Before working on or in tanks which contain or have contained this material, refer to OSHA regulations, ANSI Z49.1, and other references pertaining to cleaning, repairing, welding, or other contemplated operations.

Storage:

Keep container(s) tightly closed. Use and store this material in cool, dry, well-ventilated areas away from heat, direct sunlight, hot metal surfaces, and all sources of ignition. Post area "No Smoking or Open Flame." Store only in approved containers". Keep away from any incompatible material (see Section 10). Protect container(s) against physical damage. Outdoor or detached storage is preferred. Indoor storage should meet OSHA standards and appropriate fire codes.

2.8 Exposure controls / personal protection

Engineering controls: If current ventilation practices are not adequate to maintain airborne concentrations below the established exposure limits (see Section 2), additional engineering controls may be required. Where explosive mixtures may be present, electrical systems safe for such locations must be used.

Personal Protective Equipment (PPE):

Respiratory: A NIOSH certified air purifying respirator with an organic vapor cartridge may be used under conditions where airborne concentrations are expected to exceed exposure limits (see Section 2).
Protection provided by air purifying respirators is limited (see manufacturer's respirator selection guide). Use a NIOSH approved self-contained breathing apparatus (SCBA) or equivalent operated in a pressure demand or other positive pressure mode if there is potential for an uncontrolled release, exposure levels are not known, or any other circumstances where air purifying respirators may not provide adequate protection.
A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use.

Skin: The use of gloves impervious to the specific material handled is advised to prevent skin contact, possible irritation, and skin damage. Depending on conditions of use, apron and/or arm covers may be necessary.

Eye/Face: Approved eye protection to safeguard against potential eye contact, irritation, or injury is recommended. Depending on conditions of use, a face shield may be necessary.

Other Protective Equipment: Eye wash and quick-drench shower facilities should be available in the work area. Thoroughly clean shoes and wash contaminated clothing before reuse. It is recommended that impervious clothing be worn when skin contact is possible.
Suggestions for the use of specific protective materials are based on readily available published data. Users should check with specific manufacturers to confirm the performance of their products.

2.9 Physical and chemical properties

Appearance: Colorless
Physical Form: Liquid
Odor: Mild Gasoline-like

Odor Threshold:	No data
pH:	Not applicable
Vapor Pressure (mm Hg):	20.1 psi (1500 mmHg) @ 100°F (38°C)
Vapor Density (air=1):	2.6
Boiling Point:	82°F / 27.8°C
Solubility in Water:	Negligible
Partition Coefficient (n-octanol/water):	No data
Specific Gravity:	0.62, @ 60ºF (15.6ºC)
Conditions	
Bulk Density:	5.20 lb/gal
Percent Volatile:	100%
Evaporation Rate (nBuAc=1):	>1
Flash Point:	<-60°F/<-51°C
Test Method:	(Estimate)
LEL%:	1.4
UEL%:	7.6
Autoignition Temperature:	800°F / 426°C

2.10 Stability and reactivity

Stability:	Stable under normal ambient and anticipated storage and handling conditions of temperature and pressure. Extremely flammable in liquid and vapor phase. Vapor can cause flash fire.
Conditions to Avoid:	Avoid all possible sources of ignition (see Sections 5 and Sections 7).
Materials to Avoid (Incompatible Materials):	Avoid contact with acids and oxidizers such as chlorine and other halogens, chromates, perchlorates, peroxides and oxygen. .
Hazardous Decomposition Products:	Combustion can yield carbon dioxide, carbon monoxide.
Hazardous Polymerization:	Will not occur.

2.11 Toxicological information

Chronic Data:	No definitive information available on carcinogenicity, mutagenicity, target organ, or developmental toxicity.
Acute Data:	Isopentane - CAS: 78-78-4
Dermal LD50 =	No data available
LC50 =	140,000 ppm (4-hr., Mouse); 150,000 mg/m^3 (2-hr., Mouse)
Oral LD50 =	No data available

2.12 Ecological information

Not evaluated at this time.

2.13 Dis**posal considerations**

Disposal Methods	The disposal of Isopentane should be undertaken only by personnel familiar with the procedures for disposal. Contact the supplier for instructions. In general, should it become necessary to dispose of Isopentane, the best procedure is to burn it in a suitable burning unit available in the plant. This should be done in accordance with the appropriate regulations.
Disposal of packaging	The disposal of containers must only be handled by the gas supplier of the product.

2.14 Transport information

ROAD TRANSPORTATION

UN No.	3295
ERG No.	128
Hazchem warning	33 Flammable liquid

SEA TRANSPORTATION

IMDG	3295
Label Packaging group	Flammable liquid

AIR TRANSPORTATION

ICAO/IATA Code	3295
Class	3
Packaging group	II

Packaging instructions

Cargo	307
Passenger	305

Maximum quantity allowed

Cargo	60 litres
Passenger	5 litres

2.15 Regulatory information

EEC Hazard class	Flammable liquid
Risk phrases	R2 Risk of explosion by shock, friction, fire or other sources of ignition R10 Flammable R18 In use may form flammable explosive vapour-air mixture R34 Liquid may cause burns
Safety phrases	
	S2 Keep out of reach of children S3 Keep in a cool place S9 Keep container in a well-ventilated place S16 Keep away from sources of ignition S36 Wear suitable protective clothing S37 Wear suitable gloves S39 Wear eye / face protection S46 If swallowed, seek medical advice immediately and show this container or label S51 Use only in well-ventilated areas S56 Do not discharge into drains or the environment; dispose to an authorized waste collection point
National Legislation	None

Refer to SABS 0265 for explanation of the above.

2.16 References

SABS 0265 - Labeling of Dangerous Substances

IATA - Dangerous goods regulations 37th Edition 1996

3. Safety measures and procedures for isopentane handling in Berlin Binary Cycle Power Plant

Due the most important hazard in isopentane handling is the flammability of the fluid; Berlin Binary Cycle Power Plant designed a fire protection system, please see the layout in annex A.

In the following sections are described the criteria followed to analyze fire risk in the different equipments and components of the plant in order to minimize risks.

3.1 Isopentane turbine

Fire Hazard

Even though Isopentane is not burned inside the turbine it is a very flammable heat transfer media so that very similar reasoning applies to fire fighting for this kind of turbine as for conventional gas

turbines. Gas and fluid leakage from broken pipes and sealing is the most likely cause of fire on the outside surface of the turbine.

Fire protection

According to NFPA 850, section 5.7.4.1.1, the turbine surface should be protected by a low expansion foam water spray system. This should be a wet pilot line actuation system. Pilot line sprinkler heads shall have opening temperature of 141°C. The wet actuation pilot line shall open a deluge valve which controls flow through open nozzles that spray on the surface of the turbine. The nozzles shall be open nozzles directed at the surface of the turbine. Water density on the surface shall be 12 l/min/m². AFFF low expansion foam shall be mixed at 3% ratio with the water. Foam supply duration shall be 10 minutes.

3.2 Lubrication oil tank

Fire Hazard

This tank contains approximately 4000 kg of lubrication oil at 40 50°C. The most likely cause of fire here is radiant heating from exposure to a fire in the turbine or in the generator.

Removal of oil

The most important thing is to remove the fire load of the oil from the building in case of fire or rupture of the tank or pipes connecting to it. This should be done in a manner similar to that described in NFPA 30. A low bund, 30 cm, shall surround the tank and there shall be drains at lowest point on the floor. The drains shall be connected to a drainpipe system that connects to an oil separator with a volume of at least 5000 l. Capacity of the drainage system shall be equal to the sprinkler system capacity + 600 l/min of oil, at 30 cm head.

Fire protection

To protect the tank from exposure fire from the turbine or the generator open nozzle sprinklers shall be above the tank and on the side that faces the turbine generator set in accordance with NFPA 15. The deluge system that protects the tank shall be the same system that protects the turbine. Wet pilot line actuation sprinklers shall be above the tank with opening temperatures of 141°C.

3.3 Generator

Fire Hazard

The generator can burn due to failure. Usually in a steam turbine-generator set such a failure will destroy the generator so there would be little point in extinguishing that fire. In this case however a fire in the generator can cause fire in the very flammable Isopentane heat transfer fluid so it is very important to extinguish the fire as soon as possible.

Fire protection

The only way to extinguish a fire inside the generator is to pump fire extinguishing gas into the generator. This can be Novec 1230 (Halon substitute) or Carbon dioxide gas. The system shall be

automatic and release of gas shall be controlled by heat sensors. System design shall meet NFPA 2001.

3.4 Isopentane tank

Fire Hazard

As Isopentane is a very flammable liquid with boiling point 27,8°C. The tank contains 50.000 kg of Isopentane at 1 barg pressure. A relief valve opens at 1 barg and a rupture disk opens at 3 barg. The most likely cause of fire in the tank is ignition from external fire or lightning.

Bund and drainage

To avoid Isopentane liquid from spreading around the plant the tank shall be surrounded by a bund big enough to contain 110% of maximum amount of liquid in the tank. The bund shall have drain connected to a common oil separator for the plant. There shall be a manually operated valve on the drainage pipeline, close to the oil separator, in a safe distance from the tank. This valve should be opened daily to drain rain water from the bund. There shall be a pipeline from the relive valve opening at least 3 m above the tank.

Fire barriers

To protect the Isopentane tank from exposure to a fire in other parts of the plant a wall high enough to screen the tank from exposure from such fire shall be on the plant side of the bund. This wall shall have a 120 minutes fire rating.

Fire protection

The tank shall be protected in a similar manner as the oil tank inside the power plant. There shall be a wet pilot line of closed sprinkler heads above the top of the tank. This pilot line opens a wet actuated deluge valve which opens flow to open nozzles which spray a 3% water AFFF foam mixture on the top and sides of the tank. Design density shall be 10 l/min/m². Foam duration shall be 10 minutes. The closed sprinklers in the pilot line shall have a sheet metal above which will direct heat from eventual fire to the sprinklers. Opening temperature shall be 141°C.

3.5 Booster pumps, isopentane pumps, evaporator, recuperator and condenser

Fire Hazard

The most likely cause of fire in the pumps is from a broken pump motor, a leaking seal or broken pipe connection that will spray Isopentane over the motor. Most likely cause of fire in the heat exchanger is from an external fire or from a lightning which would ignite leaking isopentane from a broken seal or a leaking pipe connection on surface of the heat exchanger. Leaking pipe connection could be caused by an earthquake.

Fire protection for pumps

If a pump motor burns it is usually not reusable, but in order to avoid letting a small fire in the motor ignite a fire in the Isopentane fluid a closed sprinkler head shall be above each pump. That

sprinkler head shall be protected from direct sunlight with a sheet metal plate which also serves the purpose of collecting hot air from a fire and lead it to the sprinkler bulb. Opening temperature shall be 141°C. In order to make fire extinguishing more effective 3% AFFF foam is added into the water by a bladder tank ejector.

Fire protection for heat exchangers

The heat exchangers are closed vessels and a fire is not likely to occur on their surface unless liquid isopentane is leaking from broken seals or broken pipe connection. It is considered enough fire protection for these heat exchangers to spray water and 3% AFFF low expansion foam mixture over the top of them from closed sprinkler heads with attached sheet metal plate that directs eventual heat flow towards the sprinkler head. It is very important to locate the sprinklers above the most likely leakage places, pipe and instrument connection, nozzles etc. Water density shall be 10 l/min/m².

3.6 Transformers

Fire Hazard

The most likely cause of fire in the transformers is from a broken transformer that leaks oil to the surface where it ignites due to heat.

Oil drainage system

The most important thing is to remove the fire load, the transformer oil, from the transformers, if they begin to leak. There shall be a fire arrestor grid underneath the transformers and a concrete oil pit under each transformer with drainage grids which shall be connected to drainage pipeline which connect to a common oil separator with capacity at least the amount of oil in the bigger of the two transformers.

Fire barriers

There shall be a 120 minutes fire wall separating the two transformers and screening the building from fire in the transformers.

Fire protection

The transformers shall be protected with open nozzle deluge sprinklers, activated by a closed sprinkler wet actuation line which shall be located above the transformers. In order to reduce the response time of the sprinklers in the actuation line there shall be a sheet metal plate just above the line that directs eventual heat flow towards the sprinkler head. Water with 3% AFFF foam shall be sprayed on the transformer. The design of this system shall be according to NFPA 15, annex A. Water density shall be 10,2 l/min/m² at the surface of each transformer and 6,1 l/min/m² of surrounding horizontal surfaces. As the transformers have different roles and the plant will be inoperable with out either one of them it is considered justifiable to use one system to protect both transformers. The drainage system shall be designed for the flow of fire water plus the amount of oil in the bigger transformer given it will leak out in 10 minutes.

3.7 Cooling tower

Fire Hazard

The most likely cause of fire in the cooling tower is during maintenance stops.

Fire barriers

There shall be a 30 minutes fire barrier separating the two parts of the cooling tower. This is done to reduce water demand of the system as this seems to be the hydraulically most demanding part of the system.

Fire protection

The cooling tower is of the counter flow type and it shall be protected by closed sprinkler head system which will spray water over the drift eliminators and the wooden structure. The sprinkler system shall be designed in accordance with NFPA 13, pages 13-278 13-283 in the 2002 edition. Water density shall be 20 l/min/m². Opening temperature of the sprinkler heads shall be 141°C.

3.8 Cooling water pumps

Fire Hazard

The most likely cause of fire in the pumps is from a broken pump motor. A fire in one of the pumps can cause fire in the cooling tower.

Fire protection for pumps

If a pump motor burns it is usually not reusable, but in order to avoid letting a small fire in the motor ignite a fire in the cooling tower, closed sprinkler heads shall be above each pump. That sprinkler head shall be protected from direct sunlight with a sheet metal plate which also serves the purpose of collecting hot air from an eventual fire and lead it to the sprinkler bulb. Opening temperature shall be 141°C.

3.9 Control room

Fire Hazard

Fire can always occur in computers and electrical apparatus.

Smoke detection system

It is very important that there is a very sensitive smoke detection system in this room. The sensitivity of this system shall be at least one order of magnitude more than of the smoke sensors that control the fire extinguishing system. Sensor shall preferably be inside the most important cabinets.

Fire protection

The Fire extinguishing system for this room should preferably use the Novec 1230 gas but could also use inert gas. The gas shall be released both above and below the suspended floor. When gas is released the ventilation must stop and dampers in ducts that open into the room must close. The gas fire extinguishing system must be designed in accordance to NFPA 2001. If inert gas is used then measures should be taken to relief excess air from the room in order to avoid pressure build up in the room.

3.10 Characteristics of the Fire Protection System

The fire protection control system consists of the following:

- Sensors and control system.
- Electric pump, diesel pump, jockey pump.
- Cooling tower sprinkler system.
- Cooling water pumps sprinklers.
- Heat exchangers foam sprinkler system.
- Booster pumps sprinklers.
- Isopentane tank foam sprinkler system.
- Isopentane circulation pumps sprinklers.
- Lube oil console and turbine foam sprinkler system.
- Generator clean agent suppression system.
- 12.0 MVA transformer foam sprinkler system.
- 2.0 MVA transformer sprinkler system
- Fire Alarm and Automatic Clean Agent Suppression for Control Room.
- Fire hydrants located around the plant.
- Fire department connection.

Two 450 m^3 tanks that are located southeast of the main platform area supply the fire protection system with water in case of activation. The fire mains are kept full and are maintained at approximately 120 psi by a jockey pump. An electric pump provides the necessary pressure to convey 1250 GPM of water through the system and a diesel pump is installed for redundancy in case of electrical failure. They are designed to start automatically, but also have provisions for a manual start. The pumps are located in a shed next to the water tanks, along with a 300 gal fuel tank, and controls.

Pumps

The pumps are automatically started by a pump controller when the pressure in the mains drops.

Fire Pump Controllers

Fire Pump controllers are self contained units with several special features:
- Motor and controller isolating device.
- Automatic start from internal pressure switch.
- Manual electric start by pushbutton on face of controller.
- Manual mechanical start by emergency operating handle on face of controller.
- Minimum running timer to avoid short cycling and motor over-heating on water pressure fluctuations.
- Power “on” light.
- Power failure alarm (indicates power failure on the annunciator on the main control board).

- Provision for testing voltage and current.

In addition, a pump operation alarm is included on the annunciator, on the instrument controller panel.

Jockey Pump Controller

The jockey pump is controlled through an automatic control switch located by the pump. The pump can be placed in continuous operation when the switch is in the “hand” position or intermittent operation through the pressure switch when the switch is in the “auto” position. The motor controller is located in the fire protection pumps shed.

Hydrants

A total of four 4” hydrants are located outdoors in the perimeter of plant area. The hydrants are fed by the underground fire protection water loop mains surrounding the cooling towers and the control room. Every hydrant has a fire hose cabinet containing fire hoses for outdoor use.

Fire Department Connection

A fire department connection is located in front of the building, through which the fire department can supply water to the system.

Main Transformer Sprinkler System

The 12.5 MVA transformer sprinkler system consists of deluge type sprinklers with closed sprinkler wet heads actuation. The system includes an AFFF 3% foam tank with foam supply for 10 minutes and the design density is 0.25 gpm/ft² (10.2 l/min/m2).

Turbine

The turbine is protected by a deluge type sprinkler system with closed sprinkler wet heads actuation. The system includes an AFFF 3% foam tank with foam supply for 10 minutes and the design density is 0.30 gpm/ft² (12 l/min/m2).

Lube Oil Reservoir

The lube oil console is protected by a deluge type sprinkler system with closed sprinkler wet heads actuation. The system includes an AFFF 3% foam tank with foam supply for 10 minutes and the design density is 0.30 gpm/ft² (12 l/min/m2).

Fire Alarm

Smoke detectors are located beneath and above the modular floor of the control room. These detectors report to a fire alarm control panel within the control room. The panel is also connected to the fire protection pumps, waterflow switches, and the heat detectors of the turbine generator. The control room is protected by an automatic fire suppression system using ECARO 25 clean agent with an 8% design concentration and a 10 seconds discharge time. The clean agent will be discharged both above and below the modular floor in the case of system activation.

Cooling Tower

The cooling tower is protected by a wet type closed head sprinkler system with a 200°F activation temperature. The design density of the system is 0.49 gpm/ft2 (20 l/min/m2).

Isopentane Tank

The isopentane tank is protected by a deluge type sprinkler system with closed sprinkler wet heads actuation. The system includes an AFFF 3% foam tank with foam supply for 10 minutes and the design density is 0.25 gpm/ft² (10.2 l/min/m2).

Generator

The generator temperature is monitored by heat detector heads that are connected to the fire alarm control panel. At 300°F, an ECARO 25 clean agent system is automatically activated by the panel. The design clean agent concentration is 8% and the system has a 10 seconds discharge time.

In Appendix A is shown a Lay-out of the fire protection system.

3.11 Procedures for isopentane recharge and emergency response

Durante the operation of Berlin Binary Cycle Power Plant will be necessary to recharge the isopentane into the storage tank. The procedure for this activity includes the safety measures recommended for this work. Please see annex B.

Berlin Binary Cycle Power Plant has emergency procedures in case of firing and evacuation.

4. Training in isopentane handling

Operational staff of Berlin Binary Cycle Power Plant have been trained by Enex in plant operation, isopentane properties and safety requirements for isopentane handling.

Different workshops have been carried out in March 6-8 and March 13-15, 2007. En apéndice F se incluyen los listados del personal de LaGeo participante en las capacitaciones.

The contents of the workshops include:

1 Introduction and Scope
2 Safety Precautions
3 Plant Description
4 Installation
5 Plant Operating Instructions
6 Control System
7 Equipment and Systems Description
8 Maintenance
9 Utilities
10 Safety Requirements
11 Emergencies

12 Warranty
12.1 Performance Guarantee
12.2 Limitation of Liability
13 Appendices
14 Drawings

Por requerimientos contractuales, la firma diseñadora además desarrolló un taller de identificación de riesgos (HAZOP) para la operación de la planta. El taller fue desarrollado en varias etapas; a continuación se detalla el esquema general y propuesta para el desarrollo del HAZOP en el que participó el personal de LaGeo involucrado en la operación de la planta Ciclo Binario Berlín. En apéndice G se incluye el listado de personal participante en el taller HAZOP.

General

All HSE reports must be based upon an analysis of potential hazards of the site in question. We suggest using the HAZOP hazard identification method for the power plant. The HAZOP method was originally developed by Imperial Chemical Industries in England. It is a system based on a question list derived from "guide words". The VGK application is based on the Guidelines for Hazard Evaluation Procedures from Center for Chemical Process Safety which is a part of the American Institute of Chemical Engineers.

This analysis technique requires study performed by an interdisciplinary team headed by a leader and with an assistant scriber. Usually this team consists of representative from the process design group, from the operation, from the mechanical maintenance, from the instrument and control, from the laboratory if any and from the safety team.

Information to be used during HAZOP analysis

- Process Flow Diagrams
- Process and Instrumentation Diagrams
- Plot Plan and Equipment Layout Drawings, if available
- Previous Safety Analysis Reports if any, MSDS, Safety Literature if available
- Operating Procedures for Start-up, Operation and Shut-down
- Major Component Design Specifications

All of this information will be useful for the study, but of these items, however, an accurate P&ID will be most important for the review effort.

Objectives of HAZOP analysis

The objectives are to find the hazards, the possible consequences if those hazards would be materialized (decide who might be harmed and how) and evaluate the risk and decide whether existing precautions are adequate or whether more could be done. These findings are recorded in an action list and assign a responsible person for each item on the list.

Within reasonable time (to be decided upon by La Geo and Enex) the action list will be revised and status of each item checked. At that time all responsible persons must report their findings, whether

they want to use the proposed solution, if they found an alternative solution or if they have found the occurrence of the hazard so unlikely that special actions are not necessary. Such a conclusion then needs reasoning to convince the other members of the HAZOP team that no action is needed.

Agenda for HAZOP analysis

Design Team Hazop

Thursday May 26th the design team will do a preliminary Hazop analysis on the existing P&I drawings. The main emphasis will be on design related issues. Enex is responsible for supplying the group participants.

LaGeo Team Hazop

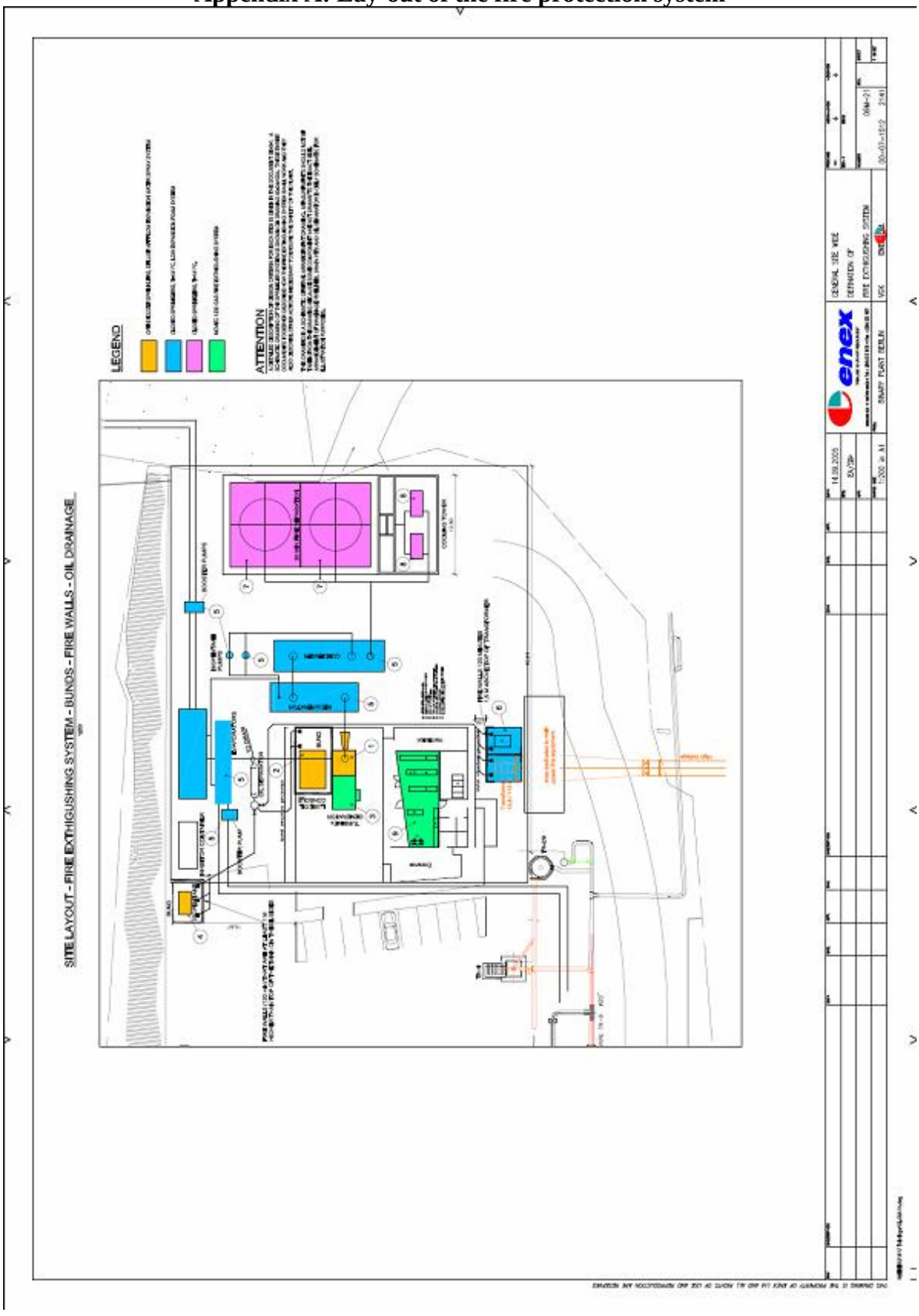
Thursday June 2nd and Friday June 3rd the operating, maintenance and safety teams of El Geo will do a Hazop analysis of the power plant P&I drawings. Saturday June 4th is scheduled as a reserve time until 12 am. El Geo is responsible for supplying the group participants.

This will be a general Hazop analysis but local conditions must be addressed specifically.

Post HAZOP activities

After the latter HAZOP analysis study the leader will make a hazop report to Enex and La Geo about the Hazop findings and the action list. This hazop report can be used as the basis for emergency, health and environmental planning for the power plant.

Appendix A: Lay-out of the fire protection system



Appendix B. Isopentane loading procedures

General

The operator of this power plant should implement, enforce and maintain at all times the loading procedures described in this document.

Safety Procedures

The operator of this power plant should implement enforce and maintain at all times written safety procedures according to the Operation and Maintenance Manual and the Material Safety Data Sheet for isopentane.

Training

The operator of this power plant should train employees in the operating procedures for the isopentane tank and related equipment, by emphasizing hazards and safe practices.

Maintenance

The operator of this power plant should establish maintenance systems for isopentane tank and related equipment, including appropriate inspections, and testing of such equipment to ensure ongoing mechanical integrity.

Preparations before Loading of Isopentane

Before the arrival of isopentane transport tank the Plant Engineer should assign the responsibility of the isopentane loading to a single technically capable person, with sufficient authority to make decisions to maintain necessary safety and mechanical integrity of the plant and equipment.

Logistic

Coordinación de rutas libres y sin riesgos hasta la planta binaria y dentro de ella hasta el tanque. The responsible person should inspect visually and if deemed necessary mechanically the isopentane tank and isopentane transfer hose and the connection fittings. If any of those are found not in working order the responsible person shall take the necessary steps to correct the situation before arrival of the isopentane tank container or at least before starting on the isopentane loading procedure. The responsible person should inspect the fire fighting equipment and test as necessary. Establecer una hora de descarga cuando la temperatura ambiente sea baja.

Procedure before loading of tank

- Check that the trailer carrying the isopentane tank container is securely braked and chock the wheels of the trailer.
- Check visually the tank container for damages and mechanical integrity, including valves and relief valves.
- Check with the shift supervisor to ensure that the cargo is of correct specification and quantity.
- Check that there is adequate space in the receiving tank. If product is already present in the receiving tank check that it is identical to the cargo being discharged.

- Check that the fire fighting equipment is ready or install fire fighting equipment as required upwind of the tank container.
- Make earth connection from the tank container's earthing point to local earth positions.
- Check that the hose connections have the same thread or fitting as the tank container. Ensure that the correct joint rings and gaskets are compatible with the cargo.
- Check that appropriate facilities exist for the draining of the hoses and valves.
- Realizar en el tanque purga total de oxigeno
- Check if the tank is safe for loading, including inert gas blanketing.
- Check the settings of the valves of the receiving tank.
- Verificar que el personal involucrado no use prendas metálicas, teléfono celular, radio de comunicación. And use anti-static cloth.
- Before discharge by pump, ensure that the danger of implosion is avoided by opening of vapor return line if closed system is being used. Ensure that venting is not prevented by any solidified cargo, closed valves or any other obstacles in the vapor return line, airline or relief valves.
- Colocación de barreras físicas y/o avisos de advertencia.
- Make sure no unauthorized persons or unnecessary personnel is present or within safety distance of the isopentane tank container or receiving tank before starting the loading procedure.
- Suspender toda actividad ajena a la descarga del isopentane con restricción total a trabajos que puedan producir chispa o flama.

Loading Procedure

- Remove tank container's bottom outlet blanking cap or flange.
- Remove the receiving tank inlet blanking cap or flange.
- Connect hose to pump and from pump to receiving tank. Ensure the connection is correct and tight.
- Connect the airline connection between tank container and vent tank or receiving tank.
- Open the airline connection to the vent tank or receiving tank.
- Open the tank container's outlet valve and the receiving tank valve.
- Open the valves on both ends of hose.
- Commence discharge.
- Check constantly for leaks in hoses or connections.
- Drain tank container.
- After Loading Procedure
- Drain hose as possible.
- Close outlet valve of tank container and inlet valve on receiving tank.
- (If the tank container has a foot valve and an external valve, make sure to close the foot valve first, then drain hose and finally close the external valve to avoid any remaining isopentane between the foot valve and the external valve.)
- Close airline connection to the vent tank or receiving tank.
- Close valves on both ends of hose.
- Disconnect the hose from the tank container and receiving tank.
- Replace blanking cap or flange on tank container and receiving tank.
- Move hoses with valves and pump to draining facilities.
- Drain hoses, collect the remaining isopentane and discard.
- Move hoses with valves and pump to storage for later use. Check if pressure testing of the hose assembly is due and arrange if necessary.
- Unchock wheels of the trailer and remove the empty tank container from the site.
- Report the discharge to Plant Engineer.

Appendix C. Procedure in case of fire

Objetive
The objective is to have a procedure to response in case of fire in Berlin Binary Cycle Power Plant.

Scope
This procedure is applicable to Berlin Binary Cycle Power Plant and its application is responsible of the Plant General Management.

Definitions
Fire: Fires start when a flammable and/or a combustible material with an adequate supply of oxygen or another oxidizer are subjected to enough heat. No fire can exist without all three elements being in place.

If the fire is not controlled could be spread, causing severe damage to the equipment of the plant and the staff of the plant.

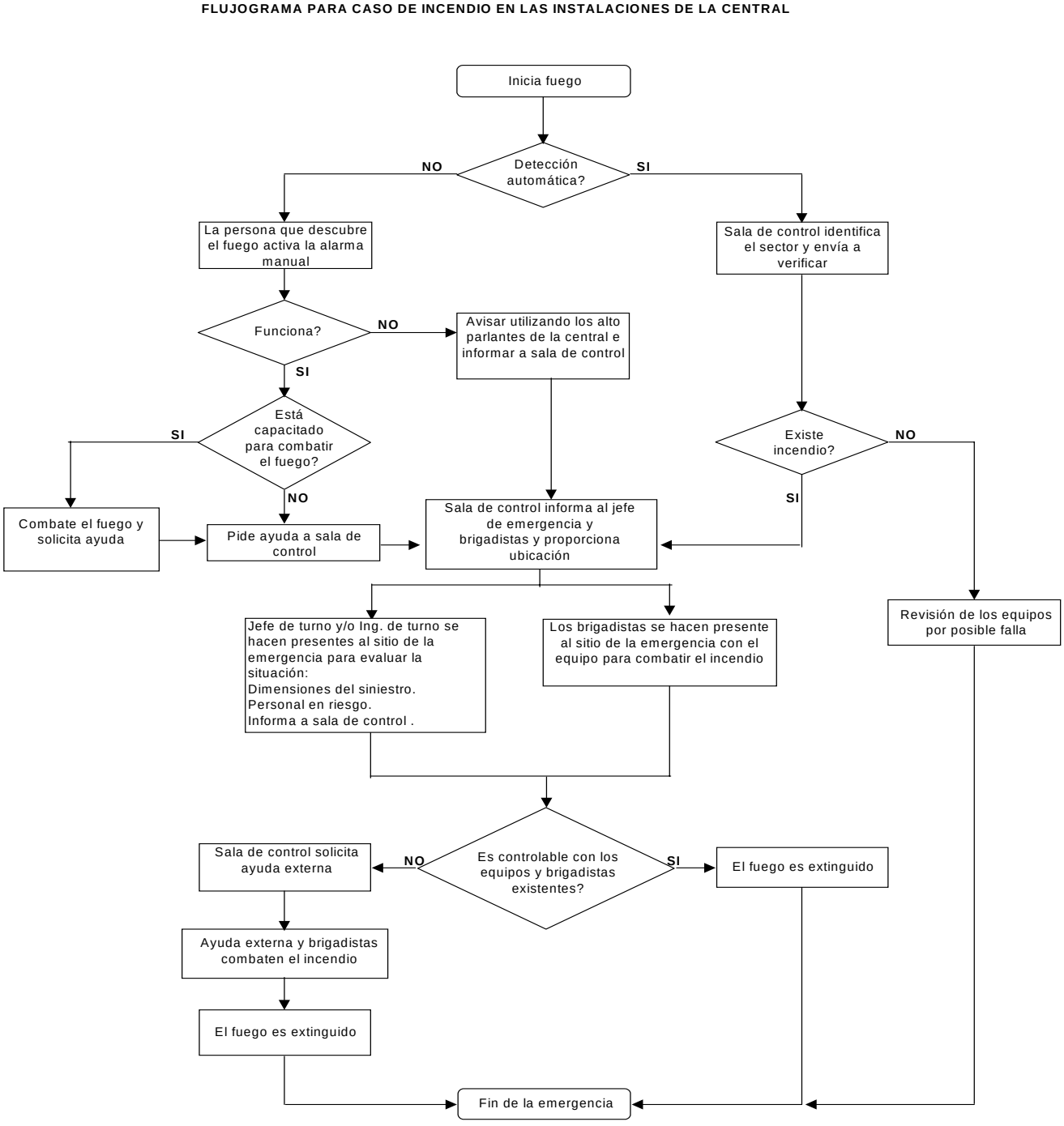
Fireman brigade: It is a team of workers, properly trained and provided of equipment to control fire. They are an organized group to service in case of fire in order to minimize damage resulting from a fire. They response immediately and take the first actions to control and extinguish fire while professional firefighters arrive to the plant.

Process description

No.	Activity	Responsable	Comments
Fire into the plant and surroundings			
1	Notify immediately to the shift manager at the control center in the plant.	The personnel that detects the fire	See annex A
2	Notify the fire to Plant Manager, shift engineer and fireman brigade through a loudspeaker.	Control center of the plant	If the emergency occur during a weekend and holidays when fireman brigade is not working, then shift personnel will in charge to control the emergency supported by security personnel.
3	Arrive to the fire place with the appropriate equipment and assessment the fire conditions.	Fireman brigade	
4	Use fire hoses if the fire is controllable by fireman brigade.	Fireman brigade	
5	Make the appropriate connections in the hoses and FIRE hydrants in order to the hoses length will be enough to attack the FIRE.	Fireman brigade	
6	Call up to the firefighters station requesting help when fire dimensions are uncontrollable.	Control center of the plant or shift engineer	
7	Cold the FIRE are while the firefighters arrive to the plant.	Fireman brigade	
8	Inspect the area where was extinguished the FIRE to avoid re-ignition.	Fireman brigade	
9	Notify shift engineer that FIRE was	Fireman brigade	

	extinguished or controlled.		
10	Recover the FIRE equipment and give the appropriate maintenance.	Fireman brigade	
11	After control the FIRE, fill the sheet in annex B.	Fireman brigade	

Flow chart in case of FIRE in the plant



Annex D. Evacuation procedure

Objective
Plant staff, external staff and visitors know the evacuation procedure to be followed in case of an emergency.

Scope
This procedure must be followed when am emergency occurs.

Plant Manager is responsible of the application of the procedure.

Definitions
Evacuation: It is the set of actions that must follow the persons threated by a circumstance that could damage them. It consists in the movement to more safety places.

Safety area: Safe and outdoors places which are identified by a rectangle with yellow diagonal lines.

Process description

No.	Activity	Responsible	Comments
1	Walk to the safe areas when alarm is listened.	Every person into the plant	Walk to the safe area in calm an in a tidy manner, using the green signals.
2	Use loudspeaker and microphone to communicate with personnel	Evacuation brigade	
3	Wait for the instructions of the evacuation brigade.	Personnel in safe areas	
4	Check a list to assure all personnel has been evacuated	Evacuation brigade	
5	Close the principal door in order to avoid cars and persons get into the plant during the evacuation.	Security staff	
6	Give visitors list to emergency chief in order to check that visitors are in the safe area.	Security staff	
7	Inspect the different plant areas to verify personnel and visitors have been evacuated to the safe areas.	Evacuation brigade	
8	A member of the evacuation brigade must be in each safe area with a first aid kit.	Evacuation brigade	
9	Require support to evacuation brigade through loudspeakers when somebody requires first aid, specifying the location of the victim.	Evacuation brigade	
10	Notify personnel when they can return to their respective work areas.	Control center	
11	When personnel return to their working areas, fill form of annex A.	Chief of evacuation brigade.	

LaGeo	**FORMATO PARA CONTROL DE SIMULACROS SEGURIDAD INDUSTRIAL CENTRAL GEOTERMICA**	Página 2 de 2
		Cambio No: 0000
		Revisión No: 0000
	Ahuachapan ☐ **Berlin** ☐	
	Revisado:	Fecha de Simulacro:

	OBSERVACIONES		
BRIGADA PRIMEROS AUXILIOS			
	SI	NO	NA
Se encuentran los equipos para prestacion de primeros auxilios en buenas condiciones y sin obstaculos?			
La Transmision de la alarma es adecuada (existencia de un herido)			
Existe colaboracion por parte de los brigadistas de primeros auxilios			
Existe coordincion entre los brigadistas de primeros auxilios			
El despliegue de los socorristas es efectivo es efectivo			
Son (es) atendida (s) la (s) victima (s) eficazmente			
Tiempo transcurrido entre el accidente y su descubrimiento.	min.		seg.
Tiempo transcurrido entre el descubrimiento y la solicitud de ayuda.	min.		seg.
Tiempo transcurrido entre la alarma y la atension de la victima.	min.		seg.
Tiempo transcurrido entre el inicio de la atension a la victima y su traslado o mitigacionde daños	min.		seg.
OBSERVACIONES Y RECOMENDACIONES.			
ZONA DE SEGURIDAD			
	SI	NO	NA
Es idonea la zona de seguridad			
Esta delimitada la zona de seguridad			
Loa brigadistas y el personal conocen la zona de seguridad a evacuar correspondiente a su ubicación.			
OBSERVACIONES Y RECOMENDACIONES.			
OBSERVACIONES Y RECOMENDACIONES GENERALES.			

Apéndice E: Emergency response procedure during construction stage

1 PURPOSE

This Project will establish site security measures to prevent unauthorised site access and enforce the Project Health Safety and Environmental issues.

2 APPLICABILITY

All project personnel.

3 AUTHORITY

Project Policy I 1010 Health Safety and Environmental Policy,
Project Manager,
Owner,

4 REFERENCES

Local Laws and Regulations,
The following Management System Procedures:
F 2310 First Aid and Medical Treatment Procedures
F 2320 Fire Prevention and Fire Fighting

5 THE CONTENTS OF EMERGENCY RESPONSE PLAN

The emergency response and management plans shall be developed and updated as the project progresses. The necessity to update the emergency response and management plan is based on the fact that risks are different throughout the project.

All contractors are required to provide resources to conduct risk assessments to identify potential emergency situations as the project progresses. The risk assessments shall be a joint effort of all contractors present at the site at each time and the process will be managed by the Engineer.

The emergency response risk assessments shall at least consider the following situations:

- Health, safety and environment (i.e. accidents, mass casualty incidents, medical evacuation, hazardous materials etc.)
- Security (i.e. workplace violence, bomb threats, acts of terrorism etc.)
- Natural (i.e. earthquake, weather etc.)
- Property damage (i.e. fire, gas explosions, molten metal explosions etc.)

The emergency response and management plan shall address the following:

- Identify resource requirements and enable efficient means of activating them if emergencies occur.

- Specify responsibilities of various responders (both internal and external)
- Describe lines of communication

An emergency management centre will be established and its operational status maintained throughout the construction project.

6 EMERGENCY RESPONSE TEAM AND FACILITIES

An emergency response team will be established and trained on a regular basis. The Emergency Response Team members shall be Qualified First Responders and maintain their training on a regular basis.

A first-aid treatment facility for at least 3-4 persons will be available throughout the project at the construction site. The facility will include first-aid kits, burn-kits, eye-wash stations, fully automatic defibrillator, oxygen masks/bags and an emergency helicopter arrival kit. An area for emergency evacuations with helicopters will designated at the construction site.

The emergency response and management plans will be coordinated with the Owner and / or local emergency plans to avoid overlapping and/or omissions during responses.

An emergency response team will be established for an immediate response to all emergencies on each operating shift. The role of the emergency response team is to provide initial relief until professional rescue organizations arrive at the scene.

The emergency preparedness and management plan will be communicated and discussed regularly to all nearby professional rescue organization. Joint and regular exercises with professional rescue organizations will be requested.

7 EMERGENCY COMMUNICATION

During an emergency it is essential that all managers keep calm at all times and ensure that information which they provide is clear and concise. If an emergency occurs the following communication lines shall be respected.

When professional emergency response organizations arrive at the construction site they will immediately take control of the scene.

DIAL

911

FOR ALL EMERGENCIES

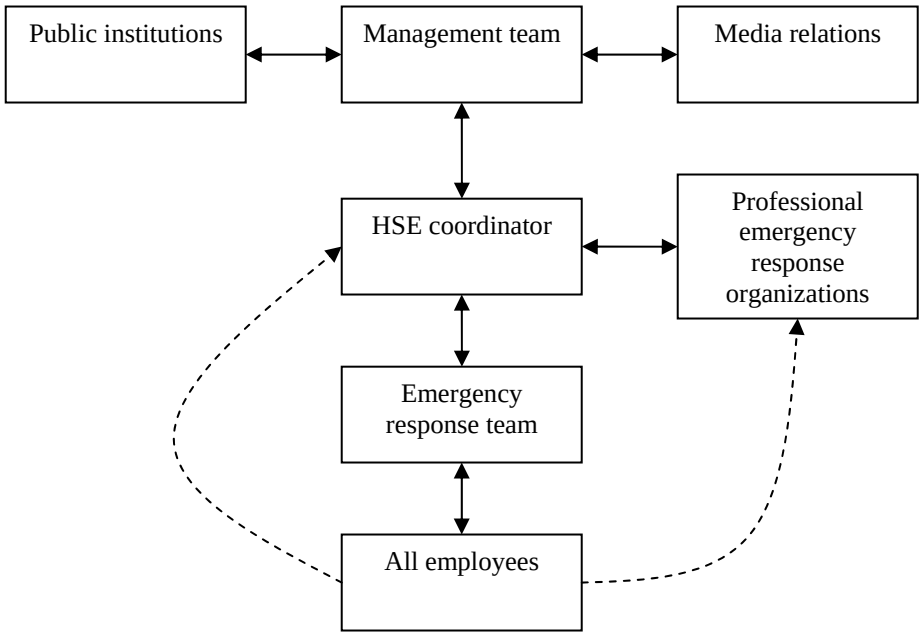
If 911 is slow to respond please call:

For Police (PNC)

PNC Berlin: 2-663-2220
PNC Mercedes Umaña: 2-629-5042

For The Red Cross
Mercedes Umaña: 2-629-5053

For the Fire Department
San Miguel: 2 669 5019
Usulutàn: 2 662 0800 / 2 662 4778



8 EVACUATION PROCEDURE

In special emergencies it might be necessary to evacuate all workers from the construction site.

If such a situation develops each contractor must make sure that all personnel are accounted for.

The highest ranking manager of each contractor at each time is responsible for reporting evacuation information to the HSE Coordinator.

9 FIRE FIGHTING PROCEDURE

The emergency response team is responsible for responding to fires in their incipient stage with portable fire extinguishers.

If the fire grows and can not be controlled the emergency response team shall pull back, take appropriate protection measures in term of loss control and wait for professional fire emergency response organizations.

10 MEDICAL EMERGENCIES

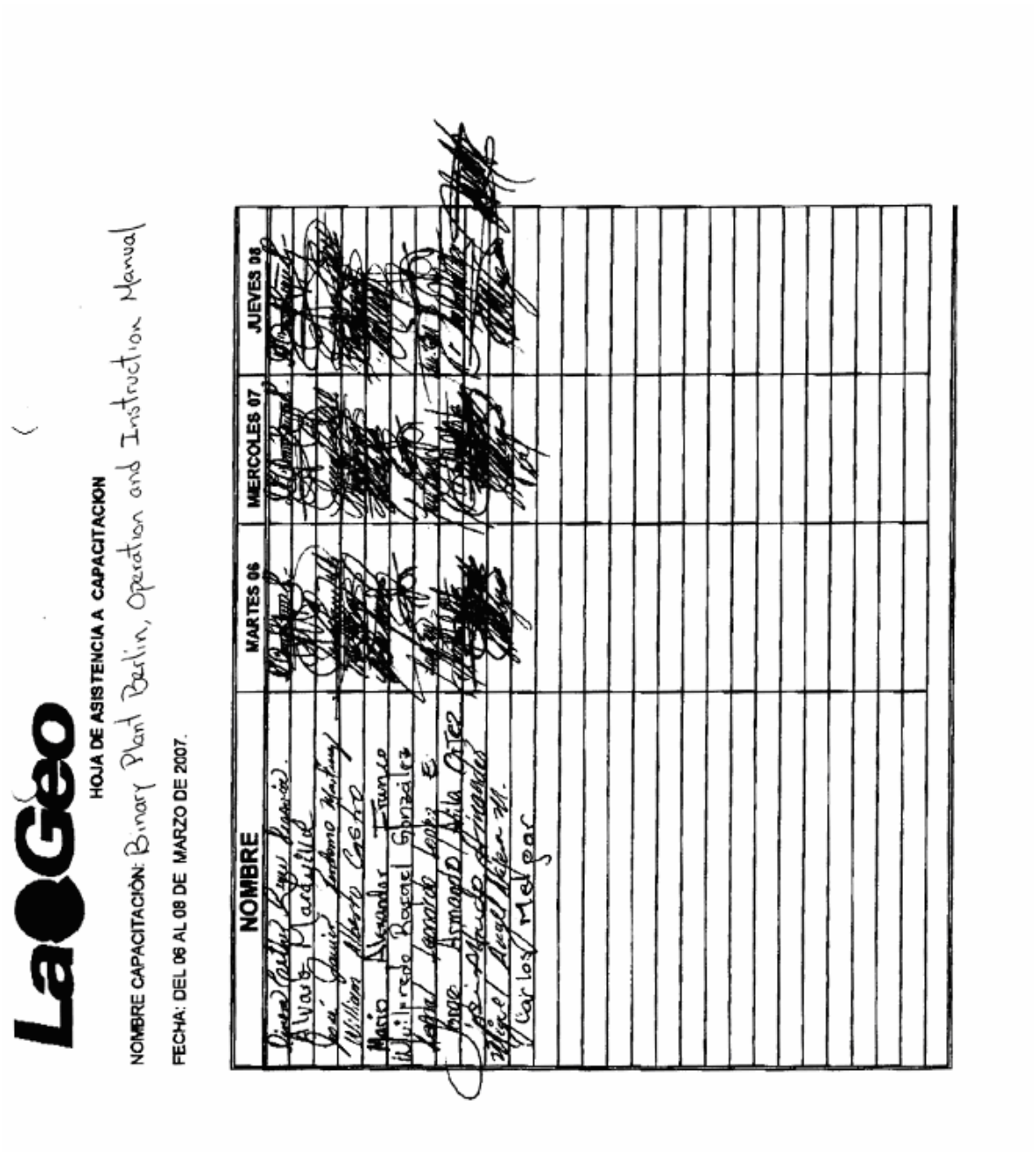
The emergency response team is responsible for responding to medical emergencies to provide first-aid care and manage the scene until professional emergency organizations arrive at the scene.

The emergency response team shall use all the methods available and as they qualify for to ensure the welfare of the victim in question, they shall also provide the victim with as much comfort as obtainable with respect to the victim's situation

11 HAZARDOUS MATERIAL INCIDENTS

The emergency response team is responsible for responding to hazardous material incidents. The role of the team is to identify the hazardous material causing the incident, contain the material and clean the material off persons if possible.

Apéndice F: Staff trained in isopentane handling.



LaGeo

HOJA DE ASISTENCIA A CAPACITACION

NOMBRE CAPACITACIÓN: Binary Plant Berlin, Operation and Instruction Manual

FECHA: DEL 06 AL 08 DE MARZO DE 2007.

NOMBRE	MARTES 06	MIERCOLES 07	JUEVES 08
Oscar Carlos Reyes Duarte.			
Alvaro Mardueño			
Jose Mauricio Contreras Martinez			
William Alberto Castro			
Mario Alexander Tunarro			
Ulises Rosael Gonzalez			
Rafael Leonardo Lobo E.			
Jorge Armando Avila Ortez			
Jose Rodolfo Hernandez			
Miguel Angel Velasquez M.			
Oscar Lopez Melgar			

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HOJA DE ASISTENCIA A CAPACITACION

NOMBRE CAPACITACIÒN: Binary Plant Berlin, Operation and Instruction Manual

FECHA: DEL 13 AL 15 DE MARZO DE 2007.

NOMBRE	MARTES 13	MIERCOLES 14	JUEVES 15
Jesus Antonio Duarte G.			
Luis G. Reiz			
Miguel M.			
Jeremias Antonio Martinez			
Wilmar Armack Campos.			
José Antonio Martínez Dubón			
Pedro Alfaro Castro			
José Edgardo Gutierrez			
Milton Ricardo Gonzalez			
Victor M. Zuleta M.			

Apéndice G: Participantes del taller de identificación de riesgos de operación HAZOP

HAZOP REPORT

Company: **LaGeo** Date: June 2nd and 3rd

Division: **Unidad Generadora de Ciclo Binaro - Berlin** 2005

Leader:	**Employed by:**	**Participants:**	**Employed by:**	**Drawings:**
Teitur Gunnarsson (TG)	VGK	Alexander Bollman	Technica International	KM-000-005.dwg
Secretary:		Ernesto Borja	Technica International	
Gunnar Tryggvason (GT)	Enex	Havier	Technica International	
		Saul Padilla	LaGeo	
		Jose Luis Henriquez	LaGeo	
		Roberto Cortez	LaGeo	
		Victor Zuleta	LaGeo	
		Ana Silvia de Arevalo	LaGeo	
		De Hsuan Wang	LaGeo	
		Roberto Betancourth	LaGeo	
		Kevin Padilla	LaGeo	
		Guido Molina	LaGeo	
		Arnoldo Perez	LaGeo	
		Juan Carlos Lopez	LaGeo	
		Fernando Mayorga	LaGeo	