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Title: SAFETY ANALYSIS REPORT
5 MW(e) RAFT RIVER RESEARCH AND DEVELOPMENT PLANT

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Attachments: EG&G Patent Docs.doc

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Subject EG&G Idaho Geothermal Reports

Dale,

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Thanks ahead for your help,
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Patty Simmons

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CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	
DOCUMENT CONTROL COPY	1-1
1.1 5 MW(e)	1-1
1.2 Safety Assessment Scope	1-3
1.3 Report Purpose, Safety Objectives and Goals	1-4
1.4 Risk Acceptance	1-5
2.0 SUMMARY SAFETY ANALYSIS	2-1
2.1 Site Characteristics Affecting the Safety Analysis	2-1
2.1.1 General Characteristics	2-1
2.1.2 Specific Characteristics	2-2
2.2 Impact of Normal and Abnormal Operations on Safety	2-3
2.2.1 Normal Operations	2-3
2.2.2 Abnormal Operations	2-3
2.3 Accident and Risk Assessment	2-4
2.3.1 Fire-Explosion Risk	2-4
2.3.2 Falls	2-5
2.3.3 Chemical Storage and Handling	2-5
2.3.4 Instrument Failure	2-5
2.3.5 Environmental Risk	2-5
2.3.6 Fire Protection	2-6
2.4 Conclusion	2-7
3.0 PLANT LAYOUT - FACILITIES, EQUIPMENT, AND SYSTEMS	3-1
3.1 System-Operating Environment	3-1
3.1.1 General Site Description, Geography, and Demography	3-1
3.1.2 Seismology	3-2
3.1.3 Hydrology	3-3
3.1.4 Weather	3-4
3.1.5 Summary of Site Characteristic Conditions Affecting Facility Construction and Operating Requirements	3-4

	<u>Page</u>
4.0 FACILITY DESIGN	4-1
4.1 Structural and Mechanical Safety Criteria	4-1
4.1.1 Safety Criteria	4-2
4.2 Facility Layout	4-3
4.3 Process Buildings	4-6
4.3.1 Cooling-Water Pump House	4-7
4.3.2 Office and Control Building	4-9
4.3.3 Fire-Water Pump House	4-11
4.4 Support Systems	4-12
4.4.1 Electrical	4-12
4.4.2 Cathodic Protection	4-14
4.4.3 Lightning Protection	4-15
4.4.4 Heat Tracing	4-17
4.4.5 Maintenance Building Facilities	4-18
4.5 Service and Utility Systems	4-21
4.5.1 Fresh, Potable Water	4-21
4.5.2 Air System	4-22
4.5.3 Telephone and Intercom	4-23
4.5.4 Sewage System	4-24
4.5.5 Heating Systems for Plant Buildings	4-25
4.6 Safety and Health Protection Systems	4-26
4.6.1 Perimeter and Area Lighting	4-26
4.6.2 Emergency Lights, Exits Signs, and Panic Hardware	4-27
4.6.3 First-Aid Facility	4-27
4.6.4 Automobile Engine-Block Heater	4-28
4.6.5 Isobutane-Detector System	4-28
4.7 Fire-Protection Systems	4-30
4.7.1 Fire-Water Supply	4-30
4.7.2 Fire Pumps	4-32
4.7.3 Fire-Water Distribution System	4-33
4.7.4 Automatic-Sprinkler Systems	4-36
4.7.5 Fire Hose Stations and Houses	4-39
4.7.6 Fire Alarms and Instrumentation	4-40
5.0 PROCESS SYSTEMS	5-1

	<u>Page</u>
5.1 Process Description	5-1
5.1.1 Geothermal-Water System	5-2
5.1.2 Nitrogen-Gas System	5-6
5.1.3 The Isobutane System	5-8
5.1.4 The Flare System	5-16
5.1.5 Cooling-Water System	5-18
5.2 Process Chemistry	5-20
5.2.1 Pretreatment of the Make-up	5-21
5.2.2 Corrosion and Scale Prevention and Special Treatments	5-23
5.2.3 Treatment for Removal of Phosphate	5-24
5.2.4 Process Chemistry Analysis	5-25
5.3 Mechanical Process Systems	5-27
5.3.1 Vapor Compressor	5-27
5.3.2 Isobutane-Water Separator (WS-101)	5-28
5.3.3 The Turbine Generator	5-28
5.4 Process Support Systems	5-32
5.4.1 Industrial Water	5-32
5.4.2 Cooling Tower	5-34
5.4.3 Holding and Cooling Ponds	5-36
5.5 Instrumentation and Control Systems	5-37
5.5.1 General	5-37
5.5.2 Data-Processing System	5-39
5.5.3 Field Instruments	5-43
5.5.4 Geothermal-System Instrumentation	5-48
5.5.5 Cooling-Water System	5-53
5.5.6 Isobutane System	5-55
5.5.7 Flare System	5-68
5.5.8 Control Systems	5-71
5.5.9 Summary	5-72
6.0 Waste Confinement and Management	6-1
6.1 Waste Management Criteria	6-1
6.2 Wastes Generated	6-4
6.2.1 Solid Wastes	6-6
6.2.2 Airborne Wastes	6-6
6.2.3 Liquid Wastes	6-6

	<u>Page</u>
6.3 Offgas Treatment and Ventilation	6-7
6.4 Solid-Waste Handling	6-7
6.5 Liquid-Waste Treatment and Disposal	6-7
6.6 Effluent and Environmental Monitoring	6-8
7.0 HAZARDS PROTECTION	7-1
7.1 Policy	7-1
7.2 Design and Operational Considerations	7-2
7.2.1 Desirable Features	7-2
7.2.2 Undersirable Features	7-4
7.3 Identification and Evaluation of Hazards	7-6
7.3.1 Hazards Not Involved	7-6
7.3.2 High Voltage	7-7
7.3.3 Flammable Liquids, Gasses, and Dusts	7-7
7.3.4 Compressed Gasses	7-9
7.3.5 Cryogenic Systems	7-10
7.3.6 High-Temperature and -Pressure Systems	7-10
7.3.7 Inert and Low-Oxygen Atmospheres	7-11
7.3.8 Effects of Chemical Exposure	7-12
7.3.9 High-Noise Levels	7-13
7.3.10 Toxic and Noxious Emissions	7-13
7.3.11 Mechanical and Moving Equipment	7-14
7.3.12 Inadequate Ventilation	7-15
7.3.13 Working at Heights	7-16
7.3.14 Material-Handling Dangers	7-17
7.3.15 Temperature Extremes	7-18
8.0 ACCIDENT SAFETY ANALYSIS	8-1
8.1 Abnormal Operations	8-1
8.1.1 A Geothermal-Water Leak	8-1
8.1.2 A Geothermal-Isobutane Separation Failure	8-2
8.1.3 Isobutane Leak to Environment or Cooling Water	8-2
8.1.4 Isobutane Detectors Not Working	8-3
8.1.5 Air-Compressor Failure or Low Nitrogen	8-3
8.1.6 Flare is Out	8-4
8.1.7 Storage Tank--Low Water	8-4
8.1.8 Fire Main Out of Service--Process Area	8-4
8.1.9 Automatic Valves Malfunction	8-5

	<u>Page</u>
8.2 Potential Accidents	8-5
8.2.1 Fire-Explosion of Flammable Liquids or Gasses	8-5
8.2.2 Turbine-Generator Problems	8-6
8.2.3 Vehicle and Mobile Equipment	8-6
8.2.4 Water System Failures and Water Problems	8-7
8.2.5 General Mechanical Incidents	8-7
8.2.6 Employee Injury or Disease Accident	8-8
8.3 Risk Evaluation	8-8
8.3.1 Isobutane Leaking to Atmosphere	8-8
8.3.2 Pump Failures	8-11
8.3.3 Malfunction of Flow Indicators and Level Indicators	8-11
8.3.4 Vehicle and Equipment	8-11
8.3.5 Fire-System Failures	8-12
8.4 Hazard Elimination	8-12
8.5 Accident Amelioration	8-13
9.0 CONDUCT OF OPERATIONS	9-1
9.1 Organizational Structure	9-1
9.2 Quality Assurance Program	9-1
9.3 Preoperational Testing and Checkout	9-1
9.4 Administrative Procedures for Conducting Operations	9-2
9.5 Training Programs	9-2
9.6 Emergency Planning	9-2
9.7 References	9-3
10.0 TECHNICAL SPECIFICATIONS	10-1
10.1 Introduction	10-1
10.2 Definitions	10-1
10.3 Safety Limits	10-6
10.3.1 Basis	10-7

	<u>Page</u>
10.4 Limiting Control Settings	10-7
10.5 Limiting Conditions for Operations	10-10
10.5.1 General	10-10
10.5.2 Operational Components	10-11
10.5.3 Temperature-Pressure Limits	10-14
10.5.4 Leakage of Isobutane	10-15
10.5.5 Flare System	10-16
10.5.6 Fire-Protection System	10-17
10.6 Surveillance Specifications	10-18
10.6.1 General	10-18
10.6.2 Operational Components	10-19
10.6.3 Temperature-Pressure Limits	10-20
10.6.4 Leakage of Isobutane	10-20
10.6.5 Flare System	10-21
10.6.6 Fire-Protection System	10-21
10.7 Design Features	10-22
10.7.1 Site	10-22
10.7.2 Pressure Boundaries	10-22
10.7.3 Flare System	10-27
10.7.4 Automatic Fire-Protection Systems	10-29
10.7.5 Isobutane Detection	10-30
10.8 Administrative Controls	10-32
10.8.1 Organization	10-32
10.8.2 Operating Personnel	10-35
10.8.3 Review and Audit	10-37
10.8.4 Technical Specification Violation	10-37
10.8.5 Plant-Operating Procedures	10-40
10.8.6 Plant-Operating Records and Reporting	10-41
10.8.7 Technical Specifications Review and Revision	10-42
10.8.8 Facility Modification	10-43
10.8.9 Documentation Requirements for Operation	10-44
10.8.10 Training	10-45
10.8.11 Pressure Vessel Inspection	10-45
10.8.12 Fire Protection Equipment Inspection	10-46
10.8.13 References	10-48

FIGURES

1. Raft River Geothermal Site Location	1-1
2. Plant Layout	4-5

	<u>Page</u>
3. Fire Water Distribution	4-34
4. Control Room Fire Annunciator Panel	4-43
5-1 Data-Handling System Block Diagram	5-40
5-2 Geothermal-Fluid System--Process Area	5-46
5-3 Cooling-Water System	5-47
5-4 Isobutane System	5-57
5-5 Flare System, Simplified Flow Diagram	5-70
9-1 Raft River 5 MW(e) Plant Operations Organization	9-4

TABLES

5.1 Geothermal-System Instrumentation	5-49
5.2 Cooling-Water Instrumentation	5-54
5.3 Isobutane-System Instrumentation	5-61
6.1 Waste-Handling and Disposal Regulations	6-2
6.2 Limits on Water Quality of Injected Fluids	6-5
6.3 Summary of Planned Environmental Monitoring Programs	6-9
9.1 System Tests	9-5
9.2 Integrated Plant Tests	9-6
10.1 5 MW(e) RRPP Operating Modes	10-5
10.2 Limiting-Control Settings	10-8
10.3 Isobutane-System Design Temperatures and Pressures	10-24
10.4 Automatic Fire-Protection Systems	10-26
10.5 AE-4 Isobutane-Detector Locations	10-31
10.6 Organizational Responsibility	10-36

1.0 INTRODUCTION

1.1 5 MW(e) Site and Support Services

The Raft River Geothermal Site is located in Southern Idaho's Raft River Valley, southwest of Malta, Idaho, in Cassia County (see Figure 1). EG&G Idaho, Inc., is the Department of Energy's (DOE) prime contractor for development of the Raft River geothermal field. Contract work has been progressing for several years towards creating a fully integrated utilization of geothermal water.

Developmental progress has resulted in the drilling of seven major DOE wells. Four are producing geothermal water from reservoir temperatures measured to approximately 149°C (approximately 300°F). Closed-in well head pressures range from 69 to 102 kPa (100 to 175 psi). Two wells are scheduled for geothermal cold 60°C (140°F) water reinjection. The prime development effort is for a power plant designed to generate electricity using the heat from the geothermal hot water. The plant is designated as the "5 MW(e) Raft River Research and Development Plant" project.

General site management assigned to EG&G has resulted in planning and development of many parts of the 5 MW program. Support and development activities have included:

- o Engineering design, procurement, and construction support.
- o Fluid supply and injection facilities, their study, and control.
- o Development and installation of transfer piping systems for geothermal water collection and disposal by injection.
- o Heat exchanger fouling tests

Fig. 1 Raft River Geothermal Site Location

- o Geothermal-water compatibility studies
- o Water-chemistry and water-treatment studies
- o Long-term corrosion studies
- o Monitor-well development and background studies.

Continuing support is expected to include:

- o Provision of temporary living quarters
- o Geothermal water supply and injection wells, including data acquisition concerning them and related monitor-well information
- o Water chemistry
- o General and preventive maintenance of buildings facilities and plant area.

1.2 Safety Assessment Scope

This Safety Assessment addresses only the 5 MW(e) Raft River Research and Development Plant, currently under construction. The primary safety concern is failure in system containment. Any rupture will create an unwanted energy release to the environment and associated high risk of injury and damage. If a failure involves hot geothermal fluids, the volume, temperature, pressure, and dissolved solids create both personal and environmental risk. If an incident or failure involves the heat transfer medium (isobutane), there is a serious fire risk. Special consideration is given to these major risks in this assessment.

Other safety concerns of the 5 MW(e) Raft River Research and Development Plant are the electrical hazards, burn hazard from hot equipment,

material handling, Cooling Tower and ponds, vehicle operation, water-treatment chemicals, and general industrial safety of operation and maintenance. Risk associated with other government agencies and subcontractors are considered residual risks. Use of the facility for education and training of transient personnel will impose additional risk that must be subject to the plant operator's control.

1.3 Report Purpose - Safety Objectives and Goals

The purpose of this report is to identify and assess the accident risks of operating the 5 MW(e) Raft River Research and Development Power Plant. The safety objective is to operate the plant in a safe manner, develop ways to reduce risk, prevent fires, and keep personal injury and damages as low as possible. The operational safety goals are:

- o Prevent major fires, explosives, and other controllable catastrophies.
- o Avoid a personnel fatality, or permanent total injury disability.
- o Keep property damage loss to less than 1¢/\$100 valuation per year.
- o Keep the Lost Work Day (OSHA) injury rate less than one (one case per 100 employee/year).
- o Keep the Lost Work Day (OSHA) days lost incidence rate less than 20 (10 days per 100 employee/year).
- o Prevent any major release of geothermal brine or other undesirable agents outside established containment boundaries.
- o Prevent any major release of isobutane except as planned through the flare.

1.4 Risk Acceptance

Management has reviewed the recognized risks associated with operation of the 5 MW(e) Raft River Research and Development Plant and accepts the residual risks as consistent with established safety goals (Chapter 1, Section 1.3). Accident prevention is an active management function used to control risk or reduce the risk to an acceptable level by imposing physical or management controls.

2.0 SUMMARY SAFETY ANALYSIS

In the following chapters of this report, factors affecting operations have been evaluated to determine risk. The report follows the format, suggested by the Department of Energy, which minimizes the chance that an important feature or system involving risk has been overlooked. This summary briefly highlights the main points that are made in the report.

At many places where problems have been identified, action has been taken to ameliorate the risk by correcting deficiencies, preparing safe procedures, creating necessary operating plans, requiring personal protection equipment, etc. Some design features built into the plant are marginal from a safety viewpoint. Those features that cannot be changed are being given special attention in procedures and will be improved, if possible, during any subsequent plant upgrade modification.

2.1 Site Characteristics Affecting the Safety Analysis

2.1.1 General Characteristics

The location of the 5 MW(e) Raft River Research and Development Plant is in a remote, nonindustrial, rural area. The nearest medical doctors and hospital are 83.7 km (52 mi) distant. This location is subject to windy, dusty, summer conditions and snowy, windy, winter weather with occasional temperature lows to -33°C (-27°F). This creates a recurring problem with freeze-up in water systems. There is a very limited supply of fresh potable water. The geothermal fluids have high levels of dissolved solids and cannot be discharged to the environment or surface streams. Injection of the used geothermal water must be to a depth below the agricultural irrigation water wells of the Raft River valley.

Any severe rain or winter warm weather causing fast snow melting may introduce safety problems from flash flooding.

2.1.2 Specific Characteristics

The working fluid being used is highly flammable isobutane. (See Chapter 5, Section 5.1.3 for Technical Specifications.) This required the process area to be designated "hazardous" and all equipment to comply with National Electric Code, Class 1, Group D, Division 1 or 2 requirements. Isobutane, due to its low vapor pressure will produce a cryogenic-type freezing effect upon contact with human skin. Safe disposal for controlled isobutane release is accomplished by a flare system which handles emergency shutdown and major relief valve discharges.

Although there are some good working platforms that accommodate safe operator access to manually operated equipment, supplemental facilities have been provided to assure complete operational access. Performance of preventive maintenance will require special rigging to some equipment.

The support facilities provide buried supply and injection geothermal piping and a pipeline through the 5 MW(e) plant. The primary runs of this pipe are made of cement-asbestos which has a higher failure rate than steel pipe. Breaks in or near the process area create burn and scald risks. A supply- or injection-pipe failure will be controlled promptly by plant and supply system shutdown.

A plant startup in cold weather has a high probability that there could be a freeze-up in some water-filled equipment. The risk is made acceptable by electrical heat tracing.

2.2 Impact of Normal and Abnormal Operations on Safety

2.2.1 Normal Operations

Proper functioning of the systems and facilities when the pressure-temperature balances are established are relatively risk free. The instrumentation provides information, signals and alarms that permit continuing safe control. The instrumentation has an emergency power source that is also backed by a battery-power supply.

Any exposed metal of the hot, geothermal-water piping or pumps, the isobutane system, the turbine, or the T-G lubricating system can cause thermal burns if contacted.

Waste vapor losses from the cooling tower include water-treatment chemicals. The water treatment blowdown waste sludge is a chemical-laden waste that requires special waste handling. Daily accumulations of solid waste occur and require disposal.

2.2.2 Abnormal Operations

The foremost abnormal situation is getting the plant started. This involves a variety of irregular and many manual functions. There is a manual release of isobutane vapors. Most of the subsystems must operate correctly. The required procedures are detailed and demand disciplined compliance to avoid an accident. The impact is that the risks are high for field operators being injured and from an isobutane fire. The risk is greatest during the final stages of startup, when the isobutane balance and purity are being established.

Routine operation of the plant with abnormalities introduces risk, even though it may be hidden. In Chapter 8, nine typical abnormal operations are discussed. In four, plant shutdown is required. In five, continuing operations are suggested only if special management approval is obtained. The instrumentation of the 5 MW(e) plant provides sufficient information to avoid abnormal operations of many types; also, it will reveal when there is an abnormality and risk is becoming unacceptable. The impact of abnormal operation in most conceivable situations is that major upset with damage should be expected unless the abnormality is corrected or the plant is shut down.

2.3 Accident and Risk Assessment

The major risk accidents that are identifiable, although simply stated, usually involve two or more failure events before a serious accident occurs. For example; an isobutane fire requires a leak from some failure and a breakdown of the control system that prevents an ignition source. Application of this premise is behind the risk assessment summary given here.

2.3.1 Fire-Explosion Risk

Fire-explosion is probably the most severe plant accident risk potential. Details are in Chapter 8, Sections 8.2.1 and 8.3.1. A large leak of isobutane, when mixed with air into the explosive range before ignition, creates a significant explosion. The resulting damage may disable the fire-suppression system. In the process area, explosive forces may open more pipes or vessels that add additional fuel. In the Cooling Tower, isobutane transported by the cooling-water pipe from a failure in the condenser creates the same explosive risk with high potential for damage to the tower.

2.3.2 Falls

A high injury risk exists from the potential of falls in the process area. Special effort is being made to overcome inadequacies for access to valves, and to high locations to accommodate preventive maintenance. These efforts, with employee training, bring a high potential into acceptable risk.

2.3.3 Chemical Storage and Handling

The facilities and equipment were not provided to completely automate handling of chemicals. Procedures and employee training can minimize, but not eliminate, the potential of this injury risk.

2.3.4 Instrument Failure

As discussed in Chapter 5, Section 5.5, almost all possibilities for accident risk from instrument failures are guarded against by multiple instruments, redundancy, alarms, etc. Some circumstances, such as an oxygen analyzer failing concurrently with the inert-gas generator, could possibly result in air mixing with isobutane vapors above the liquid seal of the knock-out drum and piping to the flare, thus creating an explosion risk in this pipe and vessel.

2.3.5 Environmental Risk

Chapter 6 provides details and shows that no present regulations are expected to be violated. The wastes generated and the handling plans for them, at this time, create no unacceptable risk. Final determination of cooling-water make-up chemicals are based on phosphates for corrosion control. Two risk potentials that receive careful study are: a) the chemicals

carried away from the cooling tower in the vapor plume, and b) the chemicals in the sludge from the cooling-water treatment blowdown.

2.3.6 Fire Protection

Fire is of great concern in this plant. Meeting the insurance industry standard of "Preferred Risk" which is the DOE requirement, has been the fire-protection goal at the 5 MW(e) plant. Buildings are of noncombustible construction and have automatic sprinkler fire suppression systems. The Cooling Tower has an interior that is combustible, but it is protected with an air-pilot detection, open-head deluge system. The main electrical substation oil-filled transformer also has an air-pilot detection, open-head deluge system. The process area piping and vessels have metal covered fiberglass insulation secured in place with metal banding. The area meets the National Electrical Code, "Hazardous Area" criteria and is protected by an air-pilot detection, open-head deluge water spray system that is divided into five zones. They provide coverage over the equipment, structures, vessels, turbine-generator, piping and storage area.

The control room and computer installation of the Office-Control Building has special fire-separation walls, with UL-rated doors and interior window protection. Halon 1301 fire suppression is provided for under-the-floor cable protection, and the room has automatic sprinklers as part of the building system.

Water supply is limited to one storage tank of 1137 m³ (300,000 gal) capacity with a major part reserved for fire protection. Adequate fire water pumping capacity is assured by an electrical driven pump with a reserve diesel driven pump as

backup. Fire water is distributed by underground piping with a loop to the process area. Fire hydrants and hose houses are strategically located. Critical information on fire systems function and malfunction is relayed to the control room fire annunciator panel, see Figure 4. No unacceptable risk or oversight are believed to exist. Plant Operations has provided hand fire extinguishers.

2.4 Conclusions

The 5 MW(e) Raft River Research and Development Plant has an outdoor process area subject to the effects of summer and winter weather. It uses a highly combustible working fluid, isobutane, which is both heated and pressurized. Available fresh water is very limited and conversion of geothermal water to acceptable plant cooling water requires chemical treatment. Cooling Tower evaporation losses concentrate dissolved chemicals (solids) in the cooling water, thus requiring additional chemical treatment and make-up water.

The alarm and signal system, automatic and remote operations, computerized data, and record collection permit good control of the plant. Startup and regular shutdowns involve many manual activities in the process areas. The variety of evolutions, valves to be operated, their location and sequence, and inherent plant hazards require disciplined, well-trained, operating personnel. Some duties involve risk; however, their identification, designed-in safety devices, redundant operating and safety controls, and proceduralized operating guides have reduced risk to acceptable levels. This plant can be operated within the safety parameters given in this report.

3.0 PLANT LAYOUT--FACILITIES, EQUIPMENT, AND SYSTEMS

3.1 System-Operating Environment

The 5 MW(e) Raft River Research and Development Plant has suitable, insulated buildings that house the offices-control room, maintenance facilities, electrical switchgear, and pump houses for cooling- and fire-water pumps. The fire-water piping, sewer lines, inplant electrical distribution systems, isobutane storage, propane storage, geothermal-water supply and discharge pipelines are buried. Other operating piping, the electrical substation, and process equipment are above ground on concrete and structural steel supports. Details, characteristics, identifiable risks, and their controls are evaluated below.

3.1.1 General Site Description, Geography, and Demography

The 5 MW(e) Raft River Research and Development Plant is located in the SW 1/4 Section 23, Range 26E, Township 15S (Boise Meridian). The "Narrows" road from U.S. Highway 81 proceeds westward to Almo. At about 9 km (5-1/2 mi.) west of U.S. Highway 81, the "Narrows" road, passes about 300 metres north of the plant site. The Raft River valley at the plant site is about 16.1 km (10 mi.) north of the Utah-Idaho border. The valley is floored by alluvial fans that extend toward the Raft River from the Jim Sage Range on the north and the Raft River Mountains on the south. To the west of the plains, the valley narrows to a width less than one-half mile. To the east and north, it broadens to a width of over 10 miles as the Raft River approaches its confluence with the Snake River. The nearest population centers are Malta (population 196), 24.1 km (15 mi.) to the north, and Burley (population 8800), 80.5 km (50 mi.) to the northwest.

3.1.2 Seismology

As inferred from geologic considerations, it is reasonable to expect seismic activity in the Raft River Valley. The area is classified in the Uniform Building Code as Seismic Risk Zone 3. A recent reclassification of seismic risk, which takes into account frequency of occurrence, places the Raft River area in a maximum peak acceleration zone of 0.10 g (5.8 M) (Ref: Civil Engineering, December 1976 - from California Applied Technology Council). Historically, three events have been recorded which occurred within 48 km (30 mi.) of the area. None of the magnitudes exceeded 5.4 (Richter). No earthquake epicenter has been recorded within a 29-km (18-mi.) radius of the development.

In 1974, a 90-day microseismic survey of the area recorded only seven events with s-p times of less than 2.0 seconds, which corresponds to epicentral distances of less than 18.3 km (11 mi.). The magnitudes of those events ranged from -0.4 to +0.2 (Richter). A single-event count yields a rate of 0.2 events per day with magnitudes greater than 0.0. This has a 95% confidence level of being within a factor of two of the ten-year seismicity rate for the area. Both the scarcity and magnitude of events indicate that the valley is more closely related to the aseismic Snake River Plain than to the seismically active Basin and Range and Intermountain Belts east and south of the valley (Ref: Kuamoto, L. H., "Microseismicity Investigation of the Raft River Valley," Colorado School of Mines, under DOE Contract, 1976.)

Geologically young fault systems cross the valley near the geothermal wells. The most recent movement of those faults was several thousand years ago (Ref: P. L. Williams, et. al., "Geology and Geophysics of the Southern Raft River Valley Geothermal Area, Idaho, USA," USGS).

Microseismic records indicate that all faults are presently dormant. Any potential movement along the faults would be indicated years or months in advance by an increase in microseismic activity. The most probable movement, should any occur, would be along the Bridge fault that runs northwest of the 5 MW(e) Raft River Research and Development Plant and intersects RRGE-1 well at depths of 1120 m (3700 ft) to 1372 m (4500 ft). The dip of the fault in this location is about 70 degrees, and any movement would probably be a normal movement in that direction.

The Raft River Geothermal area is monitored by three remote seismic recorders. Each of these units has its own battery-powered transmitter, protected by burial in underground vaults. The recordings are transmitted directly to receivers at the University of Utah, in Salt Lake City.

3.1.3 Hydrology

The Raft River is a major drainage-basin tributary to the Snake River. The basin is closed--all water comes from precipitation that falls within the basin. In its natural condition, the Raft River maintained flow throughout its reach. At present, the flow disappears in the summer near the geothermal area due to irrigation diversions. Because of extreme variations in precipitation and runoff from year to year, a "normal" flood is not easily characterized. There is no annual spring flooding along either the Raft River or its tributaries. Floods in the valley areas are generally a result of a rapid, early thaw. Damage from floods, if any occurs, is not because the floods themselves are severe, but because of man-made development on the floodplain. The historic peak flow of the Raft River near the 5 MW(e) Raft River Research and Development Plant was $58.4 \text{ m}^3/\text{s}$ (2060 cfs), as compared to a normal peak annual flow

of $30.9 \text{ m}^3/\text{s}$ (1090 cfs). Based on streamflow records, the USGS has identified flood-prone areas (100 year flood) along the Raft River. The closest point of the 5 MW(e) plant area is 228.6 m (750 ft) from the nearest flood-prone area; the area boundary there is approximately 3.05 m (10 ft) above the flood range.

3.1.4 Weather

The Raft River Valley is classified as a cold desert steppe where evaporation exceeds precipitation. The mountain ranges which bound the valley affect the wind, precipitation, and temperature patterns. Temperatures average 7.4°C (45°F) and range from -33°C (-27.4°F) to 40°C (104°F) during the period of record. Annual precipitation averages 272 mm (10.6 inches) with over half falling in May, June, and July. The predominant wind direction at RRGE-2 well, where the wind instruments are located, is from the southwest. Wind speeds average 14.5 km/h (9 mph), and the average maximum 24-hour wind speed is 25.7 km/h (16 mph). Winds gusting to 80.5 km/h (50 mph) occur several times during the year and can damage poorly anchored structures. Only limited data are available on other weather conditions in the valley. Thunderstorms occur about 7% of the year, usually between April and September. Between 1950 and 1962, three tornados were sighted in a $906.5 \times 10^7 \text{ m}^3$ (3500 mi.^2) area around the Raft River Valley.

3.1.5 Summary of Site Characteristic Conditions Affecting Facility Construction and Operating Requirements

In descending order of importance, the temperature extremes, seismic risk, and wind are believed to exert the most significant conditions affecting construction and operating requirements. Most risks, other than those caused by plant

operation, are either directly or indirectly associated with the above three conditions.

Temperature extremes create freezing, snow, and maintenance problems during winter. Jointly with the wind, cold temperatures and blowing snow create problems in outdoor travel, visibility, and maintenance. During the summer, the area vegetation is prematurely dried causing a potential external source of fire that may be accelerated by high winds. Dust resulting jointly from the temperature and wind must be dealt with during a major part of each year. Many special features have been incorporated in the plant design to minimize adversities created by temperature extremes and wind. These are discussed in subsequent parts of this document.

The seismic risk is recognized and considered appropriately in the design of all facilities. UBC Zone 3 criteria are used.

4.0 FACILITY DESIGN

The specifications for the 5 MW(e) Thermal Loop Facility provide comprehensive direction on required codes, standards, and regulations. No attempt is made to repeat these in this document. However, the intent here is to identify variations, deviations, and interrelationships of components that impact safety. When items involving hazards and potential risk are identified, these will be evaluated and discussed.

4.1 Structural and Mechanical Safety Criteria

The plant site environment has natural conditions that require the following basic standards:

- o Wind loading 1430 Pa (30 psf), building walls and roof, roof uplift, and lift on roof overhang.
- o Thermal cycling from 239.7 K (-30°F) to 322 K (+120°F).
- o Seismic, UBC Zone 3, maximum peak acceleration of 0.10 gravity
- o Burial depth of pipes with contents subject to freezing is 1.22 m (4 ft) minimum to top of the pipe.

Insulation R value and K value are adapted to the thermal weather cycles and operating component(s) involved. Insulation covering is also adapted to the service. Spray polyurethane is limited primarily to underground pipe, where required. Above-ground insulation is fiberglass with coverings suitable for the application and fire-hazard rating of flame spread less than 25 and fuel contribution less than 50.

4.1.1 Safety Criteria

In addition to that listed above, are items that are not related to natural site environmental conditions, but necessary for safety, .

- (1) Type X Gypsum drywall approximately 16-mm (5/8-in.) thick, conforming to ANSI/ASTM C36, is installed with shouldered flat-head screws. All studs are of galvanized metal, thus creating a highly fire-resistant interior for buildings, and maintaining low fuel and smoke contribution.
- (2) Pipe sleeves are used for passage of pipe through building fire separation walls. The annular space of these passages is caulked with asbestos rope. Penetrations through exterior walls are made weather tight by a 13-mm (1/2-inch) layer of mastic.
- (3) Compressed air is distributed in standard weight galvanized-steel pipe. Distribution is made at 965.2 kPa (140 psi) with pressure regulating valves to adjust pressure for operational and safety purposes. An inherent risk from misuse or improper regulator adjustments shall be controlled by management.
- (4) Piping and valve design specifications are given in the specifications Section P3. These data cover a review of valves in piping Groups I through VI. The valves are separated by types and the constructions, individual valve numbers, pipe size, design pressure, and design temperatures are given. Special comprehensive specifications are given on each pressure-relief valve.

4.2 Facility Layout

The siting of the 5 MW(e) facility represents an optimum choice. Consideration was given to both short- and long-term factors: the Bureau of Land Management withdrawal availability; present producing wells; site expansion potential and optimum use of the hot water resource. The designed layout, as shown in Figure 2, Page 4.5, provides for effective utilization with acceptance of certain risks. Evaluation shows that:

- o The hot-water supply is from producing wells Nos. 1, 2, and 3, located to the east, northeast and southeast respectively from the plant. Well No. 5 is a standby source located southwest of the plant. The supply pipe gathering system is buried. Also, the elevation of the plant results in natural flow, down the valley, toward injection wells Nos. 6 and 7, thus aiding movement of cooled water that must be pumped the relatively long distance to the injection wells.
- o The layout of operating vessels in the operating area minimizes process pipe runs, and temperature losses, and improves pump-power efficiency. These factors contribute to cost reduction and overall plant efficiency. The ground in the process area is covered with cement, supplemented with asphalt and slopes downward to the east and south. This will help remove any spill occurring in the operating area.
- o Both spillage and runoff from the deluge-sprinkler system is away from other plant facilities, except the flare-pit dike. Any large runoff of geothermal brine or isobutane will impact the environment in the runoff area below the plant. A large brine spill could, theoretically, reach the Raft River and cause downstream pollution. Control will be achieved through plant shutdown, cutoff of geothermal brine from the supply wells, or by diversion to lined holding ponds. Release of pressurized isobutane will promptly vaporize or be sent to the flare. With these measures and by use

of the heavy equipment available, spills of any practical magnitude can be controlled and contained before they reach the Raft River. Provisions for this type of action is a part of the 5 MW(e) Emergency Action Plan.

- o The Cooling Tower is on a plant area high ground level, and downwind movement of water vapor by the prevailing southwest wind will minimize vapor flow over the control room and process areas. However, moisture and overspray will accumulate and may be a problem at the adjacent electrical substation. During freezing weather, ice buildup on the electrical equipment may require a plant shutdown.
- o The cooling ponds are located south of the process area. This places them both downhill from operations control and crosswind to the prevailing wind. Therefore, effects of steam and water vapor rising from the ponds will have minimum drift over the operating equipment or control areas.
- o The flare is at the extreme southeast and downhill corner of the facility. It is a maximum inplant distance from the office-control area and at a location considered safe to and from other Raft River operating facilities and private property.
- o Entrance and egress for the plant are controlled by use of the main entrance gate and a gate in the east fence. During operations when vehicles and unauthorized personnel entry into the operating area are to be controlled, the east gate is secured. All personnel entering must pass Security and the Office-Control Building before going to the operating area. When equipment and vehicles for maintenance, or supply trucks for isobutane, nitrogen, propane, etc., are needed in the operating area, the east gate will permit direct access. Anyone in the cooling-pond area could be confined by a major fire in the operating equipment. The egress would require them to climb the fence, or pass near the fire area or flare pit.

Figure 2 Plant Layout

- o Risk is inherent to the concentration of vessels and piping in the operating area. The isobutane-storage tanks and propane tanks are buried; other piping and vessels are above ground. The upper support structures, above concrete footings, are exposed structural steel. Control of damage from fire risk is dependent upon the relief-valve system and the fire-water deluge system (see 4.6.2). A major isobutane spill with delayed ignition may cause severe damage from the vapor-cloud explosion. A boiling liquid evaporating vapor explosion (BLEVE) occurring from a smaller fire overheating a vessel to failure may cause more equipment failure also. The severity is dependent upon the spill volume and degree of vapor air mixing before ignition (see Chapter 8 Section 8.3.1).

- o A large isobutane leak that ignites promptly and causes a sustained fire should be confined by the deluge-sprinkler system. However, if the fire impingement on process vessels or piping causes pressure build-up, the relief-valve system is designed to accept the vapor discharge and conduct it to the flare where controlled burning will occur.

- o In the event of a BLEVE that damages the deluge-system piping, a major water demand without effective fire control could develop. The fire could make the deluge-riser buildings and deluge-control valves in the operating area inaccessible. The emergency fire fighting tactical plans incorporates "retrench" defensive fire fighting to utilize equipment and supplies effectively.

4.3 Process Buildings

The basic design used is "noncombustible" as defined in NFPA 220 and is not designated as protected, e.g., structural components do not have 2-hour fire resistance rating nor roof supports of 1-hour fire resistance. They utilize a concrete-slab floor, metal studs, interior fiberglass wall insulation, a metal roof covered with external

insulation and covering meeting Factory Mutual Class I. Each building is equipped with an electrical grounding grid. Special safety considerations of specific buildings follow.

4.3.1 Cooling-Water Pump House

An interior nonbearing fire partition separates the west (plant direction) end electrical switchgear room and chemical storage from the rest of the building, and from each other. A residual risk is created at the roof where the supporting purlins extend beyond the fire partition to the main roof beam that is approximately 2 m (6 ft.) beyond the partition. However, the building is provided with a wet pipe fire sprinkler system (ordinary hazard Group 1 occupancy) which reduces risk to reasonably acceptable levels.

The major part of the building is equipped with an overhead traveling crane of 4540 kg (5 ton) capacity. This facilitates adequate safe handling of heavy equipment during maintenance.

In the east corner of the main building area, there is an "under-the-floor" pump basin where water from the Cooling-Tower basin collects to provide suction for cooling-water pumps P901 and P902. There is no practical way for personnel to fall into this basin unless the motor, pipe, and related pump are removed and the opening is left unguarded. Entry and drowning risk exists at the weir between the Cooling Tower and the Cooling-Water Pump House when the guard screens are removed. Any entry or work involving the weir shall be under the administrative control of safe work permits requiring the worker to use safety belts and a secured lanyard.

The main part of the building houses water treatment equipment. Included are:

- o Anthracite filters in four separate tanks, with two associated pumps for backwash and make-up water.
- o Chemical-preparation system tanks and pumps for chemicals inhibitor feed and sulphuric-acid storage. The acid and inhibitor tanks are equipped with external level sight glasses. The lime and soda ash tanks have top entry, electrical powered, mixers. An emergency shower and eyewash is provided. It is supplied from the incoming industrial make-up water.

The water-treatment system consists of a series of tanks and pumps with mixers. These involve the clarifier, with mixer and backflush; polymer-reagent tank, pump and mixer; caustic-reagent tank, pump and mixer; bisulfite tank, pump, and mixer; sulphuric-acid tank, pump, and mixer; and a reduction tank, mixer with pretreated liquid transfer pump.

A large warm lime softener tank has an external level sight glass and a level controller. This tank has an associated clear-water-return pump, sludge-circulation pump, sludge transfer, and three options for waste discharge.

The Cooling-Water Pump House operating area risks justify a classification as "eye hazard area". All persons entering must wear safety glasses. Specific work will require more extensive eye and face protection and protective clothing. Electrical equipment of the top-entry clamp on mixer type will require good electrical ground continuity. Portable electrical equipment used for maintenance in this area should have GFCI units. The operating area equipment is three wire grounded circuits. Electrical outlets are on circuits with GFCI breakers. Administrative control of risk from electrical shock in a damp chemical area will be enforced.

The transfer of chemicals from storage to the mix tanks and their addition to the tanks involves risks from handling; breathing fumes and dust; chemical burns and dermatitis from skin exposure. Adequate operating procedures, specifying required personal protective equipment, are prepared and followed.

The west (plant) side of the building is isolated by a fire wall without doors for access to the water-treatment area. This isolated area contains a chemical-storage room on the north and the main electrical switchgear room on the south. Entrances are only from the outside, two into the switchgear room, one into the chemical-storage room. The switchgear room meets normal industrial requirements and complies with the National Electrical Code. It is a high-risk area that requires limited access. The chemical-storage area is inadequate for the variety and volume of chemicals required. External storage facilities have been pressed into service. Improved permanent facilities are needed.

Operational safety analysis and related safety are to be discussed in Section 5.2 on process chemistry.

4.3.2 Office and Control Building

The control room has a subfloor area to provide for distribution of incoming control equipment signal cables and instruments. This "under-the-floor" area is provided with a single shot, total flooding Halon 1301 fire suppression system. It is designed to maintain a 6% concentration for 10 minutes. The entire building is protected by a wet-pipe sprinkler system designed for ordinary hazard, Group 2 occupancy. The subfloor is sloped to a central drain with a 102-mm (4-inch) discharge pipe tied into the plant sewer system. No scuppers are provided.

The common interior walls of the control room are prepared as a special fire barrier; they utilize double, 16 mm (5/8 inch) gypsum surfaces to provide a 2-hour fire rating. The exhaust air louver is held open by inside and outside fusible links. The windows are of wired glass and protected, additionally, by a Class B, 1-1/2-hour-rated automatic roll-type fire shutter. The entrance door is a UL-approved Type B fire door.

A room for records storage is provided, adjacent to the control room. The only entrance is from the common building hallway. Although the room is sprinklered and is part of a noncombustible building, it does not satisfy the NFPA Code 232 as a vault or file room. Therefore, documents and original data will not be filed here when there is a need for "Safe Recordkeeping".

A chemistry laboratory, designed to provide support for the project, is in this building. It has regular drains to the sewer plus a special chemical-waste drain that removes the chemical waste to a buried stainless steel waste tank outside the building. The laboratory has conventional laboratory hoods, demineralized water, deionized water, hot and cold fresh water, compressed air, vacuum, nitrous oxide, and acetylene gas. The nitrous oxide and acetylene supply an Atomic Adsorption analysis unit used for testing. The hoods, A-A unit, and laboratory have external vents. The acetylene-supply pipe is of steel and installed according to NFPA code. It includes a conventional flashback arrestor. The laboratory is equipped for emergency egress by exit doors at opposite sides of the room. It has an emergency shower and eye-wash fountain.

A mechanical-equipment room is provided to house the fire-sprinkler riser, the deionized-demineralized water system with storage, heat exchanger, air separator, and ion-mist separator

with roof vent. It has a floor drain with 51 mm (2 inch) piping to the sewer system. Access is only by an outside door.

A heating/air condition system is located on the roof of the building. It utilizes heated ethylene-glycol from the exchanger located in the mechanical equipment room. In-duct electrical heaters have been added to this original installation. The system presents no unacceptable risk.

The remainder of the Office-Control Building provides a first-aid room, conventional offices, and change-locker rooms for men and women. A conference room is provided with a kitchen unit including an electric range with powered exhaust hood and grease filter, a microwave oven, a sink with disposal unit, countertop and storage cabinets.

4.3.3 The Fire-Water Pump House

The Fire-Water Pump House provides a heated building for suction pipe from the fresh-water storage tank to the electrical and diesel driven fire pumps. It houses the electrical control panel for the electric fire-pump motor, and a dry transformer for conversion of 4160 volt power to 480 volt. There is a small surge tank and a domestic-water pump in the building. There is an element of risk from the diesel fuel supply to the diesel driven fire pump. Noise levels will be high during pump operation and measurements will be made to determine the severity of risk and provide for personal protective equipment. The building is provided with automatic-sprinkler protection based on extra-hazard occupancy. The sprinkler heads above the high-heat sources are rated at 411 K (280°F). Special attention has been given to the dry transformer to minimize risk. It is in a metal enclosure, mounted on a raised concrete floor section. A divider was installed between the supply and

discharge wiring. During the initial 4-hour fire pump tests no safety problems were detected.

4.4 Support Systems

Discussed here are those support systems not included as a part of the "process support" in Section 5 below. Included are the, electrical system, cathodic protection, lightning protection, heat tracing, and the maintenance building facilities.

4.4.1 Electrical

A primary electrical power supply enters the 5 MW(e) plant area on overhead power poles. The supply is from the Raft River Electrical Cooperative via their substation.

The incoming power is transformed via the plant 5000 kVA transformer T-1. It has a 24,900 volts, delta, three-phase primary; and a 4160 volt grounded wye, three-phase secondary. Power leads enter the fenced plant substation where suitable transforming and routing into underground conduit distribution is made. Basic design of the electrical installation conforms to the National Electric Code. The major underground distribution is in rigid nonmetallic conduit Schedule 40 PVC and fittings encased in concrete. The upper layer of concrete encasement for duct banks containing lines operating above 300 volts is dyed red with red oxide. Conductors are copper and those of 600 volts have THW insulation.

The major distribution from the substation is to the process area and the switchgear room in the southwest corner of the Cooling-Water Pump House. General plant buildings and the area are supplied from the Cooling-Water Pump House switchgear. Major transfer points in the underground distribution are in

conventional concrete manholes. Conduit risers into buildings are coupled to the nonmetallic underground conduit with a standard galvanized steel conduit, PVC coated. All runs above ground are in metallic conduit.

The process area is designated "Hazardous" in accordance with National Electric Code, Class 1, Group D. Most parts of the area are in subclassification as Division 2. Recognized locations where conditions exceed Division 2 are required to meet Division 1 requirements. In the hazardous area, conduits are sealed to comply with NEC requirements. Electrical, potential ignition source, equipment is either intrinsically safe, UL-approved explosion proof, or purged and monitored with a system approved for hazardous areas. The monitors for air-purge units are consolidated in an area control panel and a purge-failure signal is sent to the control room. The involved equipment is not to be activated until the system can be checked and the purge reestablished. Special efforts are being made to extend the hazardous area to include the Deluge Sprinkler Riser House.

Electrical power supply for the plant is subject to the problems in the Raft River Valley that may cause a major power failure. The Raft River Coop. substations are arranged to reclose breakers automatically after a short-time delay for two cycles. A third breaker trip results in the breaker remaining open until Coop. maintenance crews can find the source of trouble, repair or isolate it, and manually close the breakers. If incoming power is interrupted from external causes, some 5 MW(e) electrical equipment will require manual check and restart, e.g., the oil-system pumps on the turbine generators. Authorized personnel involved in making checks shall open in-plant power supply breakers before starting their checks. This is an important safety requirement because the external

power supply may return at any time, thus exposing personnel making checks to energized electrical equipment they were working as cold.

At motor-control centers, the operating mechanism is mounted on the primary disconnect. It is interlocked with the unit door to prevent access unless the disconnect is in the OFF, "open" position. However, a defeater is provided to bypass the interlock. There are justifiable reasons for the defeater, its installation made it absolutely necessary that administrative controls be established to regulate the use of the interlock defeaters.

The electrical system incorporates an uninterruptable power system inverter utilizing 120-volt batteries. Also, there is a diesel electric standby power system. The limited capacity of these units will require a rigid administrative control of additional loading. Failure to keep the load within capacity of the units will cause overloading that defeats their usefulness and creates additional risk.

4.4.2 Cathodic Protection

A typical system, using a direct current rectified from alternating current, is arranged to make the underground piping a cathode part of a galvanic cell. Three rectifier units with supporting anode fields are provided for buried piping. An additional rectifier is provided in the Fire-Water Pump House to supply power to anodes suspended in the fresh (fire) water storage tank. The three field units are located near the Fire-Water Pump House, at the electrical substation, and near the process area.

The bridge rectifier is protected to prevent silicon burnout in overload conditions. Manual-reset type, thermal magnetic circuit breakers are provided on the ungrounded conductors in the AC input circuit.

No special hazards are expected from the equipment and its operation; however,^a "it is not possible to calculate the number of units to use for a specific installation, because the length of pipeline which one unit can protect varies with the resistance of the soil, size of the pipe, condition, and extent of protective coating on the pipe, and many other factors." It will be necessary to study the system, after installation, to determine voltages between pipe and ground at different points for several values of current output, and determine if the units provided are accomplishing what is expected. Electrical continuity bonds were tested at installation; breaks or failures may have developed. More units and anodes may be required. Specially constructed metal ground beds of buried metal may be necessary also. The risk is in undetected premature corrosion of buried pipe.

4.4.3 Lightning Protection

The technical specifications and drawings combine to provide for a comprehensive lightning-protection system. The protected units are the Office-Control Building, Maintenance Building, Cooling-Water Pump House, Cooling Tower, and process equipment and piping area. The primary basis for the installation is NFPA Code 78, "Lightning Protection." In each installation, the provisions for air terminals, down conductors, and ground

a. Quote from Standard Handbook for Electrical Engineers, Fink and Beaty, McGraw-Hill Book Co., 11th Edition, New York 1978.

terminals are superior to minimum code requirements. The protected buildings are metal covered, and metal frame which qualifies under 3-32 of the code as a main conductor; however, the system is independent thereof thus eliminating the risk of inadequate electrical continuity.

The process area was designed according to the special requirements of NFPA 78, Chapter 6. It has a combination of metal masts with overhead wire, air terminals and grounds. The overhead lightning cone protection more than complies with 6-3.3.5 for minimum clearance between the overhead ground wires and the highest protection on the operating area structures.

The completed installation and system check for compliance with plans and specifications, indicates that the risk is controlled to the extent expected through current technology.

4.4.4 Heat Tracing

Two heat tracing methods are provided. One uses geothermal hot water and one uses electrical heat tape. Hot water heated ethylene-glycol is provided for heating of the exterior sidewalks on three sides of the Office-Control Building and the west side of the Maintenance Building. Hot water is used in piped loops to heat the interior of the fresh-water storage tank, and the Cooling-Tower basin. Control valves are arranged to permit isolation of individual systems or segments of large systems such as the sidewalk heat tracing of the Office-Control Building. The risks are: ethylene-glycol leaves a residue in pipes that can be an explosion hazard if not cleaned properly before welding or burning. Safe work permits will be used for this type of work. Failure to maintain hot geothermal flow during sustained periods of cold weather may cause freezing and

rupture of the water pipes in the CT basin or storage tank. Any leak will contaminate the tank or basin with geothermal water until discovery and control.

Electrical heat tracing is called for in a few locations, some that are in the operating area. The technical specifications call for, "Factory Mutual-approved heat tape suitable for hazardous areas, Class I, Division 1 and 2, Group D" per NEC Section 500. Also, it is specified that power supply to the heat-tape locations shall be in conduit properly equipped with explosion-proof seals. Tape lengths are limited to 250 feet maximum. Operating specifications are:

- o Service Voltage -- 120 volts, single phase, 60 hz
- o Exposure Temperature -- (Maximum in the pipe)
 - Power on 150⁰F (66⁰C)
 - Power off 185⁰F (85⁰C)
- o Starting Current at Temperature --
 - 50⁰F .06 A per foot
 - 0⁰F .08 A per foot
 - 20⁰F .10 A per foot

The installation met quality acceptance and the piping has been insulated. The only remaining risk is that created by valving out a section of pipe that is liquid full and the heating element is left on. This could cause a valve failure or pipe rupture. It is not practical to arrange valve-tape circuit interlocks, so the prevention is through proper operating procedure and administrative controls.

4.4.5 Maintenance Building Facilities

The important support functions of electrical repair, carpentry, piping and valve repair, air compressor, emergency generator, storage, and a general maintenance area are in the Maintenance Building. These various functions have the normal risk associated with this type of work. The general area provides a drive-in access for vehicles and an overhead crane of 13,608 kg (15 ton) capacity for material handling.

The generator room is isolated from access except by an outside entrance. A special air exhaust for the diesel engine penetrates the exterior wall. The buried-outside diesel storage tank has a vent that terminates above the building roof to comply with National Fire Codes. Noise levels are high in the room when the diesel engine is in operation. The use of ear protection is an administrative requirement. The engine exhaust has a metal protective sleeve and extends through the roof of the building.

The air-compressor room is also isolated from other rooms of the building and the only entrance is from the outside. The air compressor is equipped with an aftercooler and drier. The drier has a direct piping connection to drain waste water to the floor-drain sewer. Noise levels of the compressor are high and ear protection for personnel in this room is required while the compressor is in operation. A battery installation is associated with the emergency generator and air compressor, with access only from the air-compressor room. The battery room is equipped with a water connection, floor drain, and fan-powered roof vent. There is an emergency shower outside the entry door in the compressor area. Originally, the design drawings specified metal interior walls for the battery room, but a construction change resulted in installation of gypsum wallboard

instead of metal. Individual batteries are separated within their racks by insulation. The problem of noise, chemical burn, and electric arcing between batteries via mishandled uninsulated tools are residual risks.

A storage room is equipped with a double-door rear entrance and a regular door from the main corridor. An overhead natural convection vent extends through the ceiling and roof. A floor drain plus cleanout access is connected into the regular sewer system by a 7.6 cm (3 inch) drain line. The floor drain has a sediment bucket and flat-bottom strainer. Electrical and air outlets were provided for normally expected shop needs. Although occupancy activities have changed, there are no apparent design deficiencies.

The instrument and electrical repair areas involve no special or high-risk installation. The repair areas have electrical and air outlets. The area has a floor drain. The risk of high-pressure air misuse is controlled by administrative procedure and pressure reducers are required for blow nozzle uses.

The general maintenance shop covers the entire east half of the building. It has vehicle entrances at both the north and south ends and two sets of double doors into the N-S Building corridor providing access to the storage and shop repair areas discussed above. This shop is provided with six air outlets and three floor drains. An overhead bridge crane, 13,608 kg (15 ton) double girder, top riding, pendant push button operated crane is provided for heavy handling in this shop. The crane has an 8.4 m (27-2/3 ft) span, runway length of 18.3 m (60 feet), an upper limit hook height of 5.03 m (16-1/2 ft) above floor, and the following operating speeds:

- o Hoist 0.102 m/s (20 FPM)
- o Bridge 0.382 m/s (75 FPM)
- o Trolley 0.102 m/s (20 FPM)

The minimum, design safety factor is 5 with a specification for Class C moderate, indoor service. Design features do not impose undue risk; however, this area will be exposed to vehicle risk, heavy material handling, welding, intermittent slippery floors from tracked-in snow, mud, and water. Suitable administrative controls for operational hazards will be followed.

The entire building is equipped with an automatic wet-pipe sprinkler system designed for ordinary hazard, Group 2 occupancy. This is supplemented by a centrally located fire hose station in the building corridor. There are water outlets in the two shops, and battery room. An ethylene-glycol-geothermal water heated sidewalk is provided along the west wall of the building. It will minimize risk in material handling required for the shops and compressor-battery room.

4.5 Service and Utility Systems

4.5.1 Fresh, Potable Water

A water well located southeast of the 5 MW(e) plant will supply fresh water. A well pump and buried supply line are provided to move the water to the 1137 m³ (300,000 gal) fresh-water storage tank. A "jockey" pump in the Fire-Water Pump House takes suction from the tank, discharges through a surge tank and into piping for four functions: (1) maintain pressure on the fire-water main; (2) provide a water source for the demineralizer; (3) provide the water source for deionized

water; and (4) provide the water for the domestic-water system. There are no inherent safety risks in the system; however, deficiencies can be expected to introduce risk. Arrangements permit chlorination at the storage tank in the event the bacteria count were to increase beyond acceptable potable-water limits. The only redundancy to allow for maintenance on the jockey pump is by operating one of the main fire pumps. A power outage or well-pump repair will have to be of short duration to avoid a general plant shutdown when water-storage tank levels are reduced to the fire protection requirement. The minimum water level in the tank to assure adequate fire protection is established by technical specifications at 8.5 m (28 feet).

4.5.2 Air System

The compressor located in the Maintenance Building is intended to supply air for the entire plant. It is designed to provide $.058 \text{ m}^3/\text{s}$ at 965,266 Pa (125 scfm at 140 psi). It has a receiver tank of 0.45 m^3 (120 gal) capacity. Since there are several system uses and more than sixty outlets, the system is conservatively designed. There is no alternate compressor to allow for maintenance and operation concurrently. Design calculations were based on an assumption of system leakage of $2.36 \times 10^{-5} \text{ m}^3/\text{s}$ (0.05 scfm) for each of 60 units.

An emergency cross connection in the process area piping ties the gaseous-nitrogen system to the air system. This connection has a nitrogen pressure regulating valve, a check valve preventing air from entering the nitrogen pipe, and a remote-operated valve on the air side. The remote-air valve is actuated by a sensor picking up low air pressure, opening the remote-air valve to permit nitrogen to flow into the air piping. A manual valve on the nitrogen side of the check gives manual control for isolation. Also, a check valve exists

between the operating area and maintenance area. It permits flow of air from the compressor to the operating area, but prevents the nitrogen-pressurized air pipe flow from entering the office-control-maintenance area, and air supply to the flare.

A failure in the automatic cross-over system concurrently with an air-compressor outage or a manual isolation will prevent functioning of the process air-operated valves. The air pilot system on the deluge-sprinkler control will initially remain intact; however, extended time in this condition will normally cause a pressure drop and trip of the deluge water for the zone controlled by the system whose air pressure loss is greatest.

An air system involves inherent risk in shop uses as discussed briefly in 4.4.5 above. Proper reduction of air pressure for outlets involving blow nozzles and administrative controls for workers are issued for injury prevention.

4.5.3 Telephone and Intercom

A telephone company line enters a utility box near the electrical substation. A distribution system through underground conduit supplies terminal boxes at the Cooling-Water Pump House and Office-Control Building from the utility box. Although only a limited number of telephones are provided, the system is supplemented by intercom systems discussed below. An intercom using telephone-type equipment is provided. The control switchboard has a 10-line capacity with four conversation links. The switchboard permits automatic selection of any one of the telephones in the system. In addition to the normal functions as a telephone, the switchboard is equipped to permit amplifying and paging via all units on the system. The initial installation provides:

- o Intercom telephones from floor outlets in the Fire-Water Pump House and Office-Control building.
- o Intercom telephones from wall outlets in the Maintenance Building, Office-Control Building, Cooling-Water Pump House, and Process Area.
- o Wall speakers in the Fire-Water Pump House, Maintenance Building, Cooling-Water Pump House, and Process Area.
- o Ceiling speakers in the Maintenance Building and Office-Control Building.
- o Emergency notification capability for the 5 MW(e) area only.

No significant risks are anticipated, although the units in the process area must be suitable for the NEC Class 1, Division 1 or 2, Group D classification of the area.

4.5.4 Sewage System

A normal septic-tank system was designed on the basis of 25 people in the plant. This was supplemented by an expected waste-water contribution for a combined average daily use of 2.84 m^3 (750 gal). The sludge buildup is calculated to require removal every four months. Any significant increase in personnel above the design estimate of 25 will require more frequent sludge removal.

The leaching field is equipped with parallel perforated pipe placed in gravel and covered with an earth backfill. Burial depth is sufficient to prevent freezing in normal severe cold weather. The only safety problem potential is that the leach field is on an uphill side of the plant.

4.5.5 Heating Systems for Plant Buildings

Geothermal hot water is supplied to the Office-Control Building heat exchanger for heating purposes. Underground pipe is insulated with spray-applied foam. Above-ground pipe is insulated with glass fiber mineral wool (moulded). It is covered with a canvas jacket secured with lagging adhesive. The hot-solution coils in heating units are made of copper tubing with aluminum fins.

The Office-Control Building has a central heating facility on the building roof, supplemented by electrical heaters in the main ducts. The heat ducts are in the ceiling-to-roof attic space, and have UL-approved fire dampers where a duct penetrates a separation wall or special fire enclosure. All return-air penetrations from the rooms to the main corridor are protected with fire dampers secured open with fusible links. The machinery is equipped with proper guards. There are manual balancing dampers and pitot tube test holes for air-balance studies. The roof equipment is designed for and exposed to the weather. It has bearings that require lubrication from exterior manual fittings. The external-air intakes are protected with bird screens and a back-draft damper.

The Maintenance Building, uses the geothermal water heated ethylene-glycol from the Office-Control Building for heating through unit heaters. Fans are located back of the coils and manual louvers are on the horizontal units. Fixed radial vanes are used on the vertical units.

The Cooling-Water Pump House, Fire-Water Pump House, Substation Sprinkler Riser House, and Process Sprinkler Riser House utilize electrical heaters to prevent freeze-up.

Injury or accident risks are involved in maintenance of the equipment. A metal vertical ladder provides access to the Office-Control Building roof system. The heating equipment is not near the edge of the roof and is enclosed on four sides by a metal shield that serves as a guard. The unit heaters in all areas will require ladders or scaffolds to permit maintenance or replacement. Any damage from failure in overhead piping imposes a minor burn risk and normal water damage potential. General maintenance on any of the hot liquid transmission piping has an inherent thermal risk. Proper job planning and use of personal protective equipment will be necessary. Ethylene-glycol piping will require special cleaning before welding or burning can be involved safely.

4.6 Safety and Health Protection Systems

4.6.1 Perimeter and Area Lighting

A system of electrical, pole-mounted floodlights are arranged to illuminate the major parts of the 5 MW(e) plant. There are 13 metal poles 12.1-m (30-ft) high, each with two 400 watt, 480 volt lights for the north half of the area. The operating area, south of the above-mentioned lights, is equipped with 11 floodlights individually mounted on metal poles.

The lighting will give coverage to minimize risk on off-shift needs. Despite dark spots because of shadows from building and equipment, night lighting is believed to be excellent and will pose no unacceptable risk.

4.6.2 Emergency Lights, Exit Signs, and Panic Hardware

All installations comply with NFPA 101 Life Safety Code and utilize UL-approved equipment. Emergency lights are mounted in

the main corridor of the Office-Control Building and the Maintenance Building. Illuminated Exit signs, are over each door designated as an exit. The doors are equipped with UL-approved panic hardware. The buildings are relatively small; each has only ground-level occupancy, and each building with a significant personnel occupancy has two exits. All exits open into unobstructed discharge open space more than adequate to provide all occupants with safe access to the main plant roadways. These facilities are believed adequate and offer no risk requiring supplemental measures.

4.6.3 First-Aid Facility

A small room specifically designated and equipped is provided for first-aid treatment. It is in the northeast end of the Office-Control Building where it is readily accessible to operations personnel in the building. It is also convenient to the north entrance door of the building to accommodate an injured person brought by vehicle for first aid. There is no risk in this facility per se; however this plant is 97.7 km (52 mi) from the nearest hospital with physicians available.

4.6.4 Automobile Engine-Block Heaters

The parking spaces at the curb in front of the Office-Control Building are supplied with two single and three double 120 V outlets for automobile engine-block heaters. The units are supplied power via underground conduit which projects from a concrete support. The conduit provides a junction box approximately 1.22 m (4 ft.) above grade for the heater "pigtail" cords. The box is equipped with hooks to hold the cords when they are not connected to a vehicle. The connector plug is a nylon straight blade female rated at 15A, 125V.

Experience has shown that these units are subject to abuse through failure to disconnect them from vehicles before driving away. The abuse causes breakdown at the junction of the cord and plug, with an increasing risk of electrical short. If the short causes arcing when a connection is being made, there is risk of electrical shock and arc burn. Drivers who fail to stop properly may strike the protective guard posts protecting each junction box. Suitable administrative controls and good electrical, preventive maintenance are in effect.

4.6.5 Isobutane-Detector System

The process area is equipped with 15 hydrocarbon sensors. They are arranged to provide general coverage of the operating area. Detector locations are listed in Table 10.5 of Chapter 10. A panel in the control room will, upon gas detection, alarm and show that a detector has activated. The system uses MSA Model 510 components which consists of: a remote diffusion head containing the gas-detecting sensor; a control-indicating unit with individual current regulation; indicating and warning devices; and a control-module housing which contains the control-indicating unit and transformer unit. The main diffusion head is a variation of the wheatstone bridge detector in which the active and inactive elements are made of ceramic beads supported on a coil of platinum wire. On one, the active element is coated with a catalyst that causes the combustible gas or vapor to combine with oxygen at a lower temperature. Thus, the life expectancy is prolonged for filament replacement for up to three years. The diffusion head is explosion proof, but its signal data must be relayed to the control-indicating unit at the control-module housing units outside of an explosive risk area. This can be up to 2000 feet.

A special calibration kit is provided as a supplement to the system. It requires personnel to physically test and recheck calibration of the units.

Associated with the above gas-detection equipment are two sets of International Sensor Technology Model AG 2200 systems. These units are explosion proof and designed to be highly sensitive, monitoring in parts per million from "0 to 1000".

Signals entering the collection stations are arranged to transmit an alarm signal to the control room. These signals will not indicate the instrument sensor location. Physical follow-up will be necessary to determine details concerning the leak and detector location. The choice of location for the sensors is reasonable and logical, but not necessarily what may be optimum. Only field experience and testing with portable instruments during system startup can improve upon locations. Also, this type of testing can aid in making judgments to determine if existing sensors should be relocated or supplemented. This system, like any electrical system in an area classified "hazardous" within the NEC, involves inherent risk from inadequate conduit sealing, or improper maintenance of explosion-proof components. Adequate initial equipment checks have been made and good maintenance is on a regular schedule.

4.7 Fire-Protection Systems

At this final rewrite, the fire-protection system is fully installed and tested. Therefore, the information presented shows that final test and checkout have been conducted to assure that installation requirements, as specified, have been met.

4.7.1 Fire-Water Supply

The 1136 m³ (300,000 gal) water-storage tank for fresh water (see 4.5 A above) also provides a suction source for the plant fire pumps. The storage tank is designed and constructed to NFPA 22 requirements. Review of the installation and comparison with codes reveal two potential problems.

- (1) There may be a risk (or at least not technical compliance) with NFPA 22 Par 1-5.1. This concerns fire exposure to the adjacent buildings. Actually, the Fire-Water Pump House is attached to the tank. Since both tank and pump house are at ground level, and the building is of fire-resistive construction and is sprinkler equipped, any residual fire risk is believed to be acceptable. The tank and building are considered as a single unit.
- (2) The tank capacity, when full, will supply the design 0.237 m³/s (3750 gpm) maximum flow provided from one fire pump for 80 minutes. Design of the operating area deluge-water spray zones to meet NFPA 15 Appendix A 3-2.1 utilizes the concept of the three largest zones of a system being in operation simultaneously. Demand for the three largest deluge zones is 0.21 m³/s (3326 gpm) which is within the design flow of one pump, and provides flow for approximately 90 minutes from a full storage tank. The water-use rate, if both the electric and diesel driven fire pumps operate during an emergency, will exceed the rate supplied by only one pump, due to increased flow pressure. Therefore, maximum deluge operation potential is approximately 80-minute duration from a full tank supply. The time may be significantly less. Both the tank quantity and available time of consumption appear to be marginal when measured against NFPA 13 Water Supply

recommendations. However, experienced judgment is recommended (NFPA 13 2-2.1.1(a)). In the 5 MW(e) plant, the major fire risk is the failure of isobutane containment. Since the system is confined in a closed loop with a supply limited to the capacity of 60,400 gallons water equivalent, this indicates maximum fire volume. The fire duration would then vary with the fuel-loss rate to feed the fire. The duration would be controllable, additionally, by the fuel that is retained in the underground storage tanks and the fuel that will be released automatically to the flare system. A small fire will be controlled by the deluge system. A major failure and fire will consume the fuel before the water would be consumed. Additional details will be given below on the discussion of the deluge system fire protection in the operating area.

A fresh-water well with an estimated $0.00315 \text{ m}^3/\text{s}$ (50 gpm) capacity is to supply the water-storage tank. This input rate will not have a significant impact on the use rate during a major fire. It has prompted establishment of minimum tank level requirements of 8.5 m (28 feet) which provides 1021 m^3 (270,000 gallons) at all times to assure adequate fire water. The well is located southeast of the 5 MW(e) plant area. Transmission from the well is by an electric pump discharging through approximately 926 m (1/2 mi) of 10.2-cm (4-in.) plastic pipe. The pipe routing is along the south and west sides of the plant fenced area. Minimum burial depth is 1.2 m (4 ft). During and following severe cold periods, continuous flow may be necessary to prevent freezing.

4.7.2 Fire Pumps

Two $0.1577 \text{ m}^3/\text{s}$ (2500 gpm) fire pumps are located in the Fire-Water Pump House. They take suction through a single 0.3048-m (12-in.) connection to the water-storage tank. The suction is divided in to two 0.254-m (10-in.) suction feeds to the individual pumps. One pump is driven by a squirrel cage induction motor operating on 480 volt, 3 phase, 60 Hz power. The other pump is driven by a 365 Hp @ 1800 rpm diesel engine.

The complete fire-pump installation is designed according to NFPA 20 requirements. The units and related auxiliary equipment are UL-listed for fire-pump service. They are arranged so that the electrical pump will start automatically upon 586 kPa (85 psi) water pressure on the fire main. If pressure drop continues due to excessive demand or failure of the electrical pump to start, the diesel driver will start automatically at 448 kPa (65 psi). The automatic start for the diesel engine is by electric-battery power. The batteries are equipped with a charger unit powered from a 120 volt, single phase, 60 Hz power source. The diesel-fuel system consists of an exterior buried tank of 2.498 m^3 (660 gal). A direct current electrically driven pump whose power is supplied from the diesel-battery pack removes oil from the outside tank to a $.091 \text{ m}^3$ (24 gal) inside tank. The buried tank has a standard vent elevated to 2.58 m (8-1/2 ft). The tank-fill connection is equipped with a 25.4-mm (1-in.) hose coupling, supply pipe, and return line. The installation is in compliance with the approved specifications and appears to introduce no unacceptable risk.

4.7.3 Fire-Water Distribution System

A 254-mm (10-in.) buried-pipe distribution system is looped between the Fire-Water Pump House and process area. In

addition, an 203-mm (8-in.) and 152-mm (6-in.) dead-end leg extends westward into the Office and Maintenance Building areas to supply a fire hydrant and the building sprinkler systems. From the north side of the loop, there is a short 152-mm (6-in.) pipe run to a hydrant north of the Cooling-Water Pump House, and a 254-mm (10-in.) pipe run south of the Pump House which supplies the Pump House and Cooling Tower sprinklers, substation deluge and a fire hydrant. The east side of the loop has dead-end extensions to fire hydrants on both the north and south side of the process area. There is an isolation valve (post-indicator) at about midpoint of the east side of the loop. Just south of this valve, there is a 254-mm (10-in.) pipe with PI valve control, supplying water to the five process area deluge-sprinkler valves (see Figure 3).

Each fire hydrant has an isolation gate (key) valve between it and the supply main so a hydrant outage will not require fire-main shutdown. The supply pipe to sprinkler systems in the Office-Control; Maintenance, and Cooling-Water Pump House/Cooling Tower have external PI valves only; the Cooling Tower system has an inside OS&Y valve. The PI valves comply with NFPA 24 Paragraph 3-2.6, but not the 12.2-m (40-ft) distance from the building recommended by 3-3.2. Since the building exposures are metal walls of noncombustible buildings, they do not create unacceptable risk.

The fire-main headers from the pumps enter a major distribution valve pit that is located just east of the Fire-Water Pump House. This pit contains major isolation valves for:

- o Isolation of each fire-pump discharge (2 valves)
- o Isolation of the main going northwest to the Maintenance and Office-Control Buildings

Fig. 3 Fire Water Distribution

- o Isolation of the main loop leg leaving the pit to the northeast
- o Isolation of the main loop leg leaving the pit to the southeast.

This valve pit has one drawback that introduces risk and constitutes questionable compliance with NFPA Code 24, Paragraph 3-4.2. This paragraph specifies that control valves in a pit be readily accessible. This pit is covered with reinforced-concrete inserts with plugged fittings for lifting lugs. The inserts will require a mobile crane or similar lifting device and correct-size eyebolts for their removal. A manway in the northwest corner of the cover will provide an emergency personnel access for manpower to operate valves. The valve-box cover is above grade to minimize water entry.

Beyond the controls in the main valve pit, there are additional isolation valves in the main's east loop section. One valve is south of the Cooling-Water Pump House. This one is operable only by entering the severely confined area in the pit. There is a post-indicator valve northwest of the process area. It permits isolation of the north and south sides of the loop when used with the valves of the valve pit. In the event of a major explosion, in the process area, that damages the deluge-system piping, it is very possible that access to two adjacent PI valves would be blocked by the fire. Isolation of damaged water piping would require fire-main valve closures in the major distribution valve pit. Thus, isolation would close off the deluge water and all of the fire hydrants near the process area. This risk, although remote, shall be considered in emergency plans. The plan shall provide for prompt access to the valve pit so isolation can be made before excessive water is

lost from damaged piping. Any delay in control by valves may be ameliorated by manual shutoff of the fire pumps. Since there will be almost no flow through the piping in the valve pit, it could freeze in severe cold weather. Special protection has been provided in the valve pit. Temperature measurements shall be made during cold weather to determine residual risk.

4.7.4 Automatic-Sprinkler Systems

Standard wet pipe sprinkler systems, installed in accordance with NFPA 13, are provided in the Office-Control, Maintenance, Fire-Water and Cooling-Water Pump Houses. The individual systems were hydraulically designed to determine pipe sizes. UBC earthquake Zone 3 was identified in the specifications and the installation complies with NFPA 13, 3-10. The systems are classified as follows:

- o Office-Control Building, Ordinary Hazard Group 2
- o Maintenance Building, Ordinary Hazard Group 2
- o Fire-Water Pump House, Extra Hazard
- o Cooling-Water Pump House, Ordinary Hazard Group 1

The building systems have no interior OS&Y valve except in the Cooling-Water Pump House. A PI valve is on the 254-mm (10-in.) supply pipe which supplies both the Cooling Tower and Cooling-Water Pump House. The OS&Y valve inside the CWPB permits isolation of the Cooling Tower deluge system or the building sprinklers, independently.

Deluge, dry pipe, spray systems are provided for the Cooling Tower, main transformer, and five process area zones. In each of these, the activation system is air-contained pilots using closed sprinkler heads. The Cooling Tower and transformer areas use 135⁰F-rated activator heads; the process area uses nominally 286⁰-rated heads, although some heads may require change-out to higher ratings when the system tests permit the actual radiant heat at the pilot heads to be more accurately determined.

As in the standard systems, pipe requirements were hydraulically calculated. The NFPA Codes 13, 15, and 214, as appropriate, were used for specific data. The zones of the process area were designed to provide 0.25 gpm/ft² over the surface area of vessels and piping equipment, and 0.10 gpm/ft² over the surface area of structural supports.

The greatest risk is believed to be an unexpected major failure of an isobutane vessel or pipe in the process area. To meet the requirements for multiple zones according to NFPA 15 Appendix, three zones are to be operated simultaneously. To accomplish this, the water supply requires that one pump be allowed to operate at the pump curve design point of 80 psi and 150% of design capacity, or 3750 gpm. Advance DOE approval of this was obtained, so the design subcontractor used these parameters as points, "not to be exceeded" in the design. As discussed under fire pumps and fire-water distribution systems above, the most significant risk is an explosion that breaks major water distribution lines in the process area. This may ruin the effective distribution of the water spray and cause excessive water loss. This residual risk cannot be logically protected against in sprinkler design. Its prevention in operation and maintenance is a prime operating requirement.

Halon 1301 in a single-shot total flood system is provided for the under-the-floor area of the control room in the Office-Control Building.

The stored Halon 1301 is sufficient to provide a 6% concentration for 10 minutes. This exceeds the requirement of NFPA 12A, Paragraph 2-4.2. Instantaneous operation can be initiated manually from the control room. Upon detector alarm and lights, there is a 60-second delay before actuation. There is a manual inhibit switch that can be thrown during the detector-alarm period to prevent actuation. This switch has a key-lock feature to assure that its use is deliberate. Use of the switch resets the delay. Detectors are "cross-zoned." This requires two detectors to operate to initiate system discharge. One zone is an ionization type, the other is a photoelectric type. The entire electrical system of the Halon protection is supplied emergency power from a bank of lead-acid batteries, complete with recharge unit. Although the system is small, its complexity will require good operator training to assure that it is operated correctly. This system does not introduce unacceptable risk.

4.7.5 Fire Hose Stations and Houses

The Maintenance Building has one standpipe hose station supplied from the sprinkler-system piping. This station is accessible from the high bay maintenance area or the hallway dividing the east and west halves of the building. The station has 22.9 m (75 ft.) of 38-mm (1-1/2-inch) synthetic jacket hose with a combination fog-straight stream nozzle. This hose will reach any room of the building.

A similar hose station with access only from the main hall is located in the Office-Control Building.

The hose stations involve no risk; however, one design feature utilized may cause a problem subsequently. The angle valve on the water supply is at the top of the cabinet. The fire hose drops downward from the valve connection. Past experience shows that any valve leakage will cause wetting and deterioration of the hose near the expansion ring of the coupling. On similar installations, a simple fix was made by extending a short pipe from the valve to the bottom of the cabinet, fitting an ell to this and adding the hose connection horizontally. At the bottom of the ell, drill, tap, and install an 1/8-inch petcock that is left open so any valve leakage does not permit water to reach the hose.

Outside fire-hose houses are provided near fire-main hydrants as follows:

- o North of the Maintenance, Office-Control Building
- o At the Fire-Water Pump House
- o North of the Cooling-Water Pump House and east of the Office-Control Building
- o At the east corner of the Cooling Tower.
- o One at each of the four corners of the process area.

The hose houses are equipped with: a hydrant wrench, four spanner wrenches, a leader-line wye with quarter-turn ball valves, two 38-mm (1-1/2-in.) combination nozzles, 46 m (150 ft.) of 63-mm (2-1/2-in.) and 61 m (200 ft.) of 39-mm (1-1/2-in.) CRL, W&G-treated fire hose.

There is no risk associated with the above installations; however, operating experience may justify further evaluation and additions to satisfy special purposes. For example, there were no large stream devices for use in a major size fire. A portable deluge nozzle has been prepared.

4.7.6 Fire Alarms and Instrumentation

The fire-protection detection and alarm system gives both local signals and control-room annunciation. Although the system is not a UL- or FM-approved alarm system, it meets the important needs. The detection alarm system is supplemented by a general emergency siren warning for the area. It is manually activated from the control room.

Fire-water flow measurement is facilitated by an in-line venturi tube that is mounted between a set of flanges in the fire-main piping. Integral differential pressure taps permit measurement from $0.095 \text{ m}^3/\text{s}$ (1500 gpm) to $0.379 \text{ m}^3/\text{s}$ (6000 gpm). Overall accuracy is $\pm 1.5\%$ for all flows above 20% of full rate. Readout is in the Fire-Water Pump House via a mercury manometer calibrated to show gallons per minute. This information is primarily for fire-pump testing and is not transmitted to the control room.

The Halon system protecting the subfloor area of the control room contains a signal light (alarm) and a local alarm when a detector sensor is triggered. Or, if the system is manually discharged, this action also lights an alarm lamp and sounds a local, control room, discharge alarm. Additionally, the control room contains the following controls and indicators for the Halon system:

- o System trouble lamp
- o AC Power-on lamp
- o Alarm reset switch
- o Inhibit switch
- o Alarm silence switch
- o Trouble silence switch
- o A pressure switch to sense loss of agent from the Halon container.

Halon 1301 is not immediately dangerous to life; however, chemically it is bromotrifluoromethane (CBrF_3) which breaks down to decomposition products upon fire exposure and hot metal contacts. Personnel should not remain in the control room for more than four or five minutes and certainly should not enter the under-the-floor area without self-contained breathing apparatus.

The wet-pipe sprinklers and deluge systems are equipped with local water motor gongs to indicate water flow. In addition, there is a pressure-actuated switch for fire-alarm signaling, e.g., transmission of an alarm signal to the control room fire annunciator panel. The entire system of fire suppression and protection equipment is equipped with recommended signals that are transmitted to the control room fire annunciator panel (Figure 4, Page 4.43). This unit is located at the center of the north wall in the control room. It is arranged so that information signals appear in the upper six rows on the panel. When one of these signals is being received, the annunciator sounds and that panel square is lighted. When the signal is for fire, the receipt is on one of the bottom two rows and the panel square is lighted and is red. The information displayed on this panel is:

The annunciator functions in the following sequence.

1. Normal - signal lamp is off - horn is off
2. Trouble contact abnormal, lamp is flashing, audible signal is on
3. Audible silenced - trouble contact abnormal, lamp is steady on
4. Return to Normal - same as normal 1. above
5. Lamp Test - all nameplate signals lamps on, audible signal off.

A protected low-voltage regulated DC power supply operates the annunciator so that it is functional in the event of normal AC power outage.

CONTROL ROOM FIRE ANNUNCIATOR PANEL

FIRE WATER PUMP HOUSE LOW TEMP.	SUBSTATION LOW PRESSURE AIR	COOLING TOWER LOW PRESSURE AIR	DIESEL FIRE PUMP "ON"	ELECTRIC FIRE PUMP "ON"		
SUBSTATION LOW TEMPERATURE	SUBSTATION RISER VALVE CLOSED	COOLING TOWER RISER VALVE CLOSED	DIESEL PUMP CONTROL SW. "MANUAL" OR "OFF"	ELECT. PUMP LOSS OF POWER	LOW LEVEL STORAGE TANK WATER	HIGH LEVEL STORAGE TANK WATER
PROCESS AREA ENCLOSURE LOW TEMPERATURE	PROCESS AREA LOW PRESSURE AIR	COOLING WATER PUMP HOUSE LOW TEMP.	DIESEL PUMP "TROUBLE"	ELECTRIC PUMP VALVES CLOSED	DIESEL PUMP VALVES CLOSED	WATER TANK OUTLET PUMP CLOSED
4-42 PROCESS AREA ZONE 1 VALVE CLOSED	PROCESS AREA ZONE 2 VALVE CLOSED	PROCESS AREA ZONE 3 VALVE CLOSED	PROCESS AREA ZONE 4 VALVE CLOSED	PROCESS AREA ZONE 5 VALVE CLOSED	FIRE WATER PUMP HOUSE SPRINKLER VALVE CLOSED	
SECTIONAL VALVE NO. 1 CLOSED	SECTIONAL VALVE NO. 2 CLOSED	SECTIONAL VALVE NO. 3 CLOSED	SECTIONAL VALVE NO. 4 CLOSED	SECTIONAL VALVE NO. 5 CLOSED	SECTIONAL VALVE NO. 6 CLOSED	
POST INDIC. VALVE NO. 1 CLOSED	POST INDIC. VALVE NO. 2 CLOSED	POST INDIC. VALVE NO. 3. CLOSED	POST INDIC. VALVE NO. 4 CLOSED	POST INDIC. VALVE NO. 5 CLOSED	POST INDIC. VALVE NO. 6 CLOSED	POST INDIC. VALVE NO. 7 CLOSED
FIRE FIRE WATER PUMP HOUSE	FIRE MAINTENANCE BUILDING	FIRE COOLING TOWER	FIRE COOLING WATER PUMP HOUSE	FIRE SUBSTATION AREA	FIRE OFFICE AND CONTROL BLDG.	FIRE CONTROL ROOM HALON
FIRE PROCESS AREA ZONE NO. 1	FIRE PROCESS AREA ZONE NO. 2	FIRE PROCESS AREA ZONE NO. 3	FIRE PROCESS AREA ZONE NO. 4	FIRE PROCESS AREA ZONE NO. 5		

Figure 4

5.0 PROCESS SYSTEMS

5.1 Process Description

The 5 MW(e) plant is designed to utilize the heat from geothermal hot well water to produce electricity. This plant process requires the transfer of a large volume of geothermal water from production wells. The incoming stream is pressurized by "boost" pumps and directed to a high-pressure boiler where a secondary fluid, isobutane, is converted to a vapor. The geothermal water then cascades through a high-pressure preheater, low-pressure boiler, and low-pressure preheater. Each of these units absorbs a portion of the available heat until the discharge water from the low-pressure preheater exhaust is directed to injection wells. The pressure on the geothermal water is maintained to prevent the deposition of dissolved solids that would occur from flash of water to steam.

The isobutane goes through the cascade system in a reverse sequence to the geothermal water. It, however, is separated into two flow paths, low pressure and high pressure. Each stream is heated as a liquid in the respective preheater. They then flow through the boilers where additional heat is removed from the geothermal water. The isobutane, in a vapor phase, is then routed from the boilers to the turbine low-pressure and high-pressure stages, respectively. The turbine, through a suitable transmission-gear system turns a generator designed to produce electrical power. The turbines' isobutane exhaust streams are directed to a vapor condenser where cooling water absorbs unused heat. A condensate-storage tank immediately below the condenser acts as a reservoir for the liquid isobutane and provides a suction head for the isobutane-recirculation pumps.

The cooling water from the condenser is routed to the Cooling Tower, cooled by air movement through the tower, collected in the Cooling-Tower

basin, treated for corrosion prevention, supplemented with make-up water and recycled. Provisions are incorporated to divert water to cooling/holding ponds if circumstances indicate the need.

The process system isobutane piping and equipment are filled with gaseous nitrogen before commencement of operations and following any shutdown involving system drainage. In case of major relief valve openings or a "crash" shutdown, the released isobutane vapor is collected by the working fluid flare line, and routed to a "knockout" drum where isobutane vapors go to the flare and are burned.

Details of each of these systems with risk analyses are given below.

5.1.1 Geothermal-Water System

Initial control of geothermal water entering the 5 MW(e) plant is by a normally open, hand-operated valve on the 305-mm (12-in.) supply line. The water then passes a flow-measurement element; a normally open, remote-operated valve; a 152-mm (6-in.) automatic valve; a safety-relief valve; and the normally open, hand-operated valve behind each of the "boost" pumps. Between the third valve and the pump-intake valve, there is a 305-mm (12-in.) crossover line that will permit recycle of geothermal water from the low-pressure preheater to the injection line. Also, downstream from the boost pumps and prior to entering the high-pressure boiler, there is a second, 254-mm (10-in.) crossover line used for emergency bypass between the supply and injection lines.

The first crossover line has a flow element; a hand-operated, globe valve; a normally open, remote-operated valve; a safety-relief valve; and an automatically actuated valve. The second line, downstream from the pumps has a remote-operated butterfly valve and a hand-operated globe valve.

The supply line is reduced to 254 mm (10 in.) where it divides to supply the boost pumps. Each pump is equipped with a safety-relief valve; a 25.4-mm (1-in.) manual-relief line (top vent); and a 25.4-mm (1-in.) drain line with a manual, normally open, ball valve. Downstream from the pumps, each discharge line is equipped with a swing check and a normally open, hand-operated butterfly valve. The separate 203-mm (8-in.) pump discharge lines are joined downstream and continue as a single 305-mm (12-in.) line. It contains a remote-operated, butterfly valve, normally open; a relief valve; a 305-mm (12-in.) tee; and downstream butterfly valves on each leg of the tee lines. The main, normally open, flow path is to the high-pressure boiler, then through the high-pressure preheater. The alternate flow path, normally closed, rejoins the normal flow line between the high-pressure preheater and the low-pressure boiler, thus permitting a bypass of the two high-pressure vessels.

In the normal flow line, there is a 25.4-mm (1-in.) vent with hand-operated ball valve and an incoming 25.4-mm (1-in.) gaseous-nitrogen supply line. The nitrogen, when needed, is controlled by a hand-operated ball valve and double-check valves. Downstream from the high-pressure boiler, there is a 19-mm (3/4-in.) line to a relief valve; a hand-operated butterfly valve; and a 25.4-mm (1-in.) vent line with hand-operated ball valve.

Below the high-pressure preheater, there is a 19-mm (3/4-in.) line to a relief valve and a hand-operated main line butterfly valve. Just below the hand valve, the bypass line rejoins the normal flow line. Downstream from the tee combining the large lines, there is a hand-operated 25.4-mm (1-in.) relief line valve and an incoming gaseous-nitrogen line duplicating the similar line upstream of the high-pressure boiler.

Flow through the low-pressure boiler, low-pressure preheater, the pipes joining them, and discharge lines downstream beyond the relief line duplicates the lines, valves, reliefs, and vents in the same manner and sequence as described above for the high-pressure boiler and preheater. The two 25.4-mm (1-in.) drain lines are routed to the vapor separator at the holding pond.

The main flow line downstream from the relief valve is routed through a 254-mm (10-in.) flow element, then through the normal 305-mm (12-in.) line that directs the flow back to the injection piping. As the line returns through the process area, it includes: a hand-operated butterfly valve; the tie-in for crossover just above the boost pumps; the crossover- discharge option to the boost pumps suction; another flow element; a remote-operated butterfly valve; a hand-operated globe valve; a relief valve on a 19-mm (3/4-in.) supply; an automatic-operated globe valve; a connection to divert water to the cooling-water system make-up; another relief line with relief valve and manually controlled ball valve permitting diversion of water to the vapor separator and holding pond.

This entire process-piping system for geothermal water is in the congested area underneath and to the north of the process vessels. The pipes are insulated; however, any exposed flanges and valves will introduce a burn hazard potential. Additional risk evaluation reveals:

- o A burn potential from minor leaks of water from the packing of each valve in the system (32 valves).
- o A burn potential from actuation of any relief valve in this system (10 reliefs)

- o A surprise wetting, with burn potential also, from the manual vent-line discharges (6 lines)
- o The boost-pump drain line has heat tape for freezing protection between the pump and adjacent hand-operated valve. There is about 6 m (20 ft) of above-ground pipe run that is not designated for insulation. It is possible that a freeze could occur during cold-weather shutdown. On subsequent startup, hot water would melt the ice and escape from any pipe broken by the freeze up. Upon detection, the small-diameter pipe will be replaced without plant shutdown.
- o The intent in the design apparently was to install a pressure-relief valve in any section of pipe that may be totally isolated by valves. This, however, has not been accomplished in the following sections: on 12 in. G 812A between valves GH 819, GH 868, GH 892, and GR 820; on 12 in. G 807A and 10 G 814A between valves GH 810, GH 811, GR 823, and GR 812; on 12 GH 816A between GH 892 and GR 804; on 12 in. G 801A between GR 861 and GA 803; on 12 in. G 812A between GR 820 and GH 891; and on 12 in. G 801A between GH 802, GH 860, and GR 861. Normal operation creates no need to isolate these sections. Procedures specify a management approval to permit the isolation of an unrelieved section.
- o Preventive maintenance (PM) built-in capability for handling, removal, and installation of valves is minimal. Also built-in facilities for handling large flanges and vessel heads are not incorporated. The material handling for any major overhaul and PM requiring valve removal will be a difficult problem with high injury risk. Job Safety Analysis of each handling operation shall be performed to establish a safe procedure.

5.1.2 Nitrogen-Gas System

Two storage vessels 10.7-m (25-ft) long by 1.27-m (50-in.) wide are provided for gaseous-nitrogen storage. The vessels are mounted above ground on concrete supports. The west end of each is anchored to the support, and the east end is arranged to allow slippage. Each vessel is equipped with a pressure-relief valve set to function at 6895 kPa (1000 lb) gage pressure, at 51.6°C (125°F). Normal filling is through the fill-station piping connection southwest of the tanks. The fill line has one hand-operated globe valve. However, the pipe at each vessel has a check valve arranged to allow inflow only. Vessel capacity when full is 11.36-m³ (3000-gal) water capacity each.

The vessels have two discharge line arrangements. The original (first) line has separate hand-operated globe valves at each vessel. The lines merge to a single 50.8-mm (2-in.) line equipped with a pressure-regulated valve set at 1034.2 kPa (150 psi) that is followed by a safety valve set at 1624 kPa (250 psi). This line supplies branches at four places for process piping. Each of these branch lines is equipped with a pressure-regulating valve with setting ranges of 68.9 to 172.5 kPa (10 to 25 psig). This discharge joins the plant-air piping and is equipped with a pressure-regulator valve set at 620.5 kPa (90 psig). This cross connection has been explained in 4.5 B, above, in describing the air system.

The primary use of the low-pressure nitrogen is for purging process piping and vessels when the piping and vessels in isobutane service are being filled or drained. The nitrogen minimizes corrosion through displacement of oxygen in isobutane piping and vessels. Also, it serves as an inerting medium to reduce the risk of explosion and fire. In the event of plant air pressure loss, when the valving for automatic transfer is

properly aligned, nitrogen gas provides pressure for the fire-deluge system pilot detection, the instrument air, and process area manifold boxes No. 2, 3, and 4.

The second line from the nitrogen-supply tanks is equipped with a pressure regulation set at 3265 kPa (475 psi). This is followed by a relief valve set at 3619.7 kPa (525 psi). This line supplies nitrogen to the lubrication system of the turbine generator. In the event of low pressure due to power failure or oil-pump malfunction, the N_2 pressure enters the rundown tank and forces oil through the pump and piping to ensure bearing lubrication of the turbine-generator system during coast down.

Minor nitrogen leaks do not introduce significant risk because the gas is nonflammable and the major use areas are outdoors. Breakage of small lines 13 mm (1/2 in.) is a viable possibility with injury capability. However, the distribution system is equipped with manual valves near each terminal use, thus permitting prompt local isolation of any significant leak.

A more serious risk potential is the exposure of the fill-system piping and the storage vessel to mechanical damage. The ground elevations in these areas are 1479.8 m (4854 to 4855 ft). The main roadway to the north and west, where the greatest vehicle traffic will occur, is uphill. Elevation at the southwest corner of the Cooling-Water Pump House is 4869. This is a 4.3-m (14-ft) drop in approximately 137.2 m (450 ft). A runaway vehicle could cause severe damage to either the unloading piping, the above-ground discharge pipe near the storage vessels, or to the vessels themselves. The only obstacles that might divert a vehicle is the light pole 2.7 m (9 ft) north and 7.3 m (24 ft) west of the storage vessels, or the wheel bumper block in front (west) of the unloading

nozzles. Standard barricade guard posts have been provided. They will protect the nozzles and extend northward to the roadway north of the storage vessels.

An inherent risk exists at the unloading station. It originates from the possibility of an improper connection to unload. The connections for nitrogen, isobutane drains, and propane are all 52-mm (2-in.) pipe with a brass adaptor, Acme 252, of 82.6 mm (3-1/4 in.). Bold, clear labels and color coding help minimize improper connection. However, the unloading nozzles are being equipped with the connector to accept the unloading hose the supply trucks utilize.

5.1.3 The Isobutane System

The quantity of dissolved solids, chemical make-up, and the low temperature of the Raft River geothermal water makes it undesirable to be flashed directly to steam. Therefore, early research studies determined that a binary system utilizing a heat transfer from the water to a working fluid was desirable; isobutane was chosen. The characteristics of isobutane are presented here to aid in proper recognition of risk that it adds to the 5 MW(e) plant. A review of these reveals:

- o Isobutane, (synonyms 2 methyl propane, and trimethyl methane chemical formula $(\text{CH}_3)_2\text{CH CH}_3$ or $(\text{CH}_3)_3\text{CH}$ or C_4H_{10}) is a colorless, stable gas, noncorrosive to metals, nonreactive with water.
- o Density is 0.5572 at 20°C - Vapor density 2.01 (air = 1)
- o Boiling point is -11.7°C (11°F)
- o Freezing point is -160°C (-256.4°F)

- o Ignition temperature is 462.2°C (864°F)
- o Auto ignition temperature is 543.3°C (1010°F)
- o Flammability (explosive) limits are 1.8 to 8.4% by volume in air
- o Oxygen value below which flame of isobutane vapors are extinguished when nitrogen is the diluent in air 12%. When CO₂ is the diluent in air 14.8%.
- o The molecular weight 58.12

Toxicity^a

Acute local - none

Acute systemic inhalation - slight

Chronic local - none

Chronic systemic - unknown

- o An asphyxiant hazard exists due to vapor density which results in the isobutane displacing oxygen in vessels, pits, or confined spaces.

Based on a dictionary definition, "a liquid which boils at less than about 110 K at atmospheric pressure," isobutane is not a cryogenic fluid (e.g., BP of isobutane = 261 K).

a. Sax Handbook - Dangerous Properties of Industrial Materials.

However, the way in which the isobutane is handled will involve compression and expansion of vapors. Thus, the containment pipes and valves will, at various places, exhibit severe cooling with characteristics and personnel risks similar to cryogenic handling. Isobutane, due to its low boiling point, will be very damaging to human skin or eyes when the liquid is hot or cold.

Isobutane will be delivered to the plant process area truck unloading station. A general risk for this location is discussed in 5.1.2 above, relative to the nitrogen system. Isobutane introduces an additional risk of a flammable liquid vapor. Spark-proof tools for making connections, no smoking, elimination of ignition sources, shutdown of truck engines, and protective (cryogenic) clothing will be enforced. A new regulation required for all plants by December 31, 1980, and effective immediately for new storage facilities has been installed at the 5 MW(e) unloading facility. The new transfer area protection will: provide installation of emergency-shutoff valves to protect against hose failure resulting from a number of circumstances, including ruptures, exposure to fire, and pullaways. Protection is provided to isolate plant piping and the truck in case of transfer-hose failure. Details are in NFPA 58, especially Paragraph 6210(d) of the 1979 code.

The design contractors System Operations Manual^a establishes a complex series of evolutions and checks to bring the isobutane system to operational status. In the introduction to the manual, it is stated, "This manual contains detailed procedures for facility preparation and startup of each system and subsystem. ...It does not contain procedures for operating the

a. Facilities Systems Engineering Corporation Systems Operations Manual for Raft River Geothermal Loop Facility.

facility as a whole." Some of these preliminary plans did not address all risks. It is the intent herein to present only a resume of the major procedural steps for activating and deactivating the isobutane system, sufficient to identify and evaluate omissions or actions that introduce risk.

In preparation for receiving isobutane and for startup, the procedures call for advance preparation of several subsystems. Items of safety concern not specified and involving risk that must be mitigated or accepted are:

- o Careful system check of all isobutane pipe and vessels to ensure that all flanges have the permanent bolts and nuts, and that they are made up with proper tension and thread engagement. This has been done.
- o The fire alarm system is in operation
- o The automatic fire-detection and -suppression system (entire system) is tested and operational. This has been done.
- o The manual calls for the instrument-air system to be 80 psig. However, the automatic-backup system, between the air and nitrogen, is set for nitrogen take-over when air pressure falls below 621 kPa (90 psig). The automatic system may be manually valved out. The importance of dependable operation of the automatic valves and instruments in the vital and more hazardous isobutane handling makes it undesirable to deliberately plan the operation with low- pressure air, or start at 552 kPa (80 psig) with a knowledge that the automatic nitrogen system will be overriding the air. The system has been

improved, assuring adequate pressure, by maintain 965 kPa (140 psig) in the air receiver. System operations will require normal air receiver pressures before startup.

- o Suitable personnel access, without hazard, has been provided for all manual valves, gages to be read, sample stations, etc., for the entire process area.

The first subsystem startup procedure was to fill the isobutane system with water. Initially, the storage vessels and piping were filled, vented, purged, etc., to ensure a water-full (no air) system. This was maintained for a minimum of 4 hours. Subsequently, a lineup of 43 valves were closed and 74 were opened. Additional valves are used to isolate full vessels, entry caps were removed for 5-second venting. Sixteen valves were opened for 5-second venting to flare; 25 valves were opened for venting. Following the initial water system check the piping and vessels have been drained and freed of water vapor. Nitrogen is now being used to fill the system and maintain it when isobutane is removed. New operational procedures and valve lineups are prepared and used.

The next subsystem utilized is the nitrogen system. Procedurally, it involves the flare system, knockout drum, and vapor compressor. Water is forced from the isobutane system by replacing it with nitrogen. Similar to the water-fill operation discussed above, part of the sequence involves groups of valves (25 and 13, respectively). A planned sequence and checklist will be used.

The water-displacement procedure calls for an 8-hour minimum hold time to allow drainage of residual water. Freezing weather would defeat accomplishment of this objective. A risk of overpressurizing the isobutane system from nitrogen exists;

however, the risk is mitigated to acceptable levels by:

- (a) requiring the failure of two automatic pressure-regulating valves at a time when a downstream manual valve is open, and
- (b) upon failure of the pressure-regulating valve at the nitrogen-storage tanks, protection of the pipe and vessels is provided by safety-relief valves. A reverse risk of isobutane entering the nitrogen system if the manual valves were left open is prevented by two check valves plus the two automatic regulating valves.

Piping and vessels that are to be used in isobutane service are a severe fire risk from leakage or rupture. The pressure-relief devices provided for most of the 5 MW(e) isobutane system were designed and installed contrary to commonly recommended safe practice. The isobutane drawings P2 and P3 call for 41 relief valves. Thirty-nine of these had a sight glass that is now replaced by metal and hand-operated valve between the relief and pipe or vessel to be relieved. Twenty-eight discharge to air, and 13 to piping that routes the release to the knockout drum and flare. Five of the reliefs discharging to the piping system have manual valves downstream of the relief also. Any safety expected from the relief-valve system is dependent on valve alignment, so after filling the manual valves below relief valves will be locked open. Tight procedures and compliance control at each operational step involving the relief valves shall be followed.

The originally recognized problems and risk associated with sight glasses has resulted in their being modified. The risk has been eliminated by replacing the glass with heavy metal discs.

Procedurally, the isobutane vapor is used to fill the pipes and vessels by displacing the nitrogen. The vapor compressor is

used to increase isobutane-storage vessel pressure to force liquid from the storage vessels. As isobutane liquid fills the system, the procedure requires that a pressure of 994 kPa (150 psig) be established. In this condition, 26 relief valves are opened manually to vent nitrogen and isobutane. A majority of these relief valves discharge to the atmosphere and will introduce a high fire risk. Operator error, that allows liquid isobutane to be discharged from the relief, creates severe fire and injury risk. Operators are alert to procedural requirements and properly equipped with personal protective equipment. All electrical equipment in the area is designed for Class 1, Group D, Division 1 or 2 and must be operationally complete to be safe. The area shall be considered "no smoking" and "no welding". No spark-producing tools, etc., shall be allowed. The isobutane-detection systems shall be operational and will be given a good functional check during the filling operation.

As filling the system with isobutane is completed, it then is necessary to drain part of the liquid isobutane back to storage, increase temperature to 54.4°C (130°F) by circulating geothermal hot water through the water side of exchange vessels, and establishing desired working levels of the isobutane. As in the preliminary procedural steps above, large numbers of valves must be aligned correctly, e.g., close 54 valves and open 31 valves. Special valves must be adjusted and pumps started. A preferred sequence for valves and checklists will be used to prevent operator error.

When the system is at operational temperature and pressure, it will be necessary for personnel to enter the area for a variety of reasons. Any leak is a fire hazard and may constitute a serious injury risk to an employee if the leak is invisible in the form of a jet of isobutane. The isobutane liquid boils at -11°C (11°F), any skin contact by the liquid, hot or cold,

may cause skin damage. All entry shall be controlled and personal protection specified for the type of work to be done.

The isobutane-system shutdown involves many of the same problems and risks encountered in getting the pipe and vessels full of isobutane for startup. The risks involved with valve sequences for drainback, venting trapped isobutane, or introducing air must be guarded against. The residual risks inherent to the operating personnel performing the work cannot be avoided.

In the plant normal-operating mode, much of the control system will function on "automatic" (e.g., boiler-level controllers sense high or low levels in the boilers and regulate pneumatically actuated valves to regulate flow of the isobutane). Upsets to normal balances, leaks, equipment malfunctions, plus regular checks and measurements will require personnel to enter the area. This involves risk and requires protection and control as described above.

The major risk is fire. The basic control is the automatic-actuated water deluge discussed previously (Chapter 4). The supplemental control is the safety-relief-valve system that prevents a fire from overheating vessels or piping and causing their rupture. Thirteen of these relief valves discharge into a pipe system that removes the hot isobutane from the area to the knockout drum and flare for safe disposal.

5.1.4 The Flare System

The flare with its related components provides important operational control functions. During startup and shutdown, it receives waste-isobutane vapors, isobutane-nitrogen gas mixtures, or water containing dissolved gases and then provides for their safe disposal. During regular operation, the relief

valves on major isobutane equipment are arranged to discharge into a collection system that carries the isobutane to the flare for safe disposal.

The piping for this system is designed for 476 kPa (75 psi) and 137.7°C (280°F). Large-diameter, 508-mm (20-in.) pipe is used to ensure proper movement of the vapor-gas at relatively low pressure and velocity. The "knockout drum," an integral component of the system, serves as a liquid seal, flashback arrestor and water-collection controller, and provides for liquid and gas-vapor separation. The control system is designed and built by the John Zink Company, a recognized builder of this specialized type of equipment. The components and controls are designed to meet National Electric Code Class 1, Group D, Division 2 hazardous-location requirements. These components are located outside of the originally designated hazardous-location boundaries of the process area. The flare-control area has been properly designated and adequate conduit seals incorporated to prevent compromise of required safety. The controls may be operated manually from the panels near the knockout drum (north of the flare pit) or may be fully operated and controlled from the main plant control room.

An important component of the flare system is the inert-gas generator which supplies inerting gas to the liquid seal part of the knockout drum. This generator is totally contained, to be safe in a hazardous area. It receives propane gas regulated to 56.9 kPa (8.25 psig). Plant-industrial air is provided for combustion air at 27.6 kPa (4 psig). The flare system is fully equipped with a safe-firing mechanism including: purge, purge timing, purge completion, ignition, ignition trial timing shutdown, gas solenoid, flame proven or failure shutdown, flame scanner, trouble alarm and flame failure. Combined with the firing safety devices are controls for the air supply ensuring

it is providing adequate air, control on pressure of the propane gas (e.g., high- and low-pressure switches), and finally, oxygen analyzer causing shutdown if the O_2 exceeds 2% by volume in the inert-gas stream. When maintained and operated properly, these are safe components. Modifications, changes, improper maintenance or bypassing safety controls, may result in a component or gas explosion. Adequate administrative controls to ensure disciplined operation are established to minimize risk and probability of an accident.

The flare function is keyed to a pilot flame established in the flare pit from a flame front generator. Its control panel uses piped-in propane gas at $0.001 \text{ m}^3/\text{s}$ (150 SCFH) and air supplied at $0.012 \text{ m}^3/\text{s}$ (1500 SCFH). The gases are mixed at the panel and released to the ignition line that extends to the burner inside the flare pit. Electrical power is extended to the end of the ignition line where an electrical-igniter spark creates pilot ignition. Separately, a pilot-gas-supply pipe provides propane at 103.4 kPa (15 psig) for the main pilot flame. This component is regulated by local or control-room signals which indicate whether the air and gas valves are open and that the pilot flame is proven.

When the pilot flame is proven, flare fuel from the knockout drum enters the first-stage system piping to three burners, located immediately adjacent to the pilot flame. As flare fuel flow increases, remote-controlled valves can be opened to divert fuel to the 9-burner second stage or 18-burner third stage. Ignition of these burners is by propagation from the first-stage burner.

Major risk is reduced by component design and construction. Residual risks recognized are: the components and their operating controls are outdoors, thus, subject to possible

failure from severe cold and dust typical to the area. Anyone in close proximity to the flare pit could suffer radiant heat burns when a major upset in the process area releases large quantities of isobutane. There is no area warning signal triggered in conjunction with a major release to the flare. Entry to the fenced flare area shall be controlled during plant operations. The 4.27-m-(14-ft)-high flare pit depth does not provide significant heat shielding due to the height of the burners above the pit bottom (2 m 6 ft). A special metal shield has been provided between the pit berm and the operator control stations.

5.1.5 Cooling-Water System

Geothermal water processed through the water-treatment system is accumulated in the Cooling-Tower basin and pump pit below the Cooling-Water Pump House. Two 223.8 KW (300 hp), 1775 rpm, electric motor-driven primary-cooling-water pumps take suction from the pump pit and discharge through 45.7-cm (18-in.) lines to the 61-cm (24-in.) main cooling-water loop piping. Normal operating demand is $0.97 \text{ m}^3/\text{s}$ (15,400 gpm) at 358.57 kPa (52 psig). The water flow is directly to the process area where three cooling functions are performed. These are:

- o Two passes through the isobutane condenser, tube side. Flow is directly from the main header and a hand-operated valve is used to establish the flow rate. High-pressure and temperature alarms alert the operator to take corrective action. The objective is to ensure that the isobutane- discharge temperature does not exceed 46°C (115°F).

- o A 102-mm (4-in.) pipe takes water from the main loop for the turbine-generator lubricating-system cooler and a 76-mm (3-in.) pipe takes water for the generator-cooling system.
- o During transfer of isobutane, a 51-mm (2-in.) pipe takes water from the main loop to provide a single pass through the tube side of the vapor condenser. Flow regulation is aimed at keeping the isobutane temperature below 32.2°C (90°F). Water from these systems is combined to form the return to the Cooling Tower. A flow element monitors this stream for low flow and signals the control room if it occurs.

At the Cooling Tower, the return header is divided to two risers (retaining full size for each) to the upper level of the tower, or the full stream may be routed directly to the tower basin. Temperature sensors in the water aid in regulating the way water is processed through the tower, e.g., one side, both sides, fans on low, fans on high. The water is collected in the Cooling-Tower basin, moves through a flume to the Cooling-Water Pump House pump pit for pump suction and recirculation. Also, the return header is used to supply a 38-mm (1-1/2-in.) pipe stream to the blowdown treatment system.

While the cooling water is in the Cooling-Tower basin, it may receive make-up water, dilution water, inhibitors, sulfuric acid, and chlorine. Excess water in the basin or pump pit is removed by a 152-mm (6-in.) overflow pipe that drains to the blowdown-system holding pond.

The greatest risk associated with this system is a containment-boundary failure between the isobutane and water in the condenser. To a lesser degree, the same risk exists at the vapor condenser. An isobutane detector (see description in

Chapter 4 Section 4.6.5 is provided to sense isobutane in the cooling water. The detector will send an alarm to the control room. If a major failure occurs within the condenser, there will be a pressure increase in the cooling-water pipe. Protection for the pipe are relief valves on 19-mm (3/4-in.) lines; one on the incoming pipe of the isobutane condenser and one on the discharge pipe of the vapor condenser. The reliefs are designed for the cooling-water operational system only, since the piping is Series 900 with a 1034.2 kPa (150 psig) at 66.6⁰C (150⁰F) design, whereas the cooling-water pump-head pressure is only 373 kPa (54.1 psig), the reliefs, on the cooling-water pipe, are not adequately designed for the 1585.8 kPa (230 psig) pressures designed for isobutane condensate. The risk of concern is not cooling-water pipe failure, but transfer of isobutane to the Cooling Tower as discussed in Chapter 8 Section 8.1.3, and Section 5.4.2 of this chapter.

5.2 Process Chemistry

The operations at the 5 MW(e) Raft River Research and Development Plant involve chemical processing only to allow utilization of geothermal water for make-up to the cooling system. Three processes are involved:

- o Pretreatment of the make-up for removal of silica and hardness
- o Treatment of the cooling water to prevent corrosion and scale formation
- o Treatment of the blowdown for removal of phosphate; this sludge must be removed to an approved disposal site.

In addition to the chemical-treatment processes, ponding or disposal of effluents is required. Due to the vapor loss from the plume of the Cooling Tower, the make-up rate is expected to be approximately $0.0217 \text{ m}^3/\text{s}$ (344 gpm). This concentrates the solids in the cooling-water system and requires blowdown to limit the concentration. Both the cooling water and the blowdown require chemical treatment; the cooling water to control corrosion and scale formation and the blowdown to remove phosphate. Sludges are formed in both the make-up water and the blowdown treatment. A general discussion of the physical facilities was given in Chapter 4, Section 4.3.1. More specific chemical procedures and related risks in accomplishing the chemical processing objectives are given below.

5.2.1 Pretreatment of the Make-up

A geothermal-water supply stream is removed from the process system after the water has completed its cycle through the system and before it enters the piping to the injection wells. A 152-mm (6-in.) supply pipe delivers the geothermal water from the process area. It enters a static mixer where lime and MgCl_2 are added, it passes through the direct gas concentrator and is routed to the top of the warm lime softener TK-1429, located on the southeast side of the Cooling-Water Pump House. Inside TK-1429 chemical reactions take place which reduce the levels of silica and hardness. These reactions also form a layer of sludge in TK-1429 which is recirculated by means of a sludge recirculation pump 1402, this sludge acts as a seed for the precipitation reaction which takes place in TK-1429. Soda Ash and a polymer, which aids in settling of the sludge blanket, are also added to the softener. The effluent low silica water then leaves the softener. To this effluent is added dilute sulfuric acid to reduce the pH of the water in order to prevent cementing of the filters due to CaCO_3 precipitation. The water then flows through four anthracite filters where suspended

solids are removed. The water then flows to the makeup water pump 1407 and through the level control valve CA-957 and finally to the cooling tower basin as makeup water.

When dissolved solids of the recirculating cooling water reaches a specified amount, then the cooling water basin must be blowdown. The blowdown water comes off the 61 cm (24 inch) return line before the makeup water is added. This blowdown water is sent to the chemical destruct unit, where the phosphate is removed and the clear water is then reinjected by means of a pump and ponds 705 and 706.

During cooling water system shutdowns and when trying to bring the makeup water within specifications the Water Treatment System will be put into total bypass. The water will flow from the softener back to the softener. Any needed makeup water will be added either from: 1) the industrial water system; or 2) the auxiliary line from the Geothermal Heat Loop in the cooling tower basin. The sludge blanket will be maintained by addition of chemicals as needed.

As part of this phase of the chemical processing, piping and pumps are provided to: dilute the chemical make-up tank feed, recirculate chemical feed, backwash the filters, transfer sludge, and drain, flush, and backwash the warm lime softener. The waste sludge may be transferred from the system for holding in the sludge thickener tank 1430, or further routed to the sludge-holding pond(s).

5.2.2 Corrosion and Scale Prevention and Special Treatments

In addition to pretreatment for make-up, additional water conditioning is provided.

- (1) A chlorinator is provided that meters a 25-mm (1-in.) line of gaseous chlorine directly into the Cooling-Tower basin water.
- (2) Sulphuric acid from storage tank 1421 in the Cooling-Water Pump House is pumped in a regulated quantity to an acid-dilution unit for discharge to the Cooling-Tower basin.
- (3) Feed Tanks 1419, 1420, 1441, and 1442 are used to receive and mix inhibitors for direct-pumped streams to the Cooling-Tower basin. The solutions include dispersants and inhibitors. Present considerations based on Betz Corporation chemicals include the use of:
 - o Betz 2020 dilute at 5% to pH of 5.9
 - o Betz 426 a sulphinated polystyrene
 - o Betz 35A, a polyphosphate
 - o Betz 562C for copper inhibiting.

Final water treatment includes small quantities of highly toxic Slimesides and Biosides such as Betz C-30, and Betz 508. These will probably be directly metered to the Cooling-Tower basin water.

5.2.3 Treatment for Removal of Phosphate

The main condenser utilizes ASTM A179 carbon steel tubes of 19-mm (3/4-in.) diameter with the 85 mil wall thickness. The use of phosphate to inhibit corrosion was required as an alternate to the undesirable chromium. At full-plant operation, the vapor plume loss from the Cooling Tower will concentrate

dissolved solids in the water; therefore, a continuous blowdown stream is utilized to limit the solids increase and permit the chemical treatment balances to be maintained.

Blowdown water from the cooling tower basin is treated by the Crane-Cochrane Unipac System located in the cooling water pumphouse. The Unipac system provides for removal of the residual phosphate corrosion inhibitors.

The blowdown water is received in a 350 gallon fiber glass phosphate holding tank (TK-1426).

Pump P-1414 delivers the blowdown water to the phosphate removal clarifier tank (TK-1423). A caustic reagent and a polymer are then added, through pumps P-1411 and P-1410, from supply tanks TK-1425 and TK-1423.

Sludge is removed from the tank by pump P-1409 and delivered to a sludge holding tanker, it is then transported to an appropriate landfill. Backwash tank, TK-1422 and pump, P-1408 are used for backwashing the clarifier tank. The effluent water goes to a lined pond, #706.

A sludge thickener tank is located outdoors adjacent to the warm lime softener tank. It is 2.44 m diameter x 3.66 m high (8 ft x 12 ft) and is equipped with a rotary scrapper. Thickened sludge (30-40 percent solids) is removed from the tank bottom by the sludge transfer pump, P-1416. The pump adds a small amount of flush water to assist the flow at four to five gpm, through the 152.4 mm (6 inch) line to the sludge ponds.

There are two sludge ponds. Each is approximately 53.3 m (175 feet) square on the bottom and has sloping side berms. The ponds have a holding capacity of 1893 m^3 (500,000 gallons)

each. The ponds are also used to receive wash and drain waters from the Cooling Water System as well as the storm water from the Sewage System.

The clear water out of TK-1430 overflows to TK-1436 located in the Cooling Water Pumphouse. The water from TK-1436 is pumped to the suction side of P-1402 by means of the clearwater return pump P-1415. TK-1436 is equipped with high and low level switches. These switches control P-1415.

5.2.4 Process Chemistry Safety Analysis

The general safety problems and controls are discussed in Chapter 4, Section 4.3.1 and Chapter 7, Section 7.3.14; therefore, the analyses given here are for specific problems.

- (1) Weekly supplies of bulk chemicals greatly exceed the storage facilities originally provided. Temporary facilities are arranged to accommodate storage in No. 1 well area. The use rate of the three major chemicals indicates a weekly consumption of approximately 15 522 kg (34,000 lbs). Major movements will be by forklifts, trucks, and the overhead crane. Bulk supplies of chemicals already in solution are to be stored in tanks furnished by the supplier. Piping arrangements to meter these to the use tanks will be arranged by plant operations.
- (2) Final handling of chemicals, after the major transfer in bulk, is manual by operations personnel. Facilities to improve have been installed, further improvements gained through operational handling is anticipated. However, the use of protective clothing, and eye and respiratory protection, will still be used. The change-out of chlorine

cylinders and any manual handling of highly toxic biosides and slimesides are recognized as hazardous and will be performed only in accordance with approved procedures.

- (3) The present safety shower-eyewash unit is centrally located near the sulfuric-acid pump. The chemical handling and mixing by manual evolutions are primarily at the opposite ends of the Cooling-Water Pump House. Special supplementary emergency wash equipment will be provided at these areas.
- (4) Transfer of the chemicals within the building involves overhead piping near three of the building walls. To meet safety requirements for this risk, a large leak-drip trough will be installed below these pipe runs.
- (5) Piping vibration and sway bracing, especially for some threaded plastic pipe, was improved to minimize failure.
- (6) The changes of chemicals resulting from a process change required piping modifications and additional vessels. These changes ensure that the planned chemical process transfers will be handled safely.

5.3 Mechanical Process Systems

5.3.1 Vapor Compressor

A hand-operated four-way valve is located on a 102-mm (4-in.) discharge pipe from the isobutane-storage vessels. At this four-way valve, the alignment diverts isobutane vapors into the compressor system. The vapors pass an electrical heater, a

scrubber (liquid separator), the compressor, a pulsation bottle and are redirected by the four-way valve into the plant piping. A series of piping and valve-alignment capabilities permits several options for suction and discharge arrangements. The compressor also is designed to operate from two suction pressures and at different temperatures.

The specifications call for a standard commercial vapor compressor. However, the location of the unit is in the process area that is designated "hazardous." To meet the hazardous requirements, a NEMA 7-rated unit was provided. This complies with the basic need, but NEMA 7 equipment is UL-approved for indoor locations; the installation is outdoors. The main drive motor on the compressor has been replaced to meet Safety Code requirements for the outdoor service Class 1, Group D, Div.1.

The scrubber and pulsation bottle are each equipped with a safety-relief valve that relieves to atmosphere. The scrubber also has a drain that relieves directly to atmosphere. These reliefs, when operated, will discharge isobutane. A probable ignition source is from vehicles on the roadways 7 m (22 ft) to the north and east of the vapor compressor. The physical location of the unit is on a concrete pedestal, approximately 1.2 m (4 ft) above grade. An access stair and ladder with guard rail have been installed. The unit is now in compliance with OSHA safety requirements.

5.3.2 Isobutane-Water Separator (WS 101)

Some of the FSEC documentation refer to this as a dryer (D 101). A 25.4-cm (10-in.) pipe loop from the 30.5-cm (12-in.) isobutane-circulation line exists downstream of the main isobutane pumps. This permits the liquid isobutane to enter

vessel WS 101 where a vertical filter-separator provides cleanup by coalescer elements and separator elements. The purpose is to remove entrained water to a maximum of 5 parts per million and particulate solids to 1 micron nominal size.

The vessel operates at 2.9 mPa (416 psig); design is for 4.5 mPa (650 psig). Operation temperature is 40.5°C (105°F); design is for 160°C (320°F). A safety-relief valve is provided; however, it has the typical plant manual valve between the vessel and the relief valve. A drain provided for draw-off has two control valves and is piped into adjoining drains from the low-pressure and high-pressure preheaters. The drain then joins the 50.8-cm (20-in.) main drain to the knockout drum and flare. Since the above-ground portion of this line is subject to freezing, it has electrical heat tracing. The equipment does not create functional risk, but one residual risk is present: (a) power outage during sustained cold could cause drain-line freeze.

5.3.3 The Turbine Generator

A specially designed reinforced-concrete platform was prepared to accept the turbine, its gear box, and the 5 MW generator. The mounting of these three units is on a single steel base accommodated by the platform. An integral part of the installation is the lubrication and its cooling system which are located beneath the platform. Only a brief resume of specifications^a to facilitate safety analysis is given.

a. Details are in the Burns and Roe System Design Description for the Raft River Turbine Generator Installation.

Two hot pressurized isobutane-vapor streams, 35.6 cm (14 in.) from the high-pressure and 30.5 cm (12 in.) from the low-pressure boilers are routed to the inflow nozzles of the two-stage radial turbine. The discharges are combined to exhaust directly to the water-cooled condenser. The isobutane flow rate is controlled by throttle valves and backflow is governed by the condenser pressure. The normal turbine shaft speed is 8272 rpm which enters the gear box for reduction to the driving shaft speed of 1800 rpm. Power transmission is 6606 kW (8857 hp). The generator is a Type SAB Horizontal Brushless Synchronous generated rated at 7200 kW, 4160 V, 1110 amps, 1800 rpm, 8000 kVA, 70⁰C rise by thermometer. It has Class B insulation, is totally enclosed with a top-mounted single tube type air-to-water heat exchanger. It is electrically connected in parallel with the facility grid.

Careful attention was given to ensure that the specifications were correct and complied with for the main and auxiliary support equipment, e.g., air, cooling water, nitrogen, and oil. They are suitable for the required temperatures and pressures. The equipment location is considered "hazardous" in accordance with the National Electric Code. Therefore, intrinsically safe or explosion-proof items were used. The generator, not available as explosion-proof, is totally enclosed with a water-cooled air system and brushless generator and exciter.

A nitrogen-supply pipe, direct from the storage vessel, receives gas reduced to 3102.7 kPa (450 psig) initially and finally to 206.8 kPa (30 psig) where it is used for emergency pressurization of the lube oil run-down tank. This ensures that lubrication continues when a power outage interrupts operation of the lube-oil pumps. Both the oil-reservoir and seal-oil drains have vent demisters to recover lube oil and eliminate any

isobutane. When leakage of isobutane through the oil seals is severe, the waste isobutane is rerouted to the turbine- exhaust or plant-flare collection piping.

A comprehensive component check and test procedure, suitable for the equipment involved, has been developed to guide and assure safe operations. The subsystems involved include:

- o The electrical systems
- o The cooling water
- o The isobutane
- o The fire-protection pilot and deluge.

The checks and tests have proven that safety, operational, and code requirements were incorporated, are functioning, and introduce no unacceptable risk. Analyses of the residual risk potential reveals:

- o Containment failure of the isobutane supply, exhaust, or in the turbine. Normal operation calls for flow rates of 117.68 kg/s (934,000 lb/hr). Failures such as a flange gasket, valve packing, or stress cracking, must be considered serious. The detection from an isobutane-leak detector or operation instrumentation will be prompt if the leak is very large. Thus, a prompt shutdown can be made. If a leak results in a fire, the area deluge fire-suppression system is designed to function automatically to control any expected fire.
- o Physical access and guarding is good. There is a permanent stairway to the south end of the platform. The elevated area around the turbine and generator provides walkway space and has a standard guard rail and toeboard. A new

egress from the north end of the platform, has been provided to minimize risk of being trapped there.

- o Overspeed and excess vibration that may cause damage to the turbine or generator are prevented by detectors that send alarm signals to the control and will trip the units off.
- o Major vessels and piping have safety-relief valves. This includes proper relieving for the components of the lube-oil system.
- o Fire risk is minimized by requiring the facilities and equipment to meet the National Electrical Code requirements for "Hazardous Location." The automatic deluge-water-spray system is designed to protect the vessels and their supports. The detection system is an air-pilot closed-head system backed by the nitrogen-gas system in the event of an air-system failure.
- o Cooling-water supply is part of the main plant system. A failure will prompt plant shutdown. There is risk from freezing if shutdown occurs during severely cold weather. Provisions have been made to facilitate removal of water from the cooling-water pipe risers. Special attention by operators will be necessary to ensure that cooling units on the generator and lube-oil system are drained. Drain pipes and valves are provided.

5.4 Process Support Systems

5.4.1 Industrial Water

The water system origins at Raft River facilities are developed from either the geothermal water of deep wells or domestic water

of shallow wells. At the 5 MW(e), the industrial-water system(s) are developed from shallow wells and are not identified until specifically removed from the domestic fire-water distribution system.

Two separate water systems are designated as "industrial water." First, below the sprinkler riser control valve in the Cooling-Water Pump House (CWPH), a pipe reducer provides a connection for a 102-mm (4-in.) industrial-water line. A Clayton Automatic Model RP-1 Back Flow Preventer, which has manual control valves at its entrance and discharge separates the domestic fire-water from the industrial water. The industrial system provides water for:

- o A 25.4 mm (1 in.) for sludge system flushing and circulation
- o A 31.7 mm (1-1/4 in.) for an industrial safety shower
- o A 152.4-mm (6-in.) cross-tie for cooling-water make-up
- o A 25.4 mm (1 in.) for inhibitor feed tank dilution
- o A 25.4 mm (1 in.) for acid dilution
- o A 25.4 mm (1 in.) for sample taking.

The system incorporates differential pressure relief to 13.8 kPa (2 psig). It has three test cocks and when properly set, it should introduce no contamination risk to the potable water.

The second industrial system originates at the west side of the process area. On the fire main north-south run, just south of the supply to the process area deluge-sprinkler supply, there are reducers converting the 25.4-cm (10-in.) tee branch to a 50.8-mm (2-in.) industrial-water supply. From this connection, there is a butterfly-isolation valve, then a riser bringing the pipe above ground. The above-ground pipe is equipped with a backflow-prevention system similar to the one in the CWPH,

described above. This originally supplied nine discharge connections into the process equipment; they are now out of service.

No unacceptable risks are involved in the CWP system, although trouble has been experienced with water hammer from fire-pump restart causing gasket failure. A pressure surge chamber immediately downstream from the fire pumps is being installed to mitigate this risk.

In the process area, the above-ground pipe is electrically heat traced and insulated for freezing protection. A power failure during cold weather will result in a freeze-up failure of the pipes. No provision is made for drainage. An operator failing to close the ball valve at any of the isobutane piping connections will result in the higher pressure-temperature of the isobutane system being imposed on the check valve; thus, introducing a higher risk of failure, fire, etc., than desirable. Procedures and operator-check systems are used for control.

5.4.2 Cooling Tower

A "Marley" Class 600 crossflow, two cell, one fan per cell, Cooling Tower is provided to permit regulation of temperature in the primary-cooling water. The tower is built above the concrete cooling basin which serves as the foundation. The tower is structurally framed with 102-mm x 102-mm (nominal 4-in. x 4-in.) wood columns on 1.2-m (4-ft) centers longitudinally and 2.4-m (8-ft) centers transversally. Horizontal bracing is on 1.8-m (6-ft) elevations. The lumber is treated fir, bolted together with corrosion-resistant bolts, and supplemented by special connectors and shear plates at major

structural joints. The ends are cement-asbestos and the top flooring is fir. The fill is polypropylene, the louvers along the sides are 9.5-mm (3/8-in.) corrugated-asbestos cement board on 0.9-m (3-ft) vertical spans. Each cell is serviced by an independently supported 0.61-m (24-in.) pipe discharging water for cooling. The water can be discharged to one or both sides of a cell or directly to the Cooling Tower basin. Distribution to the fill area is by polypropylene target nozzles on 0.3-m (1-ft) centers.

Each cell has a glass fiber reinforced velocity cone containing an eight blade fan 8.5 m (28 ft) in diameter. The fan blades are made of reinforced polyester and are attached to a welded steel, epoxy coal tar coated hub, that is covered by a molded fiberglass nacelle. The fan-gear box transmits the drive shaft power from an 59.7 kW (80 bhp) electrical driver located on the outside of the chimney. The motors have two speeds, with control initiated from the operating control room, or alternately may be run in reverse for periods of less than 20 minutes each to improve de-icing of the tower.

On the east end of the tower, there is an access to the fan deck provided by an open stairway with proper guard rails. A vertical, caged, ladder is provided on the west end. Standard guard rails are used to protect all exposed elevated floor areas. Access to the inner chimney (fan and gearbox) requires mechanical disassembly of an access section of the chimney. Access scaffolding will be necessary for maintenance on the fan or gear system. At ground level, there are access doors at each end of the tower and a walkway above the basin from door to door.

The tower is designed to withstand a 1436.4 Pa (30 psf) flat-wind load and to handle expected icing loads with properly

regulated operations. Fire protection is provided by a closed head air-pilot-activated, open head deluge-water spray system. Hand extinguishers are at each end of the tower and on the fan deck. The fire-suppression system was installed and then coated for corrosion protection, so careful inspection after a period of operation will be necessary to ensure that areas of piping are not corroding.

The most serious risk is from a major internal boundary failure between the isobutane-cooling water separation (e.g., condenser). Although prompt detection would be expected, the greater pressure of isobutane would, assuming the cooling-water piping will not fail, be relieved to the Cooling Tower. The tower electrical system is not explosion proof and would provide an ignition source for any isobutane-air mixture in the explosive range. An emergency plant shutdown would minimize, but probably not completely eliminate, this explosion risk.

Cooling-Tower fan blades are subject to icing that causes imbalance and vibration. They are equipped with vibration-sensitive switches that will cause automatic shutdown. The fan motors are also protected against quick rotational change by a 2-minute delay, when a forward to reverse or, vice-versa, change is made. Operational procedures incorporates a longer delay as a safety assurance.

During cold weather, special observations will be necessary to establish the degree of risk from Cooling-Tower vapor freezing on the adjacent electrical substation. This is important because of inversion, weather, and wind variations. It is especially important during de-icing, when the tower fans are reversed and vapor flow would be forced toward the substation.

Wind conditions and snow may cause severe icing of the weather-exposed access stairway. If this cannot be controlled by de-icing compounds, the stairs may require enclosure.

Operational procedures ensure personnel safety for entering or working on the Cooling Tower during operation. They reflect precautions that are commensurate with the risk introduced by the chemical treatment of the cooling water and mechanical hazards.

5.4.3 Holding and Cooling Ponds

Three ponds are provided for process support, by water holding, cooling, and process system make-up sludge. The pond nearest the process area contains a vapor-separator vessel, which initially receives incoming water, allows a release of vapor out of the top to atmosphere, and has a 0.46-m (18-in.) discharge for flow into the pond. A concrete sump in the southeast corner of the pond provides a pump suction for pick-up of water to be diverted through a 15.2-cm (6-in.) pipe to the geothermal-injection system piping. This pond is lined with "Bentonite" and may have water depths to 1.5 m (5 ft). Water near the vapor separator could be sufficiently hot on some occasions to constitute a risk to anyone falling into it.

The center pond is lined with plastic protected by an earth and rock covering. It will receive liquid-solid waste from the blowdown of the water-treatment system. Physical cleanout will be necessary from time to time as the pond area fills with solids from the sludge. This pond is relatively shallow, but will create risk to personnel because of the chemical make-up of the contents (see Subsection 5.2 for details).

The third pond is shallow, unlined, and is primarily for standby service.

A fence between the process area and ponds provides a personnel barrier and permits administrative control for access. Since there is little need for maintenance or other work in the pond area during operations, risk is minimal. When cleanout and sludge handling becomes necessary, a job evaluation and safe work procedure will control the work.

5.5 Instrumentation and Control Systems

5.5.1 General

The instrumentation and control systems have four major purposes in the Raft River Research and Development Plant operation. These systems include the components, instruments, and wiring necessary to:

- o Obtain adequate, accurate, and timely data in support of the "Research and Development" objectives of the plant.
- o Provide warning signals to alert the operator to any malfunctions or hazardous situations developing within the plant equipment
- o Provide a remote-control capability for all the valves and motors deemed functionally critical to the operation
- o Provide an orderly, nondamaging, controlled shutdown of the plant and equipment when necessary.

Underlying these objectives is the necessity for ensuring the safety of the plant, personnel, and equipment. The

instrumentation and control systems will be reviewed within broad categories to determine compliance with the safety aspect (only) of these design objectives.

Virtually all of the remote-reading instrument systems are of the type that utilize a transducer to convert the variable parameter signal to a 4-20 milliamp signal for transmission to the remote-control room. The power supplies for these systems are located in the control room. Signal-conditioning equipment mounted in the control panel adjusts the signal to be compatible with the computer/multiplexer input requirements.

Local-reading instruments read directly in engineering units as applicable.

Accuracies for both local-reading instruments and remote-reading instrument systems have been specified in accordance with good industrial practices.

5.5.2 Data-Processing System

The instrumentation system for gathering, recording, and processing experimental data is based generally on a 16-bit general purpose stored program digital computer. All incoming signals from the field are processed through a 256-input multiplexer for sequential handling by the computer. The computer and its peripherals are referred to as the plant data processing system.

The data-processing system consists generally of the digital computer: the input multiplexer, the cathode ray tubes (CRT) for readout and alarm, tape and disc storage, and the line printer for hard-copy data records (see Figure 5.1). The primary purpose of the plant data system; i.e., the computer and

*FIGURE 5-1 DATA-HANDLING SYSTEM
BLOCK DIAGRAM*

its peripherals is the handling of data in support of the research being done at the plant. The total loss of the computer system will not compromise the capability of the operator to start up, run, or to shut down the plant in an orderly manner. All parametric readings critical to plant operations are displayed on digital indicators on the graphic panel. These indicators will continue to function regardless of the status of the computer. However, because the operation of the plant without the computerized data handling leaves the operator ignorant of so many parameters, and because the recorded data is a primary product of the program, there will be administrative procedures requiring the orderly shutdown of the plant under these circumstances.

- (1) Multiplexer: The multiplexer is presently capable of accommodating 256 input signals from the field instrumentation. There are presently 219 active inputs. Future expansion of the multiplexer, if found necessary, can be effected by adding electronic modules.

The failure of the electronic multiplexer could take the form of open circuits, short circuits, grounds or freeze with nonvarying data. Regardless of the cause of failure, the net effect is the same. One or more parameters being input to the computer will not reach the computer for data handling. Historically, the most common type of failure for an electronic multiplexer is a "collapse" of the system. That is, due to a component failure, the incoming signals are not sequentially fed to the computer. These signals may be random-fed or not passed on at all. However, because the computer and its peripherals are not required for plant operation or for protection of equipment and personnel, the failure of the multiplexer in any mode is considered to be an acceptable risk.

Failure in the multiplexer would be quickly detected by the operator because of the number of sudden anomalies in the data. As with the loss of the computer itself, it is recommended that failure of the multiplexer be cause for an administrative shutdown of the plant. It is not, however, dangerous to personnel or equipment to operate the plant without the supporting data handling of the multiplexer.

- (2) Computer: The computer mainframe is used strictly for the logging, storing, and processing of the data provided from the field in support of the experimental program. It does not have any function in "controlling" any part of the plant or process. Any failure of the computer would compromise the validity of the overall data in support of that particular test. It would not jeopardize plant equipment or personnel.
- (3) Computer Peripherals: The generic term "peripherals" includes all of those electronic components and chassis shown in Figure 5-1 which complement the computer in managing the data provided from the field instrumentation.
 - (a) Cathode Ray Tubes (CRTs): There are three CRTs provided for the immediate display of specific data inputs. One CRT displays all alarming parameters. The other two CRTs display parametric data on a call-up basis. The keyboard of the third CRT is also utilized to instruct the computer and the line printer in the requirements for "hard copy." A failure in the CRT system would deny the operator access to the data indicating status of the plant processes and equipment. It would also negate any alarms from these data setpoints. However, all parameters deemed critical to the protection of equipment and personnel

have been connected directly to annunciator panels, bypassing the computer-based system. Therefore, failure of the CRT system is an acceptable risk. As stated earlier, operating and administrative procedures will require a manual shutdown due to this lack of visibility.

- (b) Modem: The modem unit is used to transmit data via commercial telephone lines between this computer and a remote unit. Because this data handling is primarily an administrative procedure, loss of the modem unit poses no unacceptable safety risks.
- (c) Paper Tape Reader: The paper-tape reader unit is used strictly for the trouble-shooting and maintenance of the computer and has no function pertinent to operation of the plant or processes. Loss of the paper-tape reader, therefore, infers no safety risks.
- (d) Digital Clock: The digital clock provides signals to the temporary and permanent data-storage equipment to clarify sequence of events recorded. Its loss or failure implies no safety considerations.
- (e) Battery: A storage battery is provided to ensure a retention of stored data for up to 20 minutes of a total loss during commercial and backup plant power. Loss of the battery, and hence of the stored data, has no safety implications to personnel or equipment.

5.5.3 Field Instruments

The instrument systems installed in the field have all been specified to be good standard industrial-quality instruments

rated for the service and environment intended. All instrument systems are based on a current loop. The transmitters develop a 4-20 ma signal which is proportional to the parameter being monitored.

Within the portions of the process area so designated, all instrumentation components are rated at Class I, Division 1 or 2, Group D Hazardous Location, in accordance with requirements of NFPA and the National Electric Code. All wiring from the field instruments back to the remote-control room utilizes two conductor No. 16 cables with a 100% overall shield. All of the wiring is totally enclosed in conduit for the electrical and physical protection of the wiring.

- (1) Temperature Measurements. All temperature measurements for remote monitoring are made utilizing "resistance temperature detectors" (RTDs) for accuracy and reliability. The RTD is spring-loaded into a thermowell which is placed in the piping or vessel to sense the most extreme conditions. The output signal of the RTD is converted by a transmitter to a 4-20 ma signal for transmission to the remote-control room. The RTD and transmitter are totally enclosed in the steel thermowell to afford maximum protection from physical damage. In the case of isobutane piping and vessels, the thermowell is seal-welded in place to preclude any leakage of the hazardous gas or liquid.
- (2) Pressure Measurements. All pressure measurements for remote monitoring are made utilizing pressure transducers with direct access to the primary fluid being sensed. The transducer converts the variable pressure to a 4-20 ma signal for transmission to the remote-control room. The pressure transducer is rated "explosion proof" to preclude

any undue hazard from the gases in the vicinity. It is housed in an insulated and heated enclosure to protect it from the elements which might have occasioned an early failure of the system. All sensing lines are heat-traced and insulated to preclude freezing damage.

- (3) Differential-Pressure Instrumentation. The differential-pressure measurement systems are exactly the same as for pressure measurement, except that two pressures are sensed and compared. The transmitted signal is proportional to the difference between the two pressures.
- (4) Flow Instrumentations. The instrumentation to measure the flow rates in the various piping systems may be either of two types:
 - (a) Sharp-edge orifices with the difference in upstream and downstream pressure being proportional to total flow.
 - (b) Turbine flow meters with the rotational speed of the small turbine being directly proportional to the total flow.

In either case, the electrical transmitter and its related support equipment are housed in heated enclosures for protection from the weather. The components are rated "explosion proof" to preclude any undue hazard from gases entering the enclosure.

- (5) Level Measurements. The level instruments generally are of either the displacer type or the totally electronic type. As with other transmitters, where required, the unit is rated for Class I, Division II, Group D Hazardous Location.

- (6) Redundancy of Instruments. A review of the simplified flow diagrams (Figures 5-1, 5-2, and 5-3) demonstrates that both explicit and implicit redundancy in the application of instrumentation will minimize the potential for loss of data due to instrument system failure. In almost all cases, the loss of a single data point can be extrapolated from adjacent data points with sufficient accuracy to negate any need for shutdown. In many cases where the measurement is more critical, a second confirming measurement is made by an identical and independent instrument system. This too, obviates the need for a shutdown.

5.5.4 Geothermal-System Instrumentation

The instrumentation installed to monitor the geothermal-water system temperature, pressures, flows, etc., has all been specified to be standard industrially rated instruments. The ranges specified were such that the instrument will be operating well within its capacity during all normal plant operating conditions. Accuracy and repeatability are also specified in accordance with good industrial practice.

The process instruments associated with the geothermal system are generally placed as shown in the simplified loop diagram in Figure 5-2. Virtually all these instruments and/or parameters are monitored by the computer. In addition, those shown with an asterisk (*) are also read out on a digital indicator suitably located on the graphic panel. For convenience, these instruments are also summarized in Table 5.1.

- (1) Instrumentation Failure Modes. Generally speaking, failure of the individual instrument systems can be assumed to be one of the following modes:

GEOTHERMAL-FLUID SYSTEM-Process Area

FIGURE
5-2

COOLING-WATER SYSTEM

FIGURE

5-3

TABLE 5.1 GEOTHERMAL-SYSTEM INSTRUMENTATION

Instrument Number	Parameter	Read Out	Mux ^a	Annun ^b
AE-1	Isobutane in geothermal water	Local	None	Yes
AE-3	Geothermal water Ph	Local	None	Yes
FE-306	Bypass flow around plant	Gr Pnl	127	No
FE-865	Geothermal water from plant	CRT	88	No
FE-880	Bypass flow around plant eq.	Gr Pnl	87	No
FE-887	HP boiler inlet	Gr Pnl	77	No
FE-892	Geothermal water to plant	Gr Pnl	84	No
TE-895	LP boiler discharge	Gr Pnl	70	No
TE-897	LP preheater discharge	Gr Pnl	75	No
TE-897	HP preheater discharge	Gr Pnl	66	No
TE-898	HP boiler suction	Gr Pnl	60	No
TE-899	HP boiler discharge	Gr Pnl	62	No
PT-115	Geothermal water to plant	Gr Pnl	128	No
PT-128	Geothermal water to injection	GR Pnl	129	No
PT-826	LP preheater outlet	CRT	74	No
PT-827	LP boiler outlet	CRT	71	No
PT-828	HP preheater outlet	CRT	67	No
PT-829	HP boiler outlet	CRT	63	No
PT-870	LP preheater inlet	CRT	72	No
PT-872	LP boiler inlet	CRT	68	No
PT-875	HP preheater inlet	CRT	64	No
PT-878	HP boiler inlet	Gr Pnl	59	No
PT-882	Comb discharge P-801 & P-802	Gr Pnl	76	No
PT-889	Geothermal water to plant	Gr Pnl	81	No
TE-207	Geothermal water from plant	Gr Pnl	125	Yes
TE-208	Geothermal water to injection system	Gr Pnl	126	No
TE-837 A/B	LP preheater inlet-outlet	CRT	73/122	No
TE-838 A/B	LP boiler inlet-outlet	CRT	69/121	No
TE-839 A/B	HP preheater inlet-outlet	CRT	65/114	No
TE-840 A/B	HP boiler inlet-outlet	CRT	61/113	No
TE-891	Geothermal water to plant	Gr Pnl	83	No

a. "MUX" specifies the multiplexer input no.

b. "ANNUN" specifies a panel mounted annunciator separate from and in addition to the CRT Annunciator System.

- o Open circuit
- o Short circuit
- o Grounded
- o Loss of power.

In addition, flow meters, both orifice and turbine types, will normally lose accuracy over a period of time due to the wear caused by flow, the deposition of minerals, etc., and the binding of bearings in the case of the turbine meters. All of these situations will be handled and predispositioned by an active preventive-maintenance program.

With the exception of "loss of power," none of the failure modes are expected to be common to more than one system or to propagate from one system to another. To enhance the reliability of the overall power-supply system, the commercial power to the data system is backed up by a diesel generator which, in turn, is backed up by a battery driven "uninterruptable power system." To minimize failure propagation, each individual instrument system is protected with fast-acting fuses that will isolate the fault.

- (2) Failure Effects. The failure of any one instrument system, regardless of mode or cause, denies that one bit of parametric data to the operator and to the data bank in the computer. The inherent maximum attainable temperature of the geothermal water is within the rating of all the associated piping and equipment. The piping system is designed for a maximum working pressure of 1207 kPa (275 psi) which is also the maximum discharge pressure of the geothermal boost pumps. Therefore, a lack or loss of visibility on system pressure similarity poses no unacceptable hazard to plant personnel or equipment. The

loss of visibility on the flow rate of geothermal water also implies no hazard. With the following two exceptions, it can be assumed that loss of any one instrument system implies no additional potential hazard to plant equipment or personnel.

- (a) The TE-207 system monitors the temperature and the "rate-of-rise" in temperature of the geothermal waste being returned to the injection system. If the rate of temperature change is greater than the predetermined setpoint, the water is dumped to a holding pond to prevent thermal stress and breakage of the transite pipe of the S&I system. While the transfer valve (SI-10 AV-2) and its auxiliaries have been specified to fail in the "safe" mode, it must be assumed that an instrument failure could be in a mode that would preclude operation of this diversion valve. This failure implies a potentially costly piping repair as well as the environmental impact of releasing considerable amounts of geothermal water to the surface. There is no apparent hazard to personnel.

Because the hypothetical failure is statistically improbable, and because it would be detected quickly downstream, management is willing to accept this risk.

- (3) Instrument system AE-1 monitors the content of isobutane in the geothermal water. Sampling and laboratory analysis procedures supplement the instrument. Failure of this instrument system denies visibility of this potentially hazardous situation. However, for this potential to be realized requires the simultaneous or sequential but unrelated failures in following three areas:

- (a) Failure in piping/heat-exchanger system which introduces isobutane into the geothermal water
- (b) Failure of AE-1 to monitor and annunciate the presence of the isobutane
- (c) Component failure downstream which ignites the isobutane.

Because of the statistical improbability of all three failures occurring simultaneously, management is willing to accept this potential risk.

- (4) Failure Detection. The failure of any instrument system to send a viable signal to the computerized data-handling system will be instantly detected by the computer and alarmed accordingly.

In the absence of the computer scanning all the inputs, all the parameters critical to the operation or to the equipment are indicated on the graphic panel. Loss of a viable signal would be noticed quickly by the operator who is visually monitoring the graphic panel.

- (5) Mitigating Design Features. The following design features have been included to minimize the potential failure of any individual instrument system.

- (a) All pressure and flow transmitters are housed in heated enclosures to protect them from the elements and to maintain a constant year-around temperature.
- (b) Temperature transmitters are totally enclosed within the heavy cast head of the thermowell.

- (c) All wiring is totally enclosed in heavy conduits.
- (d) All wiring terminations are made up tight and then sealed with lacquer after checkout
- (e) Because the flow path is generally in series, the reading of instruments located upstream and downstream will tend to confirm the appropriateness of any one parametric signal.

5.5.5 Cooling-Water System

The instrumentation installed to monitor the cooling-water flow, pressures, and temperatures has all been specified to be standard industrially rated instruments. The ranges specified were such that the instrument will be operating well within its capacity. Accuracy and repeatability are also specified in accordance with good industrial practice.

The process instrumentation associated with the cooling-water system is located generally as portrayed in the simplified loop diagram in Figure 5-3. Virtually all of these instruments are monitored by the computer. In addition, those shown with an asterisk (*) are also read out on a digital indicator suitably located on the graphic panel. For convenience, these instruments are also summarized in Table 5.2.

(1) Instrumentation-Failure Modes. In general, failure of the individual instrument system is expected to be in one of the following modes:

- o Open circuit
- o Short circuit

TABLE 5.2 COOLING-WATER INSTRUMENTATION

Instrument Number	Parameter	Read Out	Mux	Annun
AE-2	Isobutane in cooling water	Local	None	Yes
FT-930	Cool water to blowdown	CRT	101	No
FT-933	Make-up to cool-water system	CRT	97	No
FT-956	Comb discharge P-901 & P-902	Gr Pnl	98	Yes
FT-957	Cooling water to Cooling Tower	CRT	93	No
IAL-944	Current to P-901 motor	None	-	Yes
IAL-948	Current to P-902 motor	None	-	Yes
LT-957	Cooling-Tower basin	Gr Pnl	-	Yes
PDT-885	P across pump P-802	CRT	80	No
PDT-886	P across pump P-802	CRT	78	No
PT-926	Condenser Hx-101 outlet	Gr Pnl	103	No
PT-932	Condenser Hx-101	Gr Pnl	106	No
PT-939	Atmosphere Cooling Tower inlet	CRT	95	No
PT-957	Discharge pumps P-901 & P-902	CRT	99	No
TE-928	Cond. stge tk outlet	Gr Pnl	104	No
TE-929	Cond. stge tk inlet	GR Pnl	105	No
TE-934 A/B	Cond. stge tk Delta-T	CRT	102	No
TE-938	Cooling-Tower inlet - dry bulb	CRT	94	No
TE-940	Cooling-air inlet - wet bulb	CRT	96	No
TE-941	Cooling-Tower outlet - dry bulb	CRT	90	No
TE-942	Cooling-Tower air outlet - wet bulb	CRT	91	No
TE-955	Cooling-Tower basin	CRT	100	Yes
TE-963	Cooling-Tower inlet water	CRT	92	No

- o Grounded
- o Loss of power.

As with the geothermal instrumentation, the loss of power is the only mode with a potential for propagation or commonality. See Section 5.5.4 for a discussion of instrument power.

- (2) Failure Effects. As in the geothermal-water system, the loss of any one instrumentation system, regardless of cause, denies that one item of information to the operator and to the computer because of the explicit and implicit redundancy in the design and application of the instrumentation. The effect of this loss will be minimal. In most cases, the operator will be capable of continuing operation of the plant with no actual loss of control or protection. In no case does the loss of a single system imply any additional hazard to personnel or equipment.
- (3) Failure Detection. The failure of any instrument channel to send a viable signal to the computerized data-handling system will be instantly detected by the computer and alarmed accordingly.

In addition to the computer scanning of all parameters, those parameters deemed critical to plant operation are displayed on digital panel meters on the graphic panel. The loss of a viable signal to these panel meters would be quickly recognized by the operator who is continuously scanning the board and comparing the reasonableness of the readings.

- (4) Mitigating Design Features. The mitigating design features described in Section 5.5.4, under the geothermal-system instrumentation, are equally applicable to the cooling-water instrumentation.

5.5.6 Isobutane System

The instrumentation installed to monitor process parameters in the isobutane system is standard industrial-rated equipment designed and intended for use in and around a hazardous fluid. Because of the hazard potential when working with isobutane, the explicit redundancy has been increased with no lessening of the implicit redundancy.

The instruments pertinent to the isobutane system are placed generally as shown in Figure 5-4. Virtually all of these instruments are monitored by the computer. To economize on the utilization of the CRTs, some specific parameters on the turbine generator are not being included in the software for CRT read-out. With these exceptions, all parameters can be read out on the CRTs as well as generating hard copy. In addition, those instruments shown in the flow diagram with an asterisk (*) are also displayed in engineering units on digital meters mounted on the graphic panel. For convenience, the instruments and their interfaces, as they apply to the isobutane system, are listed in Table 5.3.

- (1) Instrumentation Failure Modes: In general, failure of the individual instrument systems is expected to be in one of the following modes:

- o Open circuit
- o Short circuit

ISOBUTANE SYSTEM-Sheet 2

FIGURE
5-B (Cont)

FIGURE
5-D (Cont)

TABLE 5.3 ISOBUTANE-SYSTEM INSTRUMENTATION

Instrument Number	Parameter	Read Out	Mux	Annun
FE-133	Pump P-102 discharge	Gr Pnl	54	Yes
FE-134	Pump P-101 discharge	Gr Pnl	53	Yes
FE-150	Isobutane vapor to LP TSV	GR Pnl	37	No
FE-153	Isobutane vapor to HP TSV	Gr Pnl	31	No
FE-160	Isobutane to bypass cond stge	Gr Pnl	46	No
TG-FE-213	LP turbine exhaust	CRT	220	No
TG-FE-214	HP turbine exhaust	CRT	221	No
FE-255	Isobutane to HP preheater	CRT	5	No
FE-264	Isobutane to LP preheater	CRT	11	No
FE-278	Comb discharge P-101 & P-102	Gr Pnl	55	No
FE-294	Isobutane to LP boiler	CRT	20	No
FE-296	Isobutane to LP boiler			
TG-FE-380	Isobutane to HP turbine	Gr Pnl	140	
TG-FE-381	Isobutane to LP turbine	Gr Pnl	144	
PDT-254	P across valve WA-208	CRT	21	No
PDT-297	P across valve WA-213	CRT	28	No
LT-145	Isobutane level in Tk-101	Gr Pnl	43	Yes
LT-162	Isobutane level cond. stge tk	CRT	44	No
LT-208	Isobutane level - LP boiler	Gr Pnl	14	Yes
LT-213	Isobutane level - HP boiler	Gr Pnl	24	Yes 12
PDT-148	P across HP turbine sim. valve	CRT	38	No
PDT-156	P across LP turbine sim. valve	CRT	33	No
IT-130	Current to pump P-102	Gr Pnl	-	yes
IT-137	Current to pump P-101	Gr Pnl	-	Yes
PT-129	Pump P-102 suction	Gr Pnl	58	No
PT-131	Pump P-102 discharge	Gr Pnl	56	Yes
PT-139	Pump P-101 discharge	Gr Pnl	51	Yes
PT-141	Condenser Hx-102	Gr Pnl	48	No
PT-157	Isobutane downstream of Hx-202			
PT-159	Pump P-101 suction	Gr Pnl	49	No
PT-214	HP boiler inlet	CRT	26	No
PT-234	Outlet - LP turbine sim. valve			
PT-249	HP preheater inlet	Gr Pnl	6	No
PT-250	LP preheater inlet	Gr Pnl	12	No
TG-PT-251	LP turbine impeller input	CRT	152	
TG-PT-252	LP turbine impeller input	CRT	153	
TG-PT-255	LP turbine impeller outlet	CRT	161	
TG-PT-256	LP turbine impeller outlet	CRT	162	
TG-PT-259	LP turbine exhaust vane	CRT	163	
PT-259	HP preheater outlet	Gr Pnl	1	No
TG-PT-260	LP turbine exhaust vane	CRT	164	

TABLE 5.3 (continued)

Instrument Number	Parameter	Read Out	Mux	Annun
PT-263	HP turbine sim. valve	CRT	36	No
PT-267	LP preheater outlet	Gr Pnl	8	No
TG-PT-271	HP turbine impeller inlet	CRT	165	
TG-PT-272	HP turbine impeller inlet	CRT	166	
TG-PT-275	HP turbine impeller outlet	CRT	167	
TG-PT-276	HP turbine impeller outlet	CRT	168	
TG-PT-282	HP turbine exhaust vanes	CRT	148	
TG-PT-283	HP turbine exhaust vanes	CRT	149	
PT-284	LP turbine sim valve inlet	CRT	30	No
PT-289	LP boiler	Gr Pnl	16	No
PT-293	LP boiler inlet	CRT	18	No
PT-299	HP boiler	Gr Pnl	111	No
TG-PT-346	Isobutane to HP turbine	CRT	144	
TG-PT-347	Isobutane to LP turbine	CRT	145	
TG-PT-348	Isobutane to HP turbine	None	146	
TG-PT-349	Isobutane to LP turbine	None	180	
TG-PT-359	Isobutane to LP turbine inlet	CRT	150	
TG-PT-362	Isobutane to HP turbine inlet	CRT	147	
TG-PT-368	Isobutane to HP turbine inlet	None	181	
TG-PT-391	Isobutane to LP turbine inlet	None	151	
TG-PT-450	Turbine exhaust	CRT	169	
TG-PT-451	Turbine exhaust	None	170	
TE-127	Pump P-102 discharge	CRT	57	No
TE-128	Condensate storage discharge	CRT	120	No
TE-135	Pump P-101 discharge	CRT	50	No
TE-143	Heat exchanger Hx-101 outlet	CRT	47	No
TE-144	Condensate storage tank	Gr Pnl	42	No
TE-146	Condenser inlet	Gr Pnl	41	No
TE-152	Outlet from HP turbine sim. valve	CRT	40	No
TE-154	Inlet to LP turbine sim. valve	CRT	32	No
TE-155	Isobutane downstream of Hx-202			
TE-158	Outlet from LP turbine sim. valve	CRT	35	No
TE-203 A/B	HP preheater outlet-inlet	CRT	3/123	No
TG-TE-215	LP turbine balance piston	None	171	
TG-TE-216	HP turbine balance piston	None	172	
TE-248	HP boiler discharge	Gr Pnl	No	11
TE-251	HP preheater suction	Gr Pnl	4	No
TE-253	LP preheater suction	Gr Pnl	10	No
TE-256	HP preheater discharge	Gr Pnl	2	No
TG-TE-261	LP turbine exhaust vane	CRT	198	
TG-TE-262	LP turbine exhaust vane	CRT	199	

TABLE 5.3 (continued)

Instrument Number	Parameter	Read Out	Mux	Annun
TE-262 A/B	LP preheater discharge suction	CRT	9/124	No
TE-263 A/B	HP boiler discharge suction	CRT	23/52	No
TE-265	LP preheater discharge	Gr Pnl	7	No
TE-271 A/B	LP boiler discharge suction	CRT	13/79	No
TE-279	Comb. discharge P-101 & P-102			
TE-280	LP boiler inlet	CRT	118	No
TE-281	HP boiler inlet	CRT	119	No
TG-TE-286	HP turbine exhaust vanes	CRT	196	
TE-287	LP boiler discharge	Gr Pnl	15	No
TG-TE-287	HP turbine exhaust vane	CRT	197	
TE-290	LP boiler suction	Gr Pnl	17	No
TE-298	HP boiler suction	Gr Pnl	25	No
TG-TE-350	Isobutane to HP turbine	CRT	173	
TG-TE-351	Isobutane to LP turbine	CRT	174	
TG-TE-352	Isobutane to HP turbine	None	175	
TG-TE-353	Isobutane to LP turbine	None	176	
TG-TE-358	Isobutane at HP turbine inlet	CRT	177	
TG-TE-367	LP turbine inlet	CRT	154	
TG-TE-369	Isobutane at LP turbine inlet	None	179	
TG-TE-452	Turbine exhaust	CRT	211	
TG-TE-453	Turbine exhaust	None	212	

- o Grounded
- o Loss of power.

In addition, flow meters (both orifice and turbine types) have a tendency to lose accuracy and responsiveness over a period of time due to the effects of the fluid stream. These situations will be reconciled by an active preventive-maintenance program.

A loss of power is the only failure mode with the potential for propagation or commonality. To mitigate this possibility, all wiring is protected by heavy conduits, deep underground where possible. Each individual instrument is protected and isolated by fast-acting fuses that will isolate and contain the fault. To ensure continuity of incoming power to the overall instrument system, the commercial power is backed up by a diesel generator which, in turn, is backed up by a battery-driven uninterruptable power supply.

- (2) Failure Effects: The total effect of a failure in the isobutane-system instrumentation is both more serious and more difficult to analyze. For the majority of the instruments, the effect would be the same as in the other systems; i.e., a denial of that one bit of data to the operator and to the computer. In general, this information loss is compensated for in the explicit and implicit redundancy in the design and layout of the instrumentation. The following exceptions however, deserve closer scrutiny:

- (a) Level System LT-213. The level system LT-213 senses the liquid-isobutane level in Hx-204 and generates a signal to valve WA-213 to maintain the level

prescribed. If the "system" should fail in the mode which then sent no signal to the valve, it would fail closed by design. The more serious alternative would be if the instrument system were to fail in such a manner as to call for more flow, even though the level set-point had been exceeded. Under these circumstances, the flow of isobutane into Hx-204 exceeds the demand which will raise the liquid level unduly.

If allowed to continue unabated, this could theoretically eventually cause a carry-over of liquid isobutane into the high-pressure stage of the turbine, potentially causing considerable physical damage to the blades. The design features which mitigate these catastrophic results are:

- o The isobutane pumps are operating at their most efficient point on the pump curve. Opening the valve in question will increase the actual flow a maximum of only 25%.
- o The increased flow will be sensed by FE-296, FE-255, and FE-264.
- o The increased load on the pump motor will be sensed by the motor overloads.
- o The position of valve WA-213 is continuously monitored by the computer.
- o The change in pressure drop across the valve is monitored by PDT-297.

- o The time available to the operator for corrective action is in the order of several minutes.

In summary, the implicit redundancy of the backup systems reduces the risk to an acceptable level. These backup parameters have been programmed to annunciate on CRT-1 to ensure prompt operator attention.

- (b) Level System LT-208. The level system LT-208 senses the liquid-isobutane level in the low-pressure boiler Hx-202 and generates a signal to valve WA-208 to maintain that level within prescribed limits. The review of potential damage, as well as mitigating design features, is identical to that for level system LT-213 above, except for the different equipment numbers. Reference is made to that section for a detailed review of the safety aspects.
- (c) Flow Instrument FT-278. The flow-instrumentation system FT-278 is installed to sense the combined output flow of the two isobutane pumps. The transmitted signal is utilized to modulate valve WA-278. This valve functions to control the amount of isobutane being recirculated directly back to the condensate-storage tank. This serves to allow the pumps to operate at their peak of efficiency, regardless of the demand of the plant.

Failure of the instrument-control system could cause the modulating valve to drive to fully open or to fully closed position. If the bypass should be fully open, almost totally starving the plant of circulating

isobutane, the high pressure in Hx-204 would reverse the flow pattern and would force isobutane over into Hx-202. While this unbalances the system and requires a manual shutdown of the plant, no damage to equipment would be done nor would any personnel be exposed to any unusual hazard. The design features which mitigate this particular failure are:

- o The recirculating-fluid flow is monitored by FT-160
- o The loss of primary flow would be monitored by FT-264 and FT-255
- o The reversal of flow from Hx-204 would be indicated by a negative delta-P across valve WA-213 as monitored by DPT-297.

In summary, this failure is readily and rapidly detectable by the implicit redundancy designed into the instrument system. This nominal risk is deemed to be acceptable.

- (d) Pressure Systems PT-299 and PT-289. Pressure system PT-299 senses the vapor pressure in the high-pressure boiler Hx-204. The output signal from the transmitter is utilized to modulate valve WA-304 which bypasses isobutane around the high-pressure stage of the turbine. This valve will normally float on the line to maintain a constant pressure to the turbine and to offer relief to the turbine in the event of a shutdown. A failure in the control system could conceivably drive the valve fully open or fully closed or even lock it in some mid-position. There are no

engineered features to compensate for this failure, but the multiplicity of instrumentation on the primary line to the turbine as well as on the bypass line gives assurance that this failure will be detected quickly and analyzed correctly. This minimal risk is deemed acceptable. However, one of the pressure monitors on the turbine inlet has been programmed to annunciate on CRT-1.

The function, analysis, and recommendations for the PT-289 system are identical to the above, except that they apply to the low pressure system.

- (3) Failure Detection. The explicit and implicit redundancy in the application of instrumentation give assurance that failure of any one instrument system can be quickly detected by the operator and appropriate corrective action taken. The scanning of all parameters by the computer offers the capability for the computer to annunciate the loss of a viable signal from any transmitter.

In addition to the overview of all parameters by the computer, those individual parameters deemed critical to plant operation are displayed on digital indicators on the graphic panel. Thus, any anomalies in the flow patterns or in the instrument signals become readily apparent to the operator.

- (4) Mitigating Design Features. The design features which minimize any damage potential from instrument failure are primarily the explicit and implicit redundancy of the instruments as installed. In every case and for every parameter, at least one other independent instrument system

exists which can alert the operator to the problem. Remotely controlled valving is provided to isolate quickly each major component in the plant area in the event of anomalous readings on the panel or in the computer.

5.5.7 Flare System

The flare system is installed to burn off any accumulation of waste-isobutane gas to preclude its becoming an unacceptable hazard. The various safety and vent valves in the isobutane-circulation system potentially discharge isobutane liquid and/or vapor to the piping system which carries it to the flare system for disposal by burning. A simplified flow and instrumentation diagram of the flare system is shown in Figure 5-5.

The flare system is fabricated and instrumented as a packaged integral unit by a manufacturer experienced in this type of equipment. The depth of instrumentation coverage was determined by the vendor to be adequate for comparable burners in typical installations. However, there are four areas of concern.

- (1) A failure of the oxygen-monitoring system coincident with a failure within the inert-gas generator could potentially raise the air-isobutane beyond acceptance in the piping from the seal tank to the flare pit. This could, potentially, cause flashback through this pipe causing extensive damage. Because the two requisite failures are unrelated, management can accept this risk. To minimize the damage potential, a rigorous preventive-maintenance program will regularly be applied to this instrument system to assure correct calibration and proper function at the beginning of each run.

FLARE SYSTEM
SIMPLIFIED FLOW DIAGRAM
FIGURE 5.5

INDIC. IN
REM. CTL. RM

- (2) A failure in the level-control system on the liquid-seal drum could negate both the liquid "knockout" function of the drum and also the hydraulic separation between the flare pit and the balance of the process area. The liquid level is flagged by two independent level switches, and a local sight glass has been added to give seal drum level indication. However, to maximize the operator's assurance of adequate protection in this area, a "Low Level" light will be installed in the control room. Local level indication is checked every four hours by plant personnel.
- (3) The level system in the inert-gas generator is less critical than that of the liquid-seal drum. The fill system is similarly controlled by a level system which is independent of the level-alarm system. A local sight glass level indicator has been added.
- (4) The various protective devices installed for the assurance of the pilot flame and of the flame front are standard in the industry and are felt to be adequate for this installation. A failure in any of these areas is alarmed to the control room so that corrective action can be taken immediately.

5.5.8 Control Systems

The generic term "control systems," as applied in this plant, is pertinent only to the control of valves and electric motors.

- (1) The control system for electric motors is the standard pattern throughout the electrical industry. Start-stop control is available at the remote-control panel as well as lockout-stop at the motor. Three individual and independent thermal overloads protect the three phases of

each motor. In the case of the three larger sets of pumps (P-101/2, P-801/2, and P-901/2), the motor current is monitored and alarmed. In the case of P-801/2 and P-901/2, the motor is shut down by low current. Indicating lights on the remote panel alert the the operator to the status of the pumps. These control systems are considered to be adequate.

- (2) The control system for remotely controlled valves is also considered standard for the industry. The control switch in the remote-control room electrically controls the position of a solenoid-operated valve (SOV). This SOV controls air to drive the process valve to the desired position. Limit switches energize indicating lights on the graphic panel to show the valve as fully open or fully closed. A review of the valve circuitry was made to determine if a need exists to show if the valve is stuck or the indicator light was burned out. It was determined that system instrumentation offers the operator adequate visibility for valve position. The control of valving is considered adequate and safe. However, an electrical failure, loss of flame front, combustion air, or propane will shut the system down.

5.5.9 Summary

With but few areas needing upgrading, as noted herein, the instrumentation system is considered to be safe, reliable, and adequate. Heavy reliance is placed on the explicit and implicit redundancy of the instrumentation system, as installed. All components are adequately protected from the environment and from physical abuse.

Operating procedures, preventive-maintenance schedules, calibration procedures, and other administrative controls will ensure the continued adequacy and reliability of this system throughout the life of the plant.

6.0 WASTE CONFINEMENT AND MANAGEMENT

This section summarizes the management and disposal of effluents from the 5 MW(e) Research and Development Plant. More detailed analyses and discussion are included in the Environmental Monitoring Plan, the environmental assessments for the Thermal Loop and the Research and Development Plant, and the Raft River Injection Systems Evaluation Study. The physical description of effluent systems is included in Chapter 4.0. The potential risks and consequences of failures of handling and control systems are analyzed in Chapter 5.0 and 8.0.

6.1 Waste Management Criteria

A series of federal and state regulations have been promulgated which control the handling and disposal of effluents from the 5 MW(e) Research and Development Plant. In addition, the Idaho Department of Water Resources (IDWR) has established limits which are specific to the operation of the Research and Development Plant. These regulations and limits are summarized in Table 6.1, Waste Handling and Disposal Regulations.

The most significant regulations are those which govern the geothermal fluids. The major portion of the Raft River Valley is a closed groundwater basin. Consequently, the geothermal research is being conducted without a water right. The current agreement between DOE and IDWR does not allow consumptive loss of water, including geothermal fluids at the facility. An estimated loss of $2.8 \times 10^{-2} \text{ m}^3/\text{s}$ (450 gpm) of evaporative water loss from the cooling towers is approved by IDWR during the research and testing phase of the facility. Unless other arrangements are made (e.g., water substitution), all remaining geothermal fluids must be injected.

TABLE 6.1 WASTE HANDLING AND DISPOSAL REGULATIONS

FEDERAL

1. Consolidate Permit Regulations (40 CFR Parts 122, 123, 124):
 - Resource Conservation & Recovery Act - Hazardous Waste Management Program
 - Safe Drinking Water Act - Underground Injection Control Program, National Interim Primary Drinking Water Regulations
 - Clean Water Act - National Pollutant Discharge Elimination System
2. Clean Air Act
3. Toxic Substances Control Act

STATE

1. Rules and Regulations for the Control of Air Pollution in Idaho
2. Constructon and Use of Waste Disposal and Injection Wells (proposed)
3. Idaho Water Laws and Regulations - Title 37 Chapter 21, Title 39 Chapter 1, Title 42 Chapters 1-40, of the Idaho Code.
4. Rules and Regulations for Individual and Subsurface Sewage Disposal Systems
5. Regulations Governing the Cleaning of Septic Tanks.
6. Idaho Solid Waste Management Regulations and Standards
7. Water Quality Standards and Waste Water Treatment Requirements
8. Idaho Regulations for Public Drinking Water Systems

TABLE 6.1 (CONTINUED)

IDWR LIMITS SPECIFIC TO RAFT RIVER GEOTHERMAL DEVELOPMENTS

Geothermal Discharge Criteria:

Conductivity	<3000	No restrictions
Fluoride	<2 mg/l	
Sodium Adsorption Ratio	<12	
Conductivity	3000 - 5000	1% seepage per day
Fluoride	<7 mg/l	
Sodium Adsorption Ratio	<18	
Lined Pond		
Conductivity	<5000	No seepage
Fluoride	<7 mg/l	
Sodium Adsorption Ratio	<18	
Sealed Pond		

Injection Criteria:

Chromate (as total Chromium)	0.05 mg/l
Isobutane	10 mg/l

The Raft River environmental program is currently in compliance with the underground injection control program of both the Environmental Protection Agency and IDWR. The purpose of both the federal and state regulations is to protect existing and future sources of domestic water. As applied to Raft River, these regulations would require that the quality of the injected fluids meet that of the receiving aquifer or the drinking-water standards, whichever is less stringent. Therefore, all fluids injected at RRG-6 and RRG-7 must be of equal or better quality than the injection well water. This establishes the limits on injected fluids which are shown in Table 6.2. Constituents which do not normally occur in the geothermal fluids (e.g., phosphate, isobutane) must meet drinking-water standards if injected.

These injection criteria assume there is no communication between the injection aquifers and other aquifers of high quality. Limited testing at Raft River indicates that there is such communication. Therefore, it is possible that stricter injection criteria will be established if long term continuous operation is implemented.

IDWR has established policies regarding effluent holding and disposal ponds. If the ponds receive fluids which are of higher quality than the shallow ground water, then these ponds do not need to be lined. If the ponds receive fluids which may contaminate shallow ground water, they must be constructed with either a bentonite or an artificial liner. Bentonite may be used if the function of the pond is for temporary storage. An artificial liner must be used if the pond is intended to hold fluids for long periods of time.

6.2 Wastes Generated

The wastes generated at the 5 MW(e) Research and Development Plant under normal operating conditions are listed below according to the waste form.

TABLE 6.2 LIMITS ON WATER QUALITY OF INJECTED FLUIDS^a

(Values in mg/ unless otherwise indicated)

Ca	199
K	32
Li	5.1
Mg	1.37
Na	2020
Si	42
Sr	8.0
Cl ⁻	3636
F ⁻	5.8
HCO ₃ ⁻	62
pH	7.3
Conductivity (S)	11,600

a. Based on the water quality of the injection wells.

6.2.1 Solid Wastes

Lime Softener Waste

The waste produced by the lime softener will have a sludge (i.e., solids) composition of approximately 35%. The chemical constituency of the sludge is:

Mg(OH) ₂	44%
CaCO ₃	31%
SiO ₂	18%
CaSO ₄	5%
CaF ₂	2%

The chemical complexes in this sludge are insoluble in this solution and are of a nature that does not present an environmental hazard. Due to the solids content, injection is not a viable option.

The estimated composition of the water in which the sludge is suspended is:

Cl ⁻	1200 to 1400 ppm
F ⁻	2 to 5 ppm
Na ⁺	800 to 1000 ppm
SO ₄	60 to 80 ppm
Hardness	20 to 50 ppm

When being tested at maximum capacity, the total discharge of water and suspended sludge is estimated to be 4920 liters/day. However, the discharge rate is expected to usually be less than this amount.

Seepage Potential

Parameters affecting the dispersion rate of the slurry were measured on the site where disposal of the testing fluids is to occur. The evaporation rate at Raft River averages about 0.5 cm per 24-hour period (0.85 cm per 24 hours during the summer). The rate of natural precipitation averages 0.07 cm per 24 hours. The infiltration rate of the sludge in saturated soil is 2.92 cm per 24 hours. This rate, however, drops to essentially nothing when the slurry seepage rate is measured on saturated soil covered with a 6 cm saturated sludge layer. Since the flat bottom of the reserve pit has an area of about 930 m², the maximum projected application rate of 4920 liters per day would only cover the bottom of the pit to a uniform depth of 2.3×10^{-4} cm. Obviously, in reality this does not occur. As the slurry flows from the pipe, the solids settle out of the solution, essentially sealing the bottom. Once sealed in this manner, future additions of the slurry flows over the deposition surface until all the water is evaporated from the solution. Thus, about 1/8 of the pit is effectively sealed from groundwater seepage by the sludge deposition. Currently, inputs of slurry flow across this sludge apron until the water contained in the material is evaporated. This occurs by the time the end of the apron is reached. Therefore, all available moisture from the slurry is evaporated into the air leaving essentially none of the waste slurry to seep into the groundwater. While this method of disposal is acceptable for the testing phase of the plant (i.e., FY-82), permanent disposal options would have to be explored for implementation if long-term plant operation is planned.

Chemical Destruct Clarifier Waste

Sludge produced by the chemical destruct clarifier will have a consistency of approximately 55% solids and 45% water. The water will have a conductivity of about 15,000 μ mhos, which corresponds to approximately 7500 TDS. The pH will be about ten. The dissolved solids in the water will mainly be chloride and sodium. The approximate concentration of the sludge components will be:

FePO_4	59%
CaF_2	14%
SiO_2	11%
$\text{Ca}_3(\text{PO}_4)_2$	5%
$\text{Zn}(\text{OH})_2$	4%
$\text{Mg}(\text{OH})_2$	3%

Other combinations
of chloride and
fluoride salts 4%

The approximate volume of sludge generated will be dependent on the amount of cycles at which the cooling tower is being run. At the present time, the maximum expected amount of sludge would be about 165 gallons per day, or 5000 gallons per month.

An application is currently under review by the State of Idaho Department of Health and Welfare that proposes a gravel pit near RRGE-2 for an acceptable site for land disposal. Preliminary conversations with county and state officials indicate that such a disposal plan is acceptable.

Miscellaneous Waste

Solid wastes generated at the Research and Development Plant will consist primarily of trash, including paper and wood products, glass, and scrap metal. Minor amounts of food and food-preparation wastes are expected. The estimated volume of these solid wastes is $28 \text{ m}^3/\text{mo}$ ($1000 \text{ ft}^3/\text{mo}$).

6.2.2 Airborne Wastes

There are five release points for airborne effluents at the 5 MW(e) Research and Development Plant: the Cooling Tower, the flare, the laboratory vent, and the diesel engines for the emergency generator and fire pump. Only the Cooling-Tower effluents constitute a measurable waste. Cooling-Tower drift of solids is estimated at 0.008% of the circulation rate, or a total of 0.8 kg/day (1.8 lb/day). This drift will consist primarily of NaCl. Under upset conditions, relief valves vent isobutane to the flare. Some free carbon may show as smoke from the flare if the isobutane combustion is not complete. During plant startup, 28 relief valves will vent minor amounts of isobutane to the atmosphere. Releases from the diesel engines will include minor amounts of SO, SO₂, and NO_x.

6.2.3 Liquid Wastes

This is the primary category of effluents generated at the pilot plant. Liquid effluents include:

- o Geothermal fluids. An estimated $0.12 \text{ m}^3/\text{s}$ (1960 gpm) will be discharged from the plant. This effluent will be a mixture of fluid from RRGE-1, RRGE-2, and RRGE-3 with a total dissolved solids content of approximately 220 mg/l.

- o Waste water. The design discharge of the sewage/domestic-water system is $2.8 \text{ m}^3/\text{day}$ (740 gpd).
- o Chemical. A minor amount of liquid-chemical wastes will be generated in the laboratory facility during routine chemical analyses. The estimated volume of these wastes is 0.5 /day (0.1 gal/day).
- o Isobutane. Under normal operating conditions, there will be no isobutane carryover in the geothermal fluids.

6.3 Offgas Treatment and Ventilation

There are no offgas-treatment or ventilation systems associated with the Research and Development Plant.

6.4 Solid-Waste Handling

All solid wastes generated at the Research and Development Plant will be transported to the sanitary landfill at Malta. No provisions have been made for disposal or incineration at the Research and Development Plant. No solid wastes are expected which cannot be disposed of at an approved landfill.

6.5 Liquid-Waste Treatment and Disposal

The Research and Development Plant design includes treatment only for the cooling-water treatment system effluent. Disposal methods for other liquid wastes are:

- o Geothermal fluids. The geothermal fluids will be injected at two wells, RRG1-6 and RRG1-7. The receiving zones in these two injection wells are at depths of 517-1185 m (1698-3888 ft) and 610-1175 m (2000-3858 ft), respectively.

- o Waste Water. Sewage- and domestic-water effluents will be discharged to a septic tank. The drain field from this system consists of three perforated lines extending 24 m (80 ft) from the tank. The nearest domestic-water source is 640 m (2090 ft) away. At the design capacity of $2.8 \text{ m}^3/\text{day}$, the septic tank will require service approximately every four months.
- o Chemical. Chemical wastes from the analytical laboratory will be collected at the laboratory and drained into a buried stainless-steel tank. Ultimate disposal of these chemical wastes will be disposed in a suitable landfill.
- o Isobutane. Any isobutane released from the plant under normal operating conditions will be diverted to the flare pit for combustion.

6.6 Effluent and Environmental Monitoring

Planned effluent and environmental monitoring programs are described in the Environmental Monitoring Plan for the Raft River 5MW(e) Research and Development Plant. A summary of these monitoring programs is shown in Table 6.3, Summary of Planned Environmental Monitoring Programs.

TABLE 6.3 SUMMARY OF PLANNED ENVIRONMENTAL MONITORING PROGRAMS

Area of Concern	Recommended Monitoring	Frequency
1. Water Quality and Hydrology	Chemical Analysis: Selected irrigation wells	Monthly
	Raft River	"
	Site domestic wells	"
	Sludge & holding ponds	"
	Geothermal fluids	Weekly
	Monitor wells	Quarterly
	IDWR Wells	Semiannually
	Continuous monitoring of water levels or wellhead pressure in monitor and USGS wells.	
2. Seismicity	Three geophones surrounding the site.	Continuous
3. Subsidence	Second order, first-class survey of grid.	Annually
	Spot check of wellhead elevations.	Quarterly
4. Air Quality	Particulate sampling - 3 stations	24 hrs. every 6 days
	Cooling-Tower drift sampling	To be determined
	Ambient H ₂ S Concentrations	Daily
5. Meteorology	Temperature, precipitation, wind speed and direction, barometric pressure.	Continuous
6. Raptors	Locate active ferruginous hawk nests and determine productivity. Keep track of deserted nests. Band young. Check golden eagle nesting activity.	Annually

TABLE 6.3 (Continued)

Area of Concern	Recommended Monitoring	Frequency
7. Aquatics	Fish populations, flow, water quality, and sediment characteristics.	Numbers 7-12 to be sampled every five years during plant operations operations. Next sample is to be conducted in 1982.
8. Small Mammals	Population status and distribution. Jackrabbit census. Annually	
9. Plant Ecology	Composition and percent cover on existing plots.	
10. Common Birds	Nest densities and success on existing study sites.	
11. Socioeconomics and Demography	Survey population and economic conditions.	
12. Fluorosis	Determine fluoride content of water in representative culinary wells in the valley.	
13. Heritage Resources	No monitoring required unless additional land disturbance occurs.	

7.0 HAZARDS PROTECTION

7.1 Policy

EG&G Idaho shall take all reasonable precautions to protect the safety and health of employees and members of the public. The 5 MW(e) operations shall comply with all applicable safety and health regulations and requirements (including reporting requirements) of DOE. The operational safety policy is to:

- o Provide a safe-working environment
- o Conduct operations safely and instruct employees how to avoid risks leading to injury or illness
- o Develop, operate, and maintain the 5 MW(e) plant in a manner that protects the health and safety of the public, minimizes accidental damage to property, and prevent harmful effects to the environment
- o Meet or exceed the required standards of performance in the area of occupational health, industrial and fire safety
- o Assign line management responsibility to achieve high-quality performance without interruption or loss due to accident. Operational health and safety shall be an integral part of efficient and effective management
- o Direct line managers and supervisors to accept the responsibility for preventing loss through accident, protecting property, preserving personal health and safety, correcting unsafe conditions, and following safe practices. They ensure that acceptable levels of risk are associated with all activities within their purview. When supervisors suspect or know that unsafe conditions exist they must stop the associated activities and correct the hazardous condition.

- o Require employees to take necessary precautions to prevent injury to themselves and their fellow workers. Employees are expected to learn and comply with the approved standards and procedures that apply to their area of work.

7.2 Design and Operational Considerations

The appropriate, nationally recognized codes, standards, and safety regulations were used in the basis for 5 MW(e) plant design.

Operationally, many occasions or circumstances are expected that will show the merits of good design. Also, circumstances are expected to arise that will show, where consequences must be accepted with the risk that is involved. The text of this report identifies items that fit into both the important design features and, more specifically, those with risk-consequence. The more important of these are reviewed below.

7.2.1 Desirable Features.

- (1) The normally occupied Office-Control and Maintenance Building areas are uphill and advantageously located to the prevailing-wind direction.
- (2) The plant is reasonably close to the existing and contemplated production wells.
- (3) Major in-plant electrical power is distributed in underground conduit. All major runs are protected by red concrete.
- (4) A majority of the important controls function from the operators' console in the control room and are "fail safe."
- (5) Seismic Zone 3 was utilized in design.

- (6) The process area was designed and installed to meet National Electric Code, "Hazardous Area" for Class I, Group D, Division 1 or 2 as appropriate.
- (7) Comprehensive fire-protection equipment and alarm systems were incorporated throughout the design.
- (8) Buildings are of "noncombustible" construction.
- (9) Access is controlled at the main, front entrance. Special deliveries and heavy-equipment access can be arranged for a rear entrance.
- (10) Overhead cranes were provided to accommodate heavy-material handling in the Cooling-Water Pump House and the high bay area of the Maintenance Building.
- (11) Safety showers are provided in the chemical laboratory and in the Cooling-Water Pump House.
- (12) A well-designed laboratory hood is provided for the chemical laboratory of the Office-Control Building.
- (13) Electrical grounding and lightning protection are built into all parts of the plant.
- (14) A cathodic-protection system is provided to minimize rusting of buried steel piping. Also, underground steel pipe is completely coated for corrosion protection.
- (15) A flare will be burning while the plant is in operation. This permits major upset or controlled releases of isobutane vapors to be disposed of immediately by burning in a safe location.

- (16) Provisions are made for economical geothermal water heating of the fresh-water storage tank, Cooling-Tower basin, and via a heat exchanger the Maintenance, Office-Control Buildings and their sidewalks. Buildings have backup electrical heaters for use when the hot water is shut off or for supplemental use if required.

7.2.2 Undesirable Features

- (1) Minimum pipe burial, to top of pipe, has been only 1.2 m (4 ft) This can result in water-pipe freeze-up in sustained periods of cold weather.
- (2) Additional work platforms and access to valves, vessel heads, etc. for operations and preventive maintenance have been provided.
- (3) The air compressor/receiver is conservatively designed and is dependent on the nitrogen system for backup. Once the air-receiver supply is exhausted following a power outage or compressor failure, the combustion-air supply from it to the inert-gas generator and flare-pilot flame could cause a loss of these units. At present an air bottle has been tied into the flame front generator piping to assure the pilot flame continues. The inert gas generator has a nitrogen purge gas bottle tied in to permit operation even though the inert gas generator ceases to function. Plant shutdown will be required when the back-up's are exhausted. The extra risk of operating without a flare is unacceptable.
- (4) The domestic-water supply is capable of only $0.0032 \text{ m}^3/\text{S}$ (50 gpm). This provides almost no fire emergency support to the water storage for fire protection. Any sustained

fresh-water well pump outage will quickly allow the tank level to drop to emergency demand level and create conditions to justify plant shutdown.

- (5) The electrical substation is adjacent to the Cooling Tower. Under adverse weather, especially severe cold, when the tower fan may have to be reversed for de-icing, the water vapor will move directly toward the electrical substation.
- (6) The risks from freezing on much of the above-ground piping is dependent upon an electrical-heat trace for freezing protection. A power failure would cause many problems in winter weather.
- (7) The dissolved solids in the geothermal water used for make-up and the evaporation from the Cooling Tower will result in large volumes of sludge in the water-treatment blowdown. These large volumes will require mechanical handling for removal to storage or disposal areas.
- (8) Any piping or system leak in the isobutane creates a severe fire and personal injury risk.
- (9) A majority of relief valves on the isobutane system relieve to atmosphere, any of these functioning adds fire risk.
- (10) Most isobutane-system relief valves have a manual valve between the relief and the equipment being relieved. During operations these valves are locked open.
- (11) At many places in the isobutane system, there were sight glasses which have been replaced. No failure of these units is expected.

- (12) The cooling-water treatment chemicals that are lost as a part of the steam plume from the tower will introduce environmental and personal risk in the fallout area.
- (13) The roadway from the office area turns at the Cooling-Water Pump House and is downhill to the process area. This introduces risk from a run away vehicle. Protective guarding has been installed where risk is high.
- (14) Modification of the main control room operators' console was expanded to accommodate the turbine-generator signals. This exceeded the original plans for the console. The addition has resulted in the fire alarm signal panel being blocked from the operator's view. The 85 dB alarm will alert the operator, but the operator will have to leave his/her normal location to determine the cause and return to initiate action.

7.3 Identification & Evaluation of Hazards

7.3.1 Hazards Not Involved

From the DOE recommended list of many items to be evaluated, several are not involved or are so minimal that they impose no safety significance. Items fitting this status are:

- o Explosive Substances--none per se, gasses and liquids are covered separately below.
- o Nonionizing radiation sources.
- o Radioactive material.
- o High-intensity magnetic fields.

- o Pesticide use--none in process or operational needs. Subsequent use of chemicals may be chosen to control undesirable weed growth near facilities.
- o Inadequate illumination--specific isolated small areas such as underground valve boxes, electrical manholes exist, but the plant buildings, process area, and overall area are well lighted.

7.3.2 High Voltage.

Two potential risks are identified. These are: the incoming main power source of 29 KV to the main breakers at the substation, and the power production from the plant's turbine-run generator producing 4160 Volts.

Evaluation of the risk indicates that the substation, main breaker, and transformer are enclosed by a chain-link fence. Distribution from the substation is through conduit to electrical switchgear and 4160 volts is the greatest voltage used. The distribution system is underground and complies with National Electrical Code installation requirements. The incoming line is designed for ice loading. Transfer of incoming power from the utility poles to the main breaker and main transformer are a minimum safe distance from the enclosure. The switchgear is not designed for ice loading. The Generator power leads are fully enclosed.

7.3.3 Flammable Liquids, Gasses, and Dusts

Identified are: isobutane, propane, acetylene, diesel oil, lube oil, and hydrogen. Evaluation of each follows:

- o Isobutane characteristics are given in 5.1.3. This flammable liquid is received via a standard delivery

system, designed as recommended by the NFPA. It is stored in adjacent underground pressure vessels and, with isobutane from the vapor compressor, is discharged into the process-system piping and vessels. Initial entry is in a vapor phase that is then changed to a liquid. A balance of liquid-vapor is then established and heat from geothermal water is applied to increase pressure. Additional pressure for operation is supplied by pumps and more geothermal heat. Major piping and vessels are protected by deluge-water spray systems. This use area contains detectors for leakage, relief valves for overpressure, and diversion of major discharges to a flare for safe burning. The risks remaining are: personnel injury from contact with any liquid-vapor leakage, thermal burn from contact with exposed metal of containers, and access for preventive maintenance or operations. One remote risk is inspiration of air during rapid cooldown when isobutane is returned to storage or sent to the flare. Any such air leakage must be sufficient to bring the isobutane vapor to the explosive limit (upper) at 8.4% by volume, and in some unforeseeable manner have an internal ignition source. A minor risk can occur if the inert-gas generator fails and isobutane vapors mix with air in the pipe between the flare burners and the knockout drum.

- o Propane is used very conservatively as part of the process. It provides fuel to the flare pilot and its associated flame-front generator and is the fuel for the inert-gas generator for the flare system. Although the utilization area is not protected by fixed fire-suppression equipment, it is built to meet code requirement for hazardous area. The equipment is UL-approved for propane service.

- o Acetylene is stored in bottles and is piped to the chemistry laboratory of the Office-Control Building. Installation complies with the NFPA standards for piping and backflash arrestors. The storage is outside, above ground, but will be exposed to late afternoon sun.
- o No. 2 diesel fuel oil is used to supply the diesel engine driver for the emergency generator in the Maintenance Building and for the emergency fire-water pump in the Fire-Water Pump House. In both locations, the major supply of oil is in an outside buried tank and a smaller quantity is used inside as a "day tank" supply. Both inside locations are protected with automatic-sprinkler systems.
- o Lube oil is used in connection with the two diesels mentioned above, but primarily in the turbine-generator installation in the process area. This oil system in the heated condition that exists in operation has a fire-thermal burn risk inherent to it. The lube-oil system is cooled with water from the primary-cooling system of the plant. In each case, heat exchangers are used and, in some applications, supplemental fans are used for cooling. The entire equipment at the turbine-generator is designed for Hazardous Area application, Class I, Division 2, Group D, and is protected with an automatic deluge-water spray system. Most of the piping is insulated.
- o Hydrogen is expected as an offgas from the emergency-battery bank in the Maintenance Building and from the starting batteries on the two emergency diesel engines. The engine batteries require no special provisions for this risk. The battery bank is in an enclosed room with a special exhaust through the ceiling and roof. Field monitoring while the units are in recharge or major discharge service is needed for final evaluation of risk.

7.3.4 Compressed Gases

The only significant gases not already discussed are the air and nitrogen. The air is from a normal-package compressor unit with receiver and dryer. It operates at 965 kPa (140 psi) maximum pressure and should introduce no unusual risk. The nitrogen system has been discussed in detail, including risk, in Section 5.1.2. It is received, distributed, and handled in the process area. The piping is welded at most joints. It is well protected by relief valves and pressure regulators. Its location with above-ground storage vessels is subject to the risk of physical damage, other risk is minimal.

7.3.5 Cryogenic Systems

No cryogenic systems exist in the 5 MW(e) plant. However, the cryogenic-like characteristics of the isobutane are covered in Section 5.1.3. The risk of personal injury from contact with isobutane is a potential hazard that is accepted. A containment failure is not likely or expected, but, many relief and vents must be manually operated during startup and shutdown. This risk requires and is mitigated by operator training and safe procedure.

7.3.6 High-Temperature and -Pressure Systems

Using the definition of high as "exceeding normal", three of the primary materials in the process area are high, geothermal water, isobutane, lube oil and, marginally, cooling water. Exposed, uninsulated, metal for any of these systems will cause skin burns. Only the lube-oil piping is not fully insulated. The piping on each system is adequately designed for the pressure and temperature involved; each system is equipped with relief valves. The major relief valves of the isobutane system

relieve to piping routed to the flare. Both the lube-oil and isobutane systems involve the risk of fire if the contents escape from containment. Both are fully covered with automatic fire-suppression deluge-water systems. Only a massive failure of the isobutane system may create a fire that exceeds the capacity of the fire-suppression system.

The cooling water will be hot enough upon exit from the vessels of the systems being cooled to cause thermal burns on skin contact. The pressure is approximately 379 kPa (55 psi), which is typical of domestic-water systems. Normal containment is designed for about three times operating pressures and the relief valves on the system are set at almost double operating pressure. No significant pressure-temperature problems are expected from this system.

7.3.7 Inert and Low-Oxygen Atmospheres

Inert and low-oxygen atmospheric conditions generally do not exist and are normal only in the piping of the flare system which is specially filled from the inert-gas generator. This system is inaccessible so the risk is nil. The one great risk is from accumulation of isobutane vapors, which are heavier than air, in low areas or spaces. This risk is a potential in the electrical and valve manholes near the process area. Entry shall be controlled by safe-entry permits that will require monitoring and possibly pre-purging before entry.

Any vessel entry in the process area contains an initial entry risk. Vessels have had the air displaced in the operation startup, so a risk of contamination with isobutane may exist. Initial opening requires monitoring for vapors and low oxygen before entry. The vessels in the Cooling-Water Pump House have the same entry risk because of the chemical solutions they have contained.

7.3.8 Effects of Chemical Exposure

The 5 MW(e) plant is not a chemical-processing plant, so risk from chemical exposure is not severe. The major use of chemicals will occur in the water treatment of geothermal water so it may be used in the cooling-water system. The significant risk occurs in manually transferring chemicals from storage and emptying them into the use tanks and mixers in the Cooling-Water Pump House. Sulphuric acid will be received and transferred directly to a storage vessel through a closed-piping system. Most of the other chemicals will be in bags, boxes, cans, etc. The chemical procedure is a phosphate method of water treatment. It uses caustics, such as sodium carbonate (soda ash), and calcium hydroxide (slack lime). All of these involve similar hazards, with sodium hydroxide causing the most severe personal injury risk. The risk is considered high as an acute local-contact irritant, as an ingestion problem, and as a moderate inhalation dust problem. The other caustics have similar physiological actions on the employee, but to a somewhat lesser extent.

The manual chemical handling is not covered in plant technical specifications or drawings; therefore, the risks involved and their control are through administrative procedures prepared to guide the employee actions. It is imperative that these include; eye protection, breathing protection, and protective clothing to prevent skin contact. The employees will require education on the handling risk and how to care for their protective equipment. Especially, they must be convinced that failure to comply with procedures and required protection will not be tolerated. Exposure records required by the Company Industrial Hygiene Section to meet DOE and OSHA requirements will be established and maintained.

7.3.9 High-Noise Levels

Generally, this plant does not involve machine operation that will produce a noisy plant environment. Three noise sources are recognized: the emergency diesel-generator driver, the emergency diesel fire-pump driver, and the plant air compressor. Each of these is located in a separate space without normal occupancy. Use of ear protection for entry is specified to assure acceptable risk control of noise when work is required and the units are in operation. The diesel generator and air compressor are in the Maintenance Building and may create nuisance noise to adjacent occupied areas.

7.3.10 Toxic and Noxious Emissions

A comprehensive discussion of toxic and noxious emissions is given in Chapter 6. These are minimal as plant releases. The Cooling Tower vapor plume may contain traces of treatment chemicals and downwind fallout could be a hazard. The emissions as liquid waste will contain caustics or their residue in the sludge. Any personal handling will involve risks. At present no injury-illness risks are anticipated.

The diesel engines for emergency fire-water pumping and electrical generation will result in minor amounts of sulfur oxides along with nitrous oxides, carbon and carbon dioxide. This emission will be intermittent only when the emergency units are used. The emission is through an exhaust stack above the building roof. They will not exceed the discharge of a truck engine and are believed to introduce no risk.

7.3.11 Mechanical and Moving Equipment

Identified are the air compressor, diesel-powered generator, diesel-powered fire pump, numerous electrical driven pumps,

vapor compressor, two Cooling Tower fans, the main turbine, and the main generator. Evaluation of these shows:

- o The air compressor is in an unoccupied room with only one access from the outside of the building. The moving parts are enclosed and no mechanical hazard is recognized.
- o The diesel-powered generator is in an unoccupied room with only one access from the outside of the building. The generator is fully enclosed and the diesel driver is designed for an engine cover that will enclose all moving parts. This covering should be installed. One residual risk is from the hot exhaust.
- o The diesel engine driver of the emergency fire pump is in the Fire-Water Pump House. The cooling system and power transmission moving parts are fully protected. The hot exhaust is high enough to make contact improbable. No recognized mechanical risks remain.
- o The electrical driven pumps assessed collectively present minimal risk. Those with exposed couplings between the pump and driver have independent guards. The small units have integral, guarding covers. Review of each unit will be a part of each system operation check. Any exposed mechanical hazard will be guarded.
- o Cooling-Tower fans are enclosed by the tower velocity cones. Access is only by unbolting a panel from the velocity cones. There is no access walkway to the hub of the fan. The drive shaft from the electrical driver is inaccessible except by entering the cone. No residual personal risk remains.

- o The main turbine and its gear transmission are mounted on the same base frame with the generator. Only the couplings present a potential mechanical hazard. In service, they will be guarded. Also, this equipment is on a high-level support platform with only one access stairway. Access will be restricted by plant procedure. An emergency access-egress walkway from the turbine side of the platform has been installed. It permits egress to ground level by existing ladder.

7.3.12 Inadequate Ventilation

Only two potential risk areas are recognized. The Office-Control chemical laboratory and the Cooling-Water Pump House.

The laboratory has a properly designed lab hood with ventilation exhaust. Unusual experiments shall not be undertaken outside of the hood where normal ventilation may be insufficient. The normal work planned for the lab can be handled without risks due to ventilation.

The Cooling-Water Pump House is not equipped with special ventilation. This may be a problem during material handling in the chemical-storage room. It is a small room with three stories equivalent height. Access for material is via a large roll-up vehicle door. Monitoring will be necessary to determine if additional ventilation is required. In the main part of the pump house, evaluation of specific chemical handling will be necessary. Point of operation exhaust may be required. Personal protective equipment as discussed in 7.3.8 will be provided.

7.3.13 Working at Heights

Potential risks identified are: Maintenance for the two overhead cranes, maintenance of the H&V system on the Office-Control Building roof, many places in the process area, and the Cooling Tower. Evaluation of these shows:

- o Overhead Crane in the Maintenance Building will require a portable ladder for access, electrical power lockout, and scaffold platforms or safety belts for work.
- o Overhead Crane in the CWPB presents the same situation and requirements same as in the Maintenance Building.
- o For the H&V system of the Office-Control Building, an access ladder has been installed as part of a construction modification. The facility on the roof is enclosed. Risk is minimal.
- o The process area involves an equivalent of about four stories of height. There are work platforms at three different levels. Some upper levels do not have intermediate-level platforms below them. Access to equipment components, such as a relief valve, may not be possible safely from an adjacent platform. These are risks that exist now, and more will develop when preventive maintenance and vessel inspection subsequently become necessary. This problem was called out as one of the startup prerequisite needs at the beginning of Chapter 5. Risks from working at heights has been significantly reduced. Additional needs will be handled as they are identified in actual plant operations.

- o The Cooling Tower, when maintenance is required on the tower, the fans, access stair, access ladder, sprinkler pilot, or deluge piping will involve working at heights. Permanent risk reduction is not practical. Safe work procedure guidance for each job that becomes necessary shall be required.

7.3.14 Material-Handling Dangers

Identification of potential risks include; receipt, storage, and transfer of Cooling-Water Pump House (CWPH) chemicals; preventive maintenance on valves and vessels in the process equipment. The geothermal water, sulfuric acid, isobutane, and propane are transferred by closed-piping systems and are not considered in this subsection. Evaluation of the risks shows:

- o Chemicals are expected to arrive by vehicles for delivery to the storeroom of the CWPH. The vehicle doorway and adjacent roads allow any type of vehicle to position its load close to the storage room. Small vehicles can drive or back into the storeroom. The plant design provides no storage bins, shelving, room dividers, etc. Supplies in small quantities may be handled by hand; large volumes will probably be on pallets and be handled by forklift trucks. There is no water supply or safety shower at the storage room, so arrangements will be made to provide an emergency eye wash and appropriate protective equipment for personnel involved.

Transfer of chemicals from the storeroom to the CWPH proper requires that the material be taken outside and back into the main building because there is no door penetrating the fire wall separating them. The building equipment blocks any deep vehicle penetration into the CWPH use area. A

transfer will have to be made to a suitable container in the CWPB, then the overhead traveling crane can be used for transferring chemicals to the final use point. Only adequate preplanning, developing containers to reduce personal handling during transfer, and properly using personal protective equipment will prevent injuries. The volume of chemicals required each shift indicates that a much larger chemical-storage area building will be requested.

- o The preventive-maintenance activities in the plant process areas will require job-by-job planning. Some jobs may be handled from existing equipment platforms. Many jobs and major vessel openings requiring vessel head removal will require scaffolding and a mobile crane. Once the valve, vessel head, etc., is removed, it may be feasible to transfer it to the Maintenance Building where an overhead traveling crane is available for further handling.

7.3.15 Temperature Extremes

Identified as potential risks are: severe winter cold weather; hot geothermal water; hot isobutane and its cryogenic characteristics; hot cooling water; hot turbine-generator lubricating system; diesel engines and their exhaust; and hot ethylene-glycol of the heating systems. Evaluation of these temperature risks shows:

- o Severe winter cold is significant because the 5 MW(e) plant process area is outdoors. The location is at a general elevation of 1500 m (4900 ft). Temperatures get sufficiently cold to make outdoor work difficult. Employees are provided heavy winter clothing, and job planning takes cold weather into consideration.

- o Hot geothermal water is contained in an incoming pipeline. It provides side streams for cooling-water make-up, for building heating, Cooling Tower basin heating, and fresh-water storage tank heating. After heat is removed, all except that used in cooling-water make-up is routed to injection wells. Any of this piping that is above ground is insulated. Personal risk occurs only from contact with an uninsulated pipe flange, valve, pump segment, or vessel connection, or a containment failure allowing hot water to spray on personnel.
- o Hot isobutane is contained in pipes or vessels in the process area. Due to its fire risk, the area is monitored for leaks and cooling water is monitored for isobutane-interface leaks. Due to the low-vapor pressure, transfer of isobutane will cause severe cooling of transfer piping. Also, a leak contacting skin will cause rapid skin cooling. As discussed above for geothermal water, the isobutane in the process system is heated so any exposed piping or vessel may cause burns if the uninsulated metal is contacted. The greatest probability of skin contact by isobutane is in startup and testing to establish a liquid-full status of the isobutane system.
- o Hot cooling water is primarily a problem only as it is collected from the condenser (HX401) and the turbine-generator and vapor condenser (HX601), before being returned to the Cooling Tower. Normal temperatures are acceptable; but, any upset may cause water and containment temperature to be temporarily higher. Risk of personal injury is believed minimal from either contact or leakage.

- o Hot piping of the turbine-generator lube-oil system is insulated where personnel exposure is likely. No risk is expected unless it occurs at the turbine bearings area. These are reasonably well protected by the mounting frame which requires someone to climb over the frame to reach the bearing.
- o Diesel engines and their exhausts are discussed above in 7.3.11. It is difficult for anyone to contact the exhaust without deliberate climbing to do so. The hazard is minimal.
- o The ethylene-glycol system is insulated where personal exposure is likely. Only a leak in the circulation pump or piping is likely to present any risk.

8.0 ACCIDENT SAFETY ANALYSIS

Accidents or incidents may take a variety of forms. In this chapter, primary attention will be given to problems that involve risk. The subsections are intended to supplement and compliment one another rather than be redundant.

8.1 Abnormal Operations

8.1.1 A Geothermal-Water Leak

Assume a failure from the containment system to the environment. Within the 5 MW(e) plant area, all piping is steel so a leak is not likely to be massive in size. The supply system to the 5 MW(e) contains a large amount of cement-asbestos pipe and a failure of this will release one-third or more of the incoming water. A failure of this magnitude may require operational shutdown; or during repair, operations at approximately two-thirds capacity. The operator of the supply system will be required to isolate the break, drain-down, allow some cooling, repair, flush, and warm-up before it can be returned to service. About 24 hours is a conservative time to accomplish this.

A break in the cement-asbestos line after the pipes from three wells are combined will cause an immediate loss to the boost-pump suction and will require a shutdown.

A leak in the process area that is not severe may not be cause for shutdown. This introduces an abnormal operation, and risk. Operationally, a $0.0032 \text{ m}^3/\text{S}$ (50 gpm) leak may not cause much equipment upset, but it creates a severe burn risk to any worker who encounters the steam or water. Environmentally, it is unacceptable because the $0.0032 \text{ m}^3/\text{S}$ (72,000 gal/day) is not

allowed to be wasted and there is no practical way to collect such leaks. Prompt isolation of a leak and repair will be a normal procedure.

8.1.2 A Geothermal-Isobutane Separation Failure

The isobutane detector in the geothermal water should detect a minor leak between the geothermal fluid and the isobutane. Continuing operation when this type of leak exists is abnormal. The accident determination is a matter of how severe the leak is as well as where it probably is. Since the contact interfaces are in the preheaters or boilers, it will not be visible. In most cases, the isobutane can logically be expected to leak into the geothermal water. However, in the low-pressure boiler the pressure differential is almost nil and the leakage could go either way. Any massive leak will require a plant shutdown. Small leakage of isobutane into the geothermal water will be transferred via the injection system to the wells and injected with the water. Small leakage of water into the isobutane will impose an extra demand on the separator WS101 and the drying system. Any small leak that appears to be increasing will require shutdown according to written casualty procedure, before it worsens and requires an emergency shutdown with excessive working fluid being burned at the flare.

8.1.3 Isobutane Leak to Environment or Cooling Water

The isobutane-detection system should provide a prompt warning for this type of leak, and help in determining where it is. Back-up water sampling and analysis procedures are also being followed. This type of leak, even when small, must be considered serious. Continuing operations is abnormal. The more dangerous small leak is probably into the cooling water. It would be contained until the water is distributed to the

Cooling Tower. Continuing operations may result in an explosion within the tower. This risk would be greatest if the leak existed on a calm, cool day when the fans were off or on low speed.

Continuing operations with a leak in the process area is a fire-explosion risk. If it is very small, the fuel would probably disperse before any quantity reaches the explosive range. On a calm day with a leak more than "small", the risk of explosion constantly increases. Any isobutane leak that ignites or is detected by more than one detector shall be considered too severe for continuing operations. This type of leak creates an injury risk also.

8.1.4 Isobutane Detectors Not Working

This situation is abnormal. Operations might continue indefinitely without a problem, or it may result in trouble almost immediately. A spare detector is available to permit quick correction. Continuing operations with more than one detector out of service shall require the shift supervisor to have specific approval from a higher level of management.

8.1.5 Air-Compressor Failure or Low Nitrogen

These units are critical to automatic control of the plant. Operations with either system "out" or malfunctioning should be considered abnormal. Since the nitrogen system provides the backup for the air system, it is the more critical. A power outage that interrupts work of the compressor, plus any significant air demand, will quickly deplete the storage capacity of the air receiver. Under such circumstances, low nitrogen immediately creates a situation that jeopardizes plant

operation, even to the extent of preventing a normal shutdown. Plant-operating procedures establish the conditions for control of this type of abnormal operation.

8.1.6 Flare Is Out

Several startup steps, equipment checks, and regular operations have a prerequisite for the flare to be in operation. Any of these functions without the flare operating would be considered abnormal. The risk depends on how much isobutane might be released to the flare without burning. A vapor cloud formed would tend to stay in the flare pit and ultimately explode or be dissipated. Since the vapors are heavier than air, an employee sent to check could be asphyxiated or badly burned in an explosion. No entry shall be permitted without a check for vapors, before and during entry. No sustained operation without the flare will be undertaken.

8.1.7 Storage Tank--Low Water

The predetermined water level to be maintained in the water-storage tank is based on an emergency potential. Continuation of operation when the water level is less than specified is abnormal. Hazard and risk are real only when a need occurs and the low supply proves inadequate. Plant-operations are governed by the technical specifications requiring (28 feet) of water level.

8.1.8 Fire Main Out of Service--Process Area

Any operation when the fire-water main to the process area is inoperable is abnormal and a high risk. The automatic detection and deluge systems, if out of service, create a

similar risk. As in 8.1.7 above, operations will be governed by the technical specifications.

8.1.9 Automatic Valves Malfunction

These units are critical to automatic operational control. Their upset or malfunction is abnormal to continued safe operation. The FSEC Failure Modes and Effects Analysis lists 22 units that create a safety effect (injury risk) and a high likelihood of hazard if not corrected. Nine additional units, if not operational, impose a safety effect (injury risk) only. These identified abnormalities are accounted for in operational procedures.

8.2 Potential Accidents

For this report, emphasis is directed to identification of significant events. Minor, first aid injury type accidents are not included.

8.2.1 Fire-Explosion of Flammable Liquids or Gasses

The most likely potentials for this type of accident are:

- o A gasket blowout at a pipe flange or vessel closure (manway or head)
- o Failure of bolts in piping flange or vessel closure.
- o An oil leak from the gear box of the cooling tower fans.
- o A relief valve sticking open or failing to seat after being opened manually. This is a potential in the isobutane, propane or turbine-generator lube-oil systems.

8.2.2 Turbine-Generator Problems

- (1) Lubricating-oil system failure.
- (2) Bearing overheating on turbine or the generator.
- (3) Failure of the cooling system.
- (4) Excess vibration in the turbine, the transfer gearing, or the generator.

8.2.3 Vehicle and Mobile Equipment

Risk of accidents must be considered from plant vehicle and equipment as well as from outside vehicles, such delivery trucks, construction equipment, etc. The potentials recognized are:

- o An unmanned runaway vehicle rolling downhill into piping or vessels in the process area. This type of accident is a potential that may also involve the potentials listed in 8.2.1 above.
- o Material handling by crane or forklifts that results in dropping heavy items or the load striking and damaging piping or instrumentation. This may also involve risks as listed in 8.2.1.
- o Delivery vehicles, in positioning for unloading, may strike and damage piping. Also, their operators may make improper connections to plant-fill piping or they may drive away without disconnecting fill piping.

- o Improper vehicle handling may overcome guards and damage a fire hydrant.

8.2.4 Water-System Failures and Water Problems

Occurrences with greatest probability are:

- o Failure of the supply piping (cement-asbestos) bringing geothermal water to the 5 MW(e) or of the injection piping removing water to the injection wells.
- o Failure of flanges, gaskets, or valves in the plant above-ground loop.
- o An industrial-water failure from freezing. In each such case, isolation of the piping and continuing operation is feasible.
- o A break in the underground fire-water (domestic) piping. Any delayed repair may require operation shutdown. The domestic-water supply well and piping are subject to the risk of excessive well pump-down, causing pump air-lock failure. In or following severe cold, there is a potential for the transfer pipe to freeze-up with breakage.
- o Heavy rain, rapid snow melting, or water from a system break can, if circumstances are right, flood electrical manholes.

8.2.5 General Mechanical Incidents

The possibilities for mechanical problems are infinite; however, certain recognized types of failures are more likely to cause accidents that will result in major damage or shutdown if they occur. Recognized potentials are:

- o Runaway or excessive vibration causing the Cooling Tower fans to fly apart. This is also feasible from excessive ice buildup on the fan blades.
- o Excessive ice and snow buildup on and in the Cooling Tower causing major damage. This type of damage is most likely when plant shutdown occurs at the time of a major winter storm.

8.2.6 Employee Injury or Disease Accident

Potential for major personal injury include:

- o Falling from a high work-location in the process area. The greatest risk is in-plant system testing and startup. Thereafter, the risk is from preventive maintenance on equipment where fixed platforms are not provided.
- o Skin damage from contact with an isobutane or geothermal hot water leak.
- o Fire-explosion causing major burns.
- o Skin or eye injury from mishandling of water-treatment chemicals, or an allergic reaction from repeated handling.

8.3 Risk Evaluation

The Failure Modes and Effects Analysis made by FSEC, as part of the original design, presents valuable insight into hazard analysis and risks at 5 MW(e) plant. Their evaluation considered 63 principal items in the operating modes and conditions. Twenty-one of these were evaluated in both a fail-open or fail-close situations. Failure mode probabilities were determined on reliable judgment basis and assigned

probability numbers in terms of failures per million hours of operation, e.g., failures per 114 years if operated at 24 hours per day. The highest probabilities are assigned to: boiler burst or leak at = 270; temperature indicator failures at = 62; pump "failure to run" or "runs too slow" at = 30 (both isobutane and geothermal); flow indicators at = 21; and level controllers at = 12. Practically all other items had probabilities so low as to be insignificant.

Using this information and combining it with the opinions expressed in this chapter, a more detailed evaluation of risk has been made. The more significant of these are analyzed below.

8.3.1 Isobutane Leaking to Atmosphere

A small leak of vapor introduces personal injury risk by contact and fire risk if an ignition source also occurs. These risks are much more severe if the leak is large. The greatest risk occurs if the isobutane leak is in a liquid state such as might occur during startup or from the system downstream of vessel TK 101, the isobutane pumps, supply piping to the preheaters, the preheaters and piping to the boilers. Evaluating risk reveals:

- o Rate of diffusion in still air varies as the reciprocal of the square root of the molecular weight, e.g., air into still air =

$$\frac{1}{29} = \frac{1}{5.39} = 0.186 \text{ air-to-air diffusion rate.}$$

Isobutane, $(\text{CH}_3)_3\text{CH}$ molecular weight is

$$\text{C} = 4 \times 12.011 = 48.044$$

$$\text{H} = 10 \times 1.008 = 9.072$$

$$48.044 + 9.072 = 58.116 \text{ g/mole}$$

$$\frac{1}{58.116} = \frac{1}{7.625} = 0.131 \text{ isobutane-diffusion rate to}$$

still air is then $\frac{0.131}{0.186} = 0.705$ which indicates that isobutane will diffuse into air about 71% as fast as air would. This is typical of the principal that heavy gasses diffuse slower than light gasses. When the air is not still, diffusion is accelerated and explosive mixtures will develop more quickly.

The vapor-air cloud isobutane heat of combustion is:

- o as a gas, 21242 Btu/lb
- o as a liquid, 21099 Btu/lb

Handbooks^a indicate that a gas-vapor air cloud in the explosive range can release from 2 to 10% of its heat of combustion in the form of explosive energy. The explosive potential can then be calculated on the basis of potential; minimum and maximum. For example, assume a liquid leak of 11 pounds.

Minimum Explosive Potential	Maximum Explosive Potential
11 x 21099 = 232089	11 x 21099 = 232089
0.02 x 232089 = 4641.78 Btu	0.1 x 232089 = 23208.9 Btu

Since TNT energy release is approximately 2000 Btu/lb, the above leak explosive energy equivalent is:

Minimum 2.32 lb TNT	Maximum 11.6 lb TNT
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a NFPA Handbook of Fire Protection, 14th Edition 1976.

Using the same principle, it shows that a leak of liquid of about 10 to 11 gallons, or approximately 55 pounds, creates an explosive energy potential maximum of approximately 58 pounds TNT equivalent. Liquid-isobutane leaks cannot be tolerated because their damage potential is excessive.

8.3.2 Pump Failures

An isobutane-pump failure or slow-down will cause immediate concern and corrective adjustments. The hot geothermal water would tend to overheat a reduced isobutane flow, and probably open relief valves for relief to flare. This condition would increase the risk of temperature stress damages and tube failure in the preheaters and boilers. The system alarms should alert the control room so prompt action can be taken.

A geothermal-water-supply boost pump failure or slow-down does not introduce risk in the safety area. Since this is the plant energy source, its slow-down or interruption slows down everything proportionally. Loss of supply from the pumps requires that the supply from the wells be maintained for circulation to prevent freeze-up in cold weather, or if only one boost pump is operating the plant can be operated at reduced capacity.

8.3.3 Malfunction of Flow Indicators and Level Indicators

These instruments are operational aids whose indications alert operators to potential troubles such as indicated in 8.3.1 and 8.3.2. Their failure does not introduce specific accident risk, and will cause an automatic shutdown, but manual operation without them is abnormal and shall not be permitted.

8.3.4 Vehicle and Equipment

Risk is largely dependent upon how the vehicles, trucks, or equipment are permitted to operate in the plant. Greatest safety is obtained if all trucks and heavy equipment enter the plant through the east gate. This minimizes chance of a downhill run-away. Secondly, risk is minimized by requiring speeds to be slow and a visitor escort system. This permits control and reduces damage if contact with plant equipment occurs.

Equipment, such as cranes, required in the area will be restricted to times when the plant is not in operation. Risk is greatest if equipment causes damage that is not observed or reported, thus imposing the risk at subsequent startup.

8.3.5 Fire-System Failure

Risk from fire-system failure is a double-failure situation. It is serious when another incident requiring the fire system occurs first, then the needed fire system fails, or its failure is revealed when a need occurs. A major fire-system failure, such as a break in the fire main, that deprives the process area of water shall justify plant shutdown when the failure occurs, though no need for fire suppression has yet occurred.

Sprinkler systems have one of the most reliable performance histories of any automatic equipment. The Handbook of Fire Protection states, "Failure of modern sprinklers under normal conditions is practically unknown." In 117,770 fires in sprinklered buildings, 95% of the sprinkler systems showed satisfactory performance. The greatest risk is believed to exist if a large isobutane spill occurs and the explosion (see 8.3.1 above) damages the sprinkler piping. This renders the

system useless and rapidly depletes the available fire-water supply. Emergency plans provide for good, prompt, retrench actions for isolation of fire system damage.

8.4 Hazard Elimination

- (1) This began at the start of original design. Vessels were built to ASME Code Standard requirements and are code stamped. Both piping and vessels received quality assurance checks and welding was performed by certified welders. A program of radiography was performed on critical piping during construction.
- (2) The process area was designated, designed, and built to meet "Hazardous Area" as described in the National Electric Code. The area meets Class 1, Group D, Division 1 or 2 as appropriate.
- (3) As buildings are released from construction, before occupancy, there is an occupancy-readiness review to discover and arrange correction of any safety deficiencies.
- (4) The buildings and plant facilities have complete lightning protection and equipment grounding.
- (5) Underground steel piping is protected against corrosion by wrapping and a cathodic-protection system.
- (6) Before plant operation, each system receives a complete system operation test proving its compliance with design, operability, and safety.
- (7) Standard Practices have been issued that assure that all jobs are done in an efficient safe manner. This includes coverage of both operation and maintenance and required safety precautions.

(8) Designed-in seismic protection UBC Zone 3 standards were used.

8.5 Accident Amelioration

Since plant construction, some activities mentioned below have been completed. The more important of the methods used for accident amelioration at the 5 MW(e) are:

- o A fire brigade has been organized from plant personnel. They have receive training on; fire fighting, the plant equipment and systems; and first aid and rescue.
- o A mutual-aid arrangement was made with the fire department of Malta, Idaho. They have been given training and information on the plant systems, hazards, and fire equipment.
- o Automatic fire-suppression systems are installed to protect major buildings and facilities.
- o The relief valves from major process equipment containing isobutane are piped into the flare.
- o An equipped first-aid station is provided in the Office-Control Building.
- o Operators are trained in safe operating and minor maintenance procedures. Regular safety meetings will be required for all employees.
- o Major accidents will be investigated using the system developed through the Management Oversight and Risk Tree system.
- o Safety procedures and policy are incorporated as a part of plant management responsibility.

- o Regular inspections of plant and safety equipment are scheduled and made. An appraisal by the Safety Division will be used to verify compliance with procedures.
- o New systems and changes of old procedures shall have Safety Division approval.
- o As the plant goes operational, studies will be made to develop life cycles of equipment and frequency for preventive maintenance, replacement, reinspection, etc.
- o A system for safety information and its exchange among supervisors and employees has been developed.
- o A system for safe handling and disposal of toxic and dangerous chemical waste will be followed.

9.0 CONDUCT OF OPERATIONS

9.1 Organizational Structure

Figure 9-1, Raft River 5 MW(e) Plant Operations Organization shows the line organization for the conduct of day-to-day 5 MW(e) RRPP and the supply and injection system operation. Table 10.6 shows the organizational structure for operational and safety responsibility and for technical support to assure safe operation. Administrative controls to assure safe operation are described in Technical Specification (TS) Section 10.8 of Chapter 10.

9.2 Quality Assurance Program

Safety-related quality assurance support will be utilized in procurements (Reference Section 9.7.1), plant-operating procedure reviews, annual safety audits (TS Chapter 10 Section 10.8.3), pressure-vessel inspections (TS Chapter 10 Section 10.8.11), and design review (Reference Section 9.7.1).

9.3 Preoperational Testing and Checkout

Preoperational testing and checkout will begin with a series of component tests performed by the construction contractor in accordance with contract specifications (Contract No. EW-78-B-07-1710 between DOE-ID and Mitchell Construction Company). After system/plant turnover to EG&G, system tests, (Table 9.1) were initiated. Some component tests have been repeated by EG&G prior to starting system tests for the purpose of training operators and assuring operability. Relief valves were lift-tested prior to initial fill with isobutane (Reference Chapter 10 Section 10.5.2). Integrated plant tests, (Table 9.2) will follow system tests and will be the last series of tests prior to formal plant startup and the beginning of plant performance assessment tests (Reference 9.7.2).

Readiness reviews have been conducted at appropriate points during preoperational testing and checkout to assure safe operation and compliance with Chapter 10, Technical Specifications.

Testing will be performed using reviewed and approved procedures and change control in accordance with Geothermal Technical Development Standard Practice 4.11.

9.4 Administrative Procedures for Conducting Operation

The Geothermal Technical Development Standard Practice Manual, contains the subject Administrative Procedures.

9.5 Training Programs

Training of plant-operations personnel is the responsibility of the 5 MW(e) RRRDP Plant Manager and will include classroom as well as practical study. Qualification will be documented. Standard Practice 4.5, Training Requirements, and Technical Specification 10.8.10, Training, are applicable control documents. Chapter 8, Section 8.5, Accident Ameliorization describes plans to train a fire brigade and make a mutual aid and training arrangement with the Malta, Idaho, fire department.

9.6 Emergency Planning

Table 9.3 lists twenty-four procedures for dealing with 5 MW(e) RRRDP emergency and upset conditions. These procedures will be released prior to preoperational testing and checkout. Raft River Site emergency planning is contained in the Raft River Geothermal Area Emergency Procedure, Reference 9.7.4, which deals with evacuations, re-entry, civil disorders, war, fires, and other Site emergencies. This document is current and in service.

9.7 References

9.7.1 EG&G Quality Manual

9.7.2 GP-145 Plant Performance Assessment Test Plan for the 5 MW(e)
Pilot Geothermal Power Plant, Editor and Coordinator,
C. J. Bliem, Jr., January 1979.

9.7.3 Geothermal Technical Development Standard Practice Manual.

9.7.4 Raft River Geothermal Area Emergency Procedures - to be released.

Raft River 5 MW(e) Plant Operations Organization

INEL-A-15 426

Figure 9-1

TABLE 9.1 SYSTEM TESTS

Geothermal-Fluid System
Isobutane System
Cooling-Water System
Turbine-Generator System
Data Acquisition and Plant Control
Electrical-Power System
Isobutane-Flare System
Instrument-Air System
Nitrogen System
Industrial-Water System
Fire Protection

TABLE 9.2 INTEGRATED PLANT TESTS

The Integrated Plant (IP) Test Program will follow a test plan that will use the same basic operating sequence as in Volume II, Parts 1, 2, 3, and 4 of the Facility Operating Procedures, but will include data collection from all systems. The Volume II procedures required for IP testing are as follows:

FACILITY OPERATING PROCEDURES

Part 1 - Facility--Startup

1. Facility startup checkoff list
2. Startup from thermal loop filled with air to thermal loop inerted with nitrogen
3. Startup from thermal loop inerted with nitrogen to filled with isobutane
4. Startup from cold shutdown to hot standby
5. Startup from hot standby to steady-state flow with turbine-generator bypassed
6. Startup from steady-state bypass flow to turbine-generator operation at power

Part 2 - Facility--Normal Operation

1. Normal operation with turbine-generator bypassed
2. Normal operation with turbine-generator at power

TABLE 9.2 (CONTINUED)

Part 3 - Facility--Shutdown

1. Shutdown to bypass operation from full-power operation
2. Shutdown to hot standby from normal operation with T-G bypassed
3. Cold shutdown from hot standby
4. Inerting with nitrogen from cold shutdown
5. Deleted

Part 4 - Emergency Shutdown and Upset Conditions

1. Emergency shutdown
2. Turbine trip
3. Thermal loop isobutane dump to flare system
4. Partial or total loss of geothermal-fluid flow
5. Cooling-Tower basin Low level
6. Cooling-Tower basin High level
7. Cooling-water Low flow
8. Cooling-water pump P-901 or P-902 - Low current
9. Cooling-water system - Low water temperature
10. Cooling Tower basin - High water temperature

TABLE 9.2. (CONTINUED)

11. Isobutane detected in cooling water
12. High-pressure boiler - Low level
13. High-pressure boiler - High level
14. Low-pressure boiler - Low level
15. Low-pressure boiler - High level
16. Isobutane feed pump P-101 or P-102 - Low pressure
17. Isobutane feed pump P-101 or P-102 - Low current
18. Isobutane feed pump P-101 or P-102 - Low flow
19. Condensate-storage tank - Low level or high level
20. Isobutane detected in geothermal fluid
21. Isobutane detected in process area atmosphere
22. Total loss of electrical power
23. Loss of Turbine Generator Lube oil

10.0 TECHNICAL SPECIFICATIONS

10.1 Introduction

These Technical Specifications define the limits of plant variables, operating conditions, surveillance requirements, and administrative controls which are considered necessary to operate the 5 MW(e) Raft River Research and Development Plant safely and ensure the health and safety of the public. The specifications encompass the operating and shutdown modes of the plant. The scope and purpose of these specifications are those set forth in Chapter 1, Sections 1.2 and 1.3 of this Safety Analysis Report. The subsections in these Technical Specifications entitled, Specifications and the definitions of Section 10.2 shall be amended or modified only in accordance with procedures given in 10.8.7 of this chapter. Each failure to comply with specifications will be reported, in accordance with Section 10.8, Administrative Controls. The Basis, which summarizes the technical rationale for the specifications, is included for information to clarify the intent of the specifications. The bases are not part of the specifications, and they do not constitute limitations or requirements for plant operation. These technical specifications are valid for components, systems, integrated plant and engineering tests conducted by EG&G, as well as routine power production.

10.2 Definitions

Administrative Controls: A series of organizational and administrative systems designed to ensure safe operation of the plant compliance with the Technical Specifications.

Design Features: Design characteristics of special importance to the physical barriers and vital equipment of the plant where safety margins must be maintained.

Inerted: That condition of the isobutane system wherein liquid isobutane has been drained from the system and isobutane vapor has been replaced with water or diluted and pressurized with nitrogen to exclude the possibility of explosion within the system or combustible vapor release from the system. It is also that condition of the flare piping between the knockout drum and flares that has been filled with carbon dioxide and nitrogen from the inert-gas generator.

Instrumentation Channels:

- o Check - a qualitative determination of acceptable operability by observing of channel behavior during operation. This determination shall include comparison of the channel with other independent channels measuring the same variables where available (explicit or implicit).
- o Function Test - the injection of a simulated signal into the channel as close to the primary sensor as practicable to verify operability including alarm and/or trip functions.
- o Calibration Check - a check of the channel output to see that it responds with the necessary range and accuracy to known values of the parameter which the channel monitors. The channel calibration check shall encompass the entire channel including the sensor and alarm and/or trip functions, and shall include the channel functional test.

Limiting Conditions for Operations: Either the minimum functional capability or minimum or maximum performance levels of equipment required for safe operation of the facility.

Limiting-Control Settings: The maximum allowable trip settings for certain automatic controls. The setting has been chosen such that automatic protective action will correct the controlled parameter before a safety limit is exceeded.

Limiting Trip Point: See trip limit.

Modifications: A change in configuration, function, or performance of a system.

Normal Operation: The operational phase initiated by introducing isobutane vapor to the turbine-generator, or directly to the condenser (T-G bypassed) by opening the control valve(s), for heat removal from the isobutane loop.

Operable - Operability: A system or component shall be operable or have operability when it is capable of performing its intended function within the required range and accuracy as demonstrated by its compliance with its specified surveillance requirements. Implicit in the definition shall be the assumption that all attendant instrumentation, control, and electric power required for either the system, subsystem, component, or device to perform its function(s) are also capable of performing their related support function(s).

Operating Mode (see Table 10-1): An operating mode shall correspond to any one inclusive combination of conditions of the isobutane system specified in Table 10-1. Changing conditions from those for a given operating mode to those for an operating mode with a smaller numerical identification is defined as going to a lower - operating - mode (such as from mode 4 to mode 3).

Pressure Boundary Leakage: Leakage through a non-isolable fault in the propane, isobutane, or geothermal fluid containing components, vessels and piping. Pressure boundary leakage does not include leakage through packing seals or around valve seats.

Pressure Boundary Open: Pressure boundary open is the condition of the isobutane or geothermal fluid containing vessels and piping when a component or closure has been removed and the pressure boundary is open to the atmosphere.

RRPP Plant Manager: The senior EG&G management person with responsibility for 5 MW(e) RRRDP Operations.

RRPP Area: The 5 MW(e) RRRDP area includes the Office-Control Building, Maintenance Building, Cooling Tower, and Cooling-Tower Pump House, the Fire-Water Pump House, the water-storage tank and water-supply well, electric substation, process area, flare pit, holding pond, and sludge ponds.

Raft River Geothermal Area: The RRRDP Area, including the supply and injection system.

Safety Limits: Limits upon important process variables which are found to be necessary to reasonably protect the integrity of the physical barriers which guard against the uncontrolled release of process fluids or energy.

Setpoint: The instrument channel signal value at which a protective subsystem or other trip channel is set to initiate a required action.

Shutdown: The physical action which causes the controlled reduction of temperatures and pressures and results in the isobutane system reaching the appropriate lower-operating mode condition of Table 10-1.

Surveillance Requirements: Requirements relating to either checks, tests, calibrations, or inspections to ensure that the necessary quality of systems and components is maintained, that the facility operations will be within the safety limits, and that the limiting conditions for operation and limiting-control settings will be met.

Trip Limit: The parameter limit at which an alarm or protective action will begin and ensure that the assumed limiting values in the safety analyses will not be exceeded or that supporting systems are operated within safety analysis bounds.

TABLE 10.1. 5 MW(e) RRRDP OPERATING MODES

<u>Mode</u>	<u>Supply of Geothermal Fluid Flow through Plant</u>	<u>Isobutane Vapor Flow to Condenser</u>
1. Lay-up	None, or minimum for freeze protection	System inerted
2. System preparation	Increasing	None
3. Thermal loop shutdown	Decreasing	Decreasing while bypassing turbine
4. Thermal loop startup	Increasing	Increasing while bypassing turbine
5. Emergency shutdown	Suddenly none	Suddenly none
6. Standby	None, or minimum flow for freeze protection or pressurization	Decreasing
7. Turbine trip	Constant	Constant through turbine bypass
8. Turbine shutdown	Constant	Constant while decreasing through turbine and increasing through bypass
9. Turbine startup	Constant	Constant while increasing through turbine and decreasing through bypass
10. Normal operation	Constant	Constant through turbine

Upset Conditions: Any deviation from normal conditions anticipated to occur often enough that design should include a capability to withstand the conditions without operational impairment. The upset conditions include those transients which result from any single-operator error or control malfunction, transients caused by a fault in a system component requiring its isolation from the system, and transients due to loss of load or power. Upset conditions include any abnormal incident not resulting in a forced outage, and also forced outages for which the corrective action does not include any repair of mechanical damage.

Valve: The term "valve" as used in this document includes the main portion of the valve, the actuator, and all subsystems necessary for operation of the valve.

Value: All quantities specified are true values; however, instrumentation and relief valve setpoints shall not include accuracy or response time allowances, i.e., setpoints are not required to be offset from the trip limit.

10.3 Safety Limits

The objective of safety limits is to maintain the integrity of process components during normal operation and upset conditions so that components do not rupture or allow leakage of isobutane.

The following safety limits shall apply to the 5 MW(e) Raft River Research and Development Plant's process parameters as they affect normal steady-state operation and operational transients:

- o The isobutane pressure in the preheaters and boilers shall not exceed 4929 kPa (715 psig).
- o The isobutane pressure in the condenser shall not exceed 1744 kPa (253 psig)

- o The geothermal-fluid pressure in the tube side of HX-201, HX-202, HX-203 and HX-204 1724 kPa (250 psig). The pressure in the remainder of the geothermal fluid system shall not exceed 1896 kPa (275 psig).
- o The heatup or cooldown rate of any part of the process system shall not exceed $0.47^{\circ}\text{C}/\text{m}$ ($50^{\circ}\text{F}/\text{hr}$).
- o The isobutane pressure in the process system shall not fall below 0 kPa (0 psig).

10.3.1 Basis

The pressure safety limits for the preheaters, boilers, condenser and condensate storage tank and water separator are the maximum pressures allowed by Article UG-125(c) Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. The pressure safety limits for the geothermal fluid system are the design pressures specified by the AE. The maximum heat-up and cool-down rates are based on design specifications. The lower-limit pressure of zero excludes the possibility of introducing air (oxygen) into the isobutane system and creating an explosive mixture.

10.4 Limiting-Control Settings

Critical process parameters shall be controlled by automatic alarms or protective action so the safety limits are not exceeded. In cases where automatic controls have not been provided, procedures for appropriate operator action will be followed. These are summarized in Table 10.2.

Basis: The control setpoints are based on referenced engineering studies as well as vendor data.

TABLE 10.2. LIMITING-CONTROL SETTINGS

INSTRUMENT RELIEF VALVE No.	PARAMETER	LIMITING-CONTROL SETTING/SET PRESSURE	SAFETY LIMIT	REMARKS
PI-229	Isobutane pressure-high- pressure boiler	380 psig alarm 385 psig control valve opens	650 psig	Alarm and opens WA-304, bypass to turbine exhaust
PI-289	Isobutane pressure-low- pressure boiler	205 psig alarm 210 psig control valve opens	650 psig	Alarms and opens WA-303, bypass to turbine exhaust
PI-141	Condenser isobutane pressure	200 psig	253 psig	Alarm - requires operator action
WS-270 (3x4)	Low-pressure preheater relief (isobutane)	650 psig	715 psig	Valve opens to flare system at 650 psig
MS-277 (2-1/2x4)	High-pressure preheater relief (isobutane)	650 psig	715 psig	Valve opens to flare system at 650 psig
WS-317 (1x2)	Low-pressure boiler relief (isobutane)	650 psig	715 psig	Valve opens to flare system at 650 psig
WS-318 (1x2)	High-pressure boiler relief (isobutane)	650 psig	715 psig	Valve opens to flare system at 650 psig
WS-409	Condenser	230 psig	253 psig	WS-409 opens to flare system at 230 psig
WS-409A (2-6x10)	relief (isobutane)	235 psig		WS-409A opens to flare system at 235 psig
WS-627 (3/4x1)	Vapor-condenser relief (isobutane)	250 psig	275 psig	Valve opens to flare system at 250 psig
PI-878	Geothermal- fluid pressure inlet to high- pressure boiler	230 psig	250 psig	Alarms--requires operator action.

TABLE 10.2. LIMITING-CONTROL SETTINGS (Cont'd)

INSTRUMENT RELIEF VALVE No.	PARAMETER	LIMITING-CONTROL SETTING/SET PRESSURE	SAFETY LIMIT	REMARKS
TI-898	Geothermal-fluid temperature inlet to high pressure boiler	45 ⁰ per hour	50 ⁰ F per hour (heat- up or cool- down)	Alarm--requires operator action
TI-265	IC4 outlet from low-pressure preheater	40 ⁰ per hour	50 ⁰ F per hour	Alarm--requires operator action
TI-256	IC4 outlet from high-pres- sure preheater	40 ⁰ F per hour	50 ⁰ F per hour	Alarm--operator action required
TI-287	IC4 outlet from low-pres- sure boilers	40 ⁰ F per hour	50 ⁰ F per hour	Alarm--operator action required
TI-248	IC4 outlet from high-pressure boiler	40 ⁰ F per hour	50 ⁰ F per hour	Alarm--operator action required
Isobutane system pressures	Isobutane pressure	3 psig	0 psig	Operator action required
PI-10-128	Injection, high pressure	140 paif	150 psig	Alarm and automatic shutdown of P-801 and P-802.

10.5 Limiting Conditions for Operation

10.5.1 General

- (1) Limiting Conditions for Operation and action requirements shall be applicable during all operational modes unless specified otherwise.
- (2) Adherence to the requirements of the Limiting Conditions for Operation and/or associated action within the specified time interval shall constitute compliance with the specification. In the event the Limiting Condition for Operation is restored prior to expiration of the specified time interval, completion of the action statement is not required unless the action calls for an engineering evaluation. Restoration or the normal system status stated in a Limiting Condition for Operation must be maintained for 24 hours or equal to the specified time interval for action (whichever is less) prior to placing the system again in the off-normal condition.
- (3) In the event a Limiting Condition for Operation and/or associated action requirements cannot be satisfied, or if restoration of a Limiting Condition for Operation does not meet the minimum time in (2) above, the process loop shall be in at least Mode 3, thermal-loop shutdown within 1 hour unless corrective measures are completed that permit operation under the permissible action statements for the specified time interval as measured from initial discovery. Exceptions to these requirements shall be stated in the individual specifications.

- (4) Entry into an operational mode shall not be made unless the conditions of the Limiting Conditions for Operation for the mode being entered, or the mode from which the special test is being initiated, are met without reliance on provisions contained in the action statements. (Action statements in Section 10.5 which specifically refer to the surveillance requirements of Section 10.6, or provisions for specified maintenance in Section 10.5, are excepted.) This requirement may be waived by the 5 MW(e) RRPP Plant Manager with justification for one Specific Limiting Condition for Operation for entry into Mode 1 or Mode 3. The safety justification shall be established in writing prior to entering the operational mode and retained in the Facility Records. This provision shall not prevent passage through operational modes as required to comply with action statements.
- (5) The plant shall be shut down or the facility placed in a safe condition whenever in the judgment of the 5 MW(e) RRPP Plant Manager or the delegated alternate, or the Chief Operator, the risk of hazardous incident warrants such action.

10.5.2 Operational Components

(1) Safety-Relief Valves

- a. Mode 1 through 10: WS-607 and WS-607a on isobutane-storage tank TK-601, and WS-608 and WS-608a on isobutane-storage tank TK-602 shall be operable with the lift settings of 1723 kPa (250 psig).

If the requirements of the above specification are not met, tank pressures on both tanks shall be observed and recorded every 4 hours using PI-626a, PI-626b, PI-629a, and PI-629b. If the pressure in either tank reaches 1379 kPa (200 psig), that tank shall be vented to the flare until pressure falls below 1379 kPa (200 psig), or both valves on each tank are restored to operability. If both valves on an isobutane-storage tank are not restored to operability within 48 hours, then that tank shall be vented to the flare.

- b. Modes 2 through 10: The relief valves listed in Table 10.2 shall be operable.

If the requirements of the above specification cannot be met, the system shall be placed in Mode 3, thermal loop shutdown, within 1 hour and thermal-loop temperature reduced below 130°F within 8 hours. The pressure in the unprotected component(s) shall be observed and recorded every 4 hours. If the pressure in the unprotected component(s) reaches 1379 kPa (200 psig) after the initial 8 hours, the pressure shall be relieved by opening the isolation valves leading to lower pressure portions of the system, or the component shall be vented to the flare (isolation of the unprotected component from the rest of the system is optional during venting) until pressure falls below 1379 kPa (200 psig). If relief-valve operability is not restored within 72 hours, the thermal-loop isobutane shall be drained to the storage tanks and Mode 1 initiated.

(2) Turbine-Bypass Valves

Modes 5 through 10: The low- and high-pressure turbine bypass valves WA-303 and WA-304 shall be operable and capable of opening in response to the setpoints in Table 10-2.

If the requirements of the above specifications are not met, the system shall be placed in Mode 3, thermal-loop shutdown within 1 hour, except that the Mode 3 requirement for bypassing the turbine is waived.

(3) Cooling-Water Pumps

Modes 2 through 10: At least one of the cooling-water pumps P-901 or P-902 shall be operable.

If the requirements of the above specifications are not met, an emergency shutdown, Mode 5, shall be initiated immediately.

(4) Thermal Safety-Relief Valves

No section of the isobutane system shall be isolated unless protected from overpressure by an operable thermal safety-relief valve or one of the operable safety-relief valves listed in Table 10-2.

If the requirements of the above specification are not met for an isolated section of the isobutane system, that section shall be drained to the storage tank if possible. If this is not possible, the section shall be vented to the flare.

10.5.3 Temperature-Pressure Limits

(1) Heatup and Cooldown Rates

Modes 2 through 10: The isobutane or geothermal-fluid systems heatup/cooldown rates shall not exceed 0.47°C (50°F) per hour.

If the requirements of the heatup/cooldown rate specification are not met, the plant shall be placed in Mode 3, thermal-loop shutdown within 1 hour and isobutane-system temperature reduced to 54.4°C (130°F) within 8 hours. Prior to progressing to Mode 2 or a higher mode of operation, the requirements of 10.8.4 shall be met.

(2) Temperature Differentials

- a. Startup Modes 2, 4, and 9: Tube side/shell side startup fluid-temperature differentials shall not exceed the following:

HX-201, Low-Pressure Preheater - 28°C (50°F)
HX-202, High-Pressure Preheater - 28°C (50°F)
HX-203, Low-Pressure Boiler - 44°C (80°F)
HX-204, High-Pressure Boiler - 44°C (80°F)
HX-401, Condenser - 111°C (200°F)

- b. Upsets during Modes 2 through 10: Tube side/shell side fluid temperatures as a result of an upset shall not exceed the following:

HX-201, Low-Pressure Preheater - 106°C (190°F)
HX-202, High-Pressure Preheater - 106°C (190°F)

HX-203, Low-Pressure Boiler - 106°C (190°F)
HX-204, High-Pressure Boiler - 106°C (190°F)
HX-401, Condenser - 133°C (240°F)

If the requirements of the temperature differentials specifications are not met, the plant shall be placed in Mode 3, thermal-loop shutdown, within 15 minutes and isobutane temperature reduced to 54.4°C (130°F) within 8 hours. Prior to progressing to Mode 2 or a higher mode or operation, the requirements of 10.8.4 shall be met.

(3) Low Isobutane Pressure

The pressure of isobutane in the system shall be maintained above ambient atmospheric pressure. (Table 10.2 calls for 20.7 kPa (3 psig).)

If the requirement of the above specification is not met, action shall be taken to pressurize the system without introducing air.

(4) The instrument air pressure shall be maintained at about 620.5 kPa (gage) (90 psig) or the set pressure at which the nitrogen system backup is activated.

If the requirement of the above specification is not met, the Flare System backup air accumulator shall be placed in service and the instrument air supply to the flare shall be shutoff. In addition the plant shall be placed in Mode 3. Thermal Loop Shutdown, within one hour and isobutane system temperature reduced to less than 54.5°C (130°F) within eight hours. Prior to progressing to Mode 2 or a higher mode of operation the requirement of 10.8.4 shall be met.

- (5) At least one nitrogen storage tank shall be maintained in service at a minimum gage pressure of 5.52 MPa (800 psig) in order to provide nitrogen for purges of the isobutane system and for a two-hour backup period during loss of air.

10.5.4 Leakage of Isobutane

- (1) Isobutane Leakage into the Atmosphere:

Isobutane leakage into the atmosphere shall not exceed 40% of the lower explosive limit.

If the requirement of the above specification is not met, the plant shall be placed in Mode 3, thermal-Loop shutdown within 1 hour and the isobutane temperature reduced to 54.4°C (130°F) within 8 hours. Prior to progressing to Mode 2 or higher mode of operation, the requirements of 10.8.4 shall be met.

- (2) Isobutane Leakage into the Cooling Water or Geothermal Fluid:

Isobutane leakage into the cooling water or geothermal fluid shall not exceed 0.6% by weight.

If the requirements of the above specifications are not met, the plant shall be placed in Mode 5, emergency shutdown. Prior to progressing to Mode 2 or a higher mode of operation, the requirements of 10.8.4 shall be met.

10.5.5 Flare System

- (1) Pilot Flame

There shall be a pilot flame continuously burning.

(2) Oxygen in Inert-Gas Generator

The oxygen level in the inert-gas generator shall not exceed 2% by volume.

(3) Liquid-Seal Levels

- a. The liquid-seal level in the upper compartment of the knockout/liquid-seal vessel shall be greater than 3.15 m (10-1/3 ft) above the bottom of the seal leg.
- b. The liquid seal level in the inert gas generator shall be greater than 0.18 m (7-1/4 inches) above the bottom of the tank. If the requirements of these specifications are not met, Mode 3, shall be initiated within 15 minutes and isobutane temperature reduced to 54.4°C (130°F) within 8 hours. Prior to entering Mode 2 or a higher mode of operation, the requirements of 10.8.4 shall be met.

10.5.6 Fire-Protection System

(1) Water-Storage Tank Water Level

The level of water in the 1136 m³ (300,000 gal.) storage tank shall not fall below 8.5 m (28 ft).

If the requirement of the above specification is not met, corrective action shall be initiated immediately. If the minimum level is not capable of being restored within 2 hours, isobutane temperature in the process loop shall be reduced below 54.4°C (130°F) within the following (next) 8 hours.

(2) Fire Pumps

Both fire pumps shall be operable.

If the requirements of this specification cannot be met, one fire pump may be out of service for up to 8 hours. If both fire pumps cannot be restored to operability within 8 hours, the isobutane temperature in the process loop shall be reduced below 54.4°C (130°F) in the following (next) 8-hour period.

(3) Deluge Systems

The dry-pipe deluge systems shall be operable.

If the requirement of the above specification cannot be met, one deluge system at a time may be out of service for a period of 2 hours. If a 2-hour period is exceeded, the isobutane temperature in the process loop shall be reduced to 54.4°C (130°F) in the following 8-hour period.

(4) Wet-Pipe Sprinkler Systems

Wet-pipe sprinkler systems shall be operable.

If the requirements of the above specification cannot be met, these systems may be individually or collectively out of service for 72-hour period provided a fire-watch is maintained. Continued outage without shutdown shall require approval of the Plant Manager and the Safety Division.

The Control Room Halon System shall be operable.

If the requirements of this specification cannot be met, this system may be out of service for a 72-hour period provided a fire-watch is maintained. Continued outage without shutdown shall require approval of the Plant Manager and the Safety Division.

10.6 Surveillance Specifications

10.6.1 General

- (1) Surveillance requirements shall be applicable during the operational modes associated with related individual Limiting Conditions for Operation.
- (2) Each surveillance requirement shall be performed within the specified time interval with:
 - o A maximum allowable extension not to exceed 25% of the surveillance interval
 - o A total maximum combined interval time for any three consecutive surveillance intervals shall not exceed 3.25 times the sum of the specified surveillance intervals.
- (3) Performance of the surveillance requirement within the specified time intervals shall constitute compliance with operability requirements for a Limiting Condition for Operation and associated action statements, unless obvious deficiencies are noted; in which case, the system or component shall be considered inoperable. The specified surveillance requirements shall be performed also following any maintenance on a component (for which surveillance

requirements are specified in the following Section 10.6) which could effect the performance of that component before that component can be considered operable.

10.6.2 Operational Components

- (1) Modes 1 through 10: The safety-relief valves shall be lift-tested prior to initial fill with isobutane and shall be lift-tested thereafter on a schedule defined by the Maintenance Action Guides.
- (2) Modes 5 through 10: The turbine-bypass valves shall be tested prior to initial thermal-loop startup with isobutane in the system, and thereafter on a schedule defined by the Maintenance Action Guides.
- (3) Modes 2 through 10: The cooling-water pumps shall be serviced and maintained in accordance with the Maintenance Action Guides. Pump-discharge pressures, PI-945 and PI-949; total flow rate, FI-956; and motor current, ISL-944 and ISL-948 shall be observed and recorded at least once every 24 hours when the pumps are operating. Observed values shall be compared with baseline startup test data for evidence of deterioration in performance.
- (4) Thermal safety-relief valves (pressure-temperature type) on the isobutane system shall be lift-tested prior to initial fill with isobutane and shall be lift-tested thereafter on a schedule defined by the Maintenance Action Guides.

10.6.3 Temperature-Pressure Limits

- (1) Modes 2 through 10: TI-898, TI-265, TI-256, TI-287, and TI-248 shall be checked every hour; an alarm (see Table 10.2) requires immediate corrective action.

- (2) Modes 2, 4, and 9: Tube side/shell side fluid-temperature differentials shall be checked every hour; an alarm (see Table 10.2) requires immediate corrective action.

NOTE: Instruments and alarm settings to be identified and added to Table 10.2 in conjunction with system operation testing.

- (3) Isobutane pressures in the process loop shall be observed and recorded at least every 4 hours.
- (4) Instrument air pressure shall be observed and recorded at least every 4 hours.
- (5) Nitrogen pressure shall be observed and recorded at least every 4 hours.

10.6.4 Leakage of Isobutane

- (1) Checks of detectors for any indication of leakage of isobutane into the atmosphere shall be made every hour.
- (2) Modes 2 through 10: Checks of detectors for any indication of leakage of isobutane into the cooling water and geothermal fluid shall be made every 8 hours.

10.6.5 Flare System

- (1) The presence of a pilot flame shall be observed and recorded hourly.
- (2) The oxygen level in the inert-gas generator shall be observed and recorded hourly.

- (3) Liquid-seal levels shall be observed and recorded hourly.

10.6.6 Fire-Protection System

- (1) The water level in the storage tank shall be observed and recorded every 4 hours.
- (2) The fire pumps shall be started, operated, and checked weekly and before any plant startup following a plant shutdown greater than seven days. Regular inspectors tests shall be performed annually.
- (3) The deluge system shall be inspected weekly for operability and alarm functions. Regular inspectors tests shall be performed each six months.
- (4) The wet-pipe sprinkler systems shall be inspected weekly for operability and alarm functions. Regular inspectors tests will be performed each six months.
- (5) The Halon system shall be inspected weekly for operability and alarm functions. It shall have cylinders weight-tested each six months and a general system test each six months.
- (6) The fire-alarm system shall be tested monthly. Regular inspectors tests shall be performed each six months.

10.7 Design Features

General information is provided in this section for the purposes of identifying the design characteristics of special importance to the physical barriers and vital equipment of the plant where the safety margins must be maintained.

10.7.1 Site

The 5 MW(e) RRRDP area is located within the Raft River Geothermal area as described in Section 1.0. The area is under the jurisdiction of the federal government. The nearest population centers are Malta and Burley, Idaho. The events with safety consequences to the off-site public, who might be in the immediate vicinity at the time, are a major isobutane spill with delayed ignition (vapor-cloud explosion) or a boiling liquid evaporating vapor explosion (BLEVE), if an uncontrolled fire overheated a fuel-containing vessel.

10.7.2 Pressure Boundaries

- (1) The isobutane-containing vessels and components are two underground isobutane-storage tanks, the low- and high-temperature preheaters, low- and high-pressure boilers, the turbine case, the condenser, the condensate-storage tank, two circulating pump cases, the water separator, the vapor compressor unit - condenser - condensate receiver, and interconnecting piping and valves.
- (2) The maximum amount of isobutane in the system at any one time is the maximum liquid content of the storage tanks or approximately 20.9 m^3 (55,200 gal).
- (3) Materials of construction are carbon steel for all pressure boundaries with the exception of the preheaters and boilers which have admiralty tubes for the geothermal fluid, and Inconel shell expansion joints, and the Type-304 stainless steel expansion joints between the turbine generator and condenser, and between the condenser and condensate-storage tank. Pipe-flange gaskets are Type-304 stainless steel spiral wound with compressed asbestos fill and a solid

stainless steel outer ring. The butterfly- and ball-valve seats are double-sealed for fire safety; seals are Teflon for butterfly valves and Teflon with a secondary metal-to-metal seal for ball valves. Globe valves and check valves have 13% chromium-stainless seats. Relief valves have Viton resilient-seat seals. Valve stem packing is Teflon and Viton. Valves for the isobutane-storage tanks are especially designed for LP gas service and UL-tested; storage-tank valves with actuating devices satisfy NFPA requirements.

- (4) Design pressures and temperatures are tabulated in Table 10.3.
- (5) The plant, including the isobutane system, is designed for 161 km/h (100 mi/h) wind loads; and an ambient temperature range of -34 to $+49^{\circ}\text{C}$ (-30 to $+120^{\circ}\text{F}$) and UBC Seismic Zone 3 (maximum peak acceleration 0.10 g).

10.7.3 Flare System

The flare system is a John Zink Linear-Relief Gas Oxidizer (LRGO) designed to burn up to 63 kg/s ($500,000\text{ lb/hr}$) of isobutane with a backpressure not to exceed 345 kPa (50 psig) at the connection point to the 50.8-cm (20-in.) flare header. Total isobutane in the plant at any time is estimated to be approximately $117,936\text{ kg}$ ($260,000\text{ lb}$). Descriptions of the components of the system and their function follow:

- o Drip leg--A buried 3.05-m (10-ft) section of 50.8-cm (20-in.) pipe at the end of the buried 50.8-cm (20-in.) flare header. Liquids collected in the drip leg can be drained via a 102-mm (4-in.) pipe into the flare pit for disposal or burning by opening a manual valve. There is no

TABLE 10.3. ISOBUTANE-SYSTEM DESIGN TEMPERATURES AND PRESSURES

COMPONENT	DESCRIPTION	DESIGN PRESS (psig)	DESIGN TEMP. (F)	FLANGE RATING
P-101	Isobutane pump	230 suction 650 discharge	280 280	
P-102	Isobutane pump	230 suction 650 discharge	280 280	
WS-101	Water separator	650	320	
HX-201	Low-temperature preheater	650 shell side 250 tube side	320 320	
HX-202	Low-pressure boiler	650 shell side 250 tube side	320 320	
HX-203	High-temperature preheater	650 shell side 250 tube side	320 320	
HX-204	High-pressure boiler	650 shell side 250 tube side	320 320	Match interfacing
Turbine	Turbine-generator	640 inlet 230 exhaust	320 280	pipng
HX-401	Condenser	230 shell side 75 tube side	280 280	
ES401,402 403 & 404	Expansion joints	230	280	
TK-101	Condensate-stor- age tank	230	280	
TK-601	Isobutane-storage tank	250	275	
TK-602	Isobutane-storage tank	250	275	
VC-701	Vapor-compressor unit	250	275	
HX-601	Vapor condenser	250 shell side 75 tube side	275 100	
R-601	Condensate receiver	250	275	

TABLE 10.3. ISOBUTANE SYSTEM DESIGN TEMPERATURES AND PRESSURES (Cont'd)

COMPONENT	DESCRIPTION	DESIGN PRESS (psig)	DESIGN TEMP. (F)	FLANGE RATING
Piping Group I				
Series 100	Isobutane condensate	230	280	150 lb.
Series 400	Isobutane exhaust	230	280	150 lb.
Series 500	Isobutane exhaust	75	280	150 lb.
Series 600	Isobutane fill & drain	250	275	150 lb.
Series 700	Isobutane vent	250	275	150 lb.
Valves	Butterfly Ball Globe Check Pressure-relief Isobutane-storage	Design pressure and temperature ratings for valves meet or exceed the interfacing piping design.		Flanged valve match inter- facing piping
Piping Group II				
Series 200	Isobutane fluid (pump discharge to boilers)	650	320	300 lb.
Series 300	Isobutane vapor (boilers to to turbine)	650	320	300 lb.
Valves	Butterfly Ball Globe Check Pressure-relief	650 650 650 650 650	320 320 320 320 320	300 lb. 300 lb. 600 lb. 300 lb. Match inter- facing piping.

TABLE 10.4. AUTOMATIC FIRE-PROTECTION SYSTEMS

PROTECTED ITEM	CLASSIFICATION	DESIGN NFPA NO./TITLE	TYPE OF FIRE-PROTECTION SYSTEM	OTHER INFORMATION
Office-Control Building	Ordinary Hazard Group 2	13-Sprinkler Systems	Wet-pipe sprinkler	
Maintenance Building	Ordinary Hazard Group 2	13-Sprinkler Systems	Wet-pipe sprinkler	
Fire-Water Pump House	Extra Hazard Group 1	13-Sprinkler Systems	Wet-pipe sprinkler	High temperature heads located over heat sources.
Cooling water	Ordinary Hazard	13-Sprinkler Systems	Wet-pipe sprinkler	
Cooling Tower		13-Sprinkler Systems 15-Water-spray fixed systems	Deluge-type water-spray fixed system	Rate of application per NFPA 2142 Chapter 5 per 5.2.2. Activation by pilot head quartz bulb-type rated at 175°F.
		214--Water Cooling Towers		
5000 KVA Transformer		13-Sprinkler Systems 15-Water-spray system	Deluge-type water-spray fixed system	Rate of application per NFPA 15. Activation by pilot head quartz bulb type rated at 135°F
Control room		12-Halon 1301 Systems	Halon 1301	Single-shot total flooding system maintaining a concentration of 6% by volume for not less than 10 minutes.
Process Area	5 systems Extra hazard (design for any three to operate simultaneously)	13-Sprinkler Systems 15 Water spray fixed system	Deluge type water spray fixed system	Rate of application 0.25 gpm per sq ft over vessels, piping, and equipment. 0.10 gpm per sq ft over structure supports. Activation by fusible link pilot heads rated at 175°F.

liquid-level instrument on the drip leg. The drip leg is equipped with a flame arrester at its terminus.

- o Knockout/liquid-seal vessel--A vertical cylindrical two-compartment vessel 1.8 m (6 ft) in diameter by approximately 3.7 m (12 ft), head seam to head seam. The 50.8-cm (20-in.) flare line enters the lower section of the vessel tangentially where liquid and vapor separate. A gage glass indicated liquid level. Liquid can be routed to the flare pit via the 102-mm (4-in.) drain line from the drip leg. Vapor from the lower (knockout) section rises through a central conduit into the upper liquid-sealed portion of the vessel. The water seal functions as a flame arrester. After passing through the water seal, vapor exits the top of the vessel via a 50.8-cm (20-in.) pipe to the flare-pit burners. The vessel is heat-traced to prevent seal water from freezing.
- o Flare Pit and Three-Stage Burner--The flare pit, 15 m wide x 45.7 m long (50 ft wide x 150 ft long), is located at the terminus of the flare header at the extreme southeast and downhill corner of the plant area. It is a maximum in-plant distance from the office/control area and at a distance considered safe from other Raft River Facilities and private property. Contained in the flare pit is the three-stage burner assembly. The first-stage, 102-mm (4-in.) burner header has three burners and has no isolation valve separating it from the knockout/liquid-seal vessel. The third-stage, 50.8-cm (20-in.) burner header has 18 burners, and the second-stage, 15.2-cm (6-in.) burner header (nine burners) stand on either side of the 102-mm (4-in.) burner header. Both the 15.2-cm (6-in.) and 50.8-cm (20-in.) burners are staged by automatic valves. The automatic-staging valves are bypassed by rupture discs

which would function in the event of loss of electrical power and instrument-air supply. The pilot light is centered on the three burners of the 102-mm (4-in.) header. The pilot light is served by a 51-mm (2-in.) propane line and 25.4-mm (1-in.) pilot-ignition line from the flame-front generator (FFG) located near the knockout/liquid-seal vessel. The 102-mm (4-in.) drain line from the drip leg also terminated near the pilot.

- o Inert-Gas Generator (IGG)--The IGG burns propane in a water-sealed vessel. The inert gas (CO_2 and N_2) passes through the IGG water seal to the liquid-seal section of the knockout/liquid-seal vessel and thence to the flare lines providing a continuous inert-gas purge. An oxygen analyzer on the outlet of the IGG monitors oxygen content. High- oxygen level trips an alarm and lights a red light on the remote-monitor panel in the control room. The IGG also has a backup system consisting of two 220 SCF nitrogen bottles.
- o Flame-Front Generator (FFG)--A flame front propagates from the FFG down a 25.4-mm (1-in.) pipe to light the flare pilot.
- o Instrument Panels--Two instrument panels, one for the IGG and one for the FFG and flare system, are located at the flare and are purged with instrument air to exclude explosive mixtures. A third remote monitor and control panel is located in the control room. The control room panel's only control function is starting the FFG to light the pilot which is possible only if the local/dual-operation switch on the FFG/flare local panel is positioned on dual. The control-room panel is also equipped with an alarm and colored indicating lights for

monitoring pilot-flame failure, second- and third-stage valve status, the IGG, and the knockout/liquid-seal vessel.

- o Utilities--The flare system is supplied with instrument air, industrial water, propane, and 110 volt electrical power. The electrical power comes from the emergency-power system via panel "UP" in the control room. Instrument air for controls and FFG combustion air is supplied from that part of the instrument air-nitrogen system that is isolated from nitrogen make-up by a check valve. A backup air accumulator provides combustion air for the FFG in the event the air compressor fails and the nitrogen storage tanks pressurize the air system.

10.7.4 Automatic Fire-Protection Systems

- (1) A description of the automatic fire-protection systems is contained in Chapter 4.0. Protected buildings, structures, areas and equipment, and the type of automatic protection, classification, and NFPA reference are tabulated in Table 10-4.
- (2) Fire-Water Supply and Distribution - A fresh-water well $0.003 \text{ m}^3/\text{s}$ (50 gpm) capacity supplies the 1136 m^3 (300,000 gal.) water-storage tank. Two $0.158 \text{ m}^3/\text{s}$ (2500 gpm) fire pumps, one electric and one diesel, supply a 25.4-cm (10-in.) fire-main system which serves the process area, Cooling Tower, Cooling-Water Pump House, transformers, and Fire-Water Pump House. An 20.3-cm (8-in.) main serves the Maintenance Building; a 15.2-cm (6-in.) main serves the Office-Control Building (see Figure 3 in Chapter 4.0). Chapter 4.0 provides a complete description and discussion of the supply and distribution system.

10.7.5 Isobutane Detection

- (1) Leakage paths through isobutane system pressure boundaries and turbine-shaft seals lead to the atmosphere, the cooling-water system, the geothermal-fluid system, and the flare system. In the case of the turbine-shaft seals, isobutane would be carried with the lubricating oil leaving the turbine to the seal-oil drainers; these two components vent to the oil-drainer demister, which in turn vents to the 76-cm (30 in.) turbine exhaust. Liquid oil from the oil drainers passes to the oil-reservoir vessel. A vent fan pulls air through the oil-reservoir vessel to the oil-reservoir demister, and another fan boosts vapors from the demister to the flare line. In the event the vent fans fail, vapors would exit the oil-reservoir vessel vent which is equipped with a screen-type flame arrester.
- (2) Isobutane Detectors - Isobutane leakage into the air is detectable by 15 hydrocarbon sensors, AE-4-1 thru 15, located in the process and tank-farm area. A complete description of the system is contained in Chapter 4.0. Drawing reference coordinates and descriptive locations are tabulated in Table 10-5. The range for these detectors is 0 to 100% of the lower explosive limit (LEL). Calibration gas mixtures of isobutane and air provide a means to set the high-level alarm points at 40% LEL which annunciate in the control room. The two annunciators do not indicate which of the 15 sensors caused the alarm. Physical follow-up is required to identify the leak-sensors location. The isobutane detector in the geothermal-fluid system, AE-1, is located downstream of the low-pressure preheater (HX-201) and the isobutane detector for the cooling-water system, AE-2, is located downstream of the isobutane condenser, HX-401, (in the CWPB) and the

TABLE 10.5. AE-4 ISOBUTANE-DETECTOR LOCATIONS

<u>DETECTOR NO.</u>	<u>FSEC DWG. NO.</u>	<u>DWG. COORDINATES</u>	<u>DESCRIPTIVE LOCATION</u>
AE-4-1	E-22	E-5	East of HX-401
-2	E-22	H-6	North end of HX-401
-3	E-22	C-6	South end of HX-401
-4	E-22	E-6	West of HX-401
-5	E-22	E-8	South of AE-4 shelter
-6	E-22	H-4	North end of HX-204
-7	E-23	H-5	North end of HX-202
-8	E-19	D-7	Southwest of tank farm
-9	E-23	D-5	East of HX-202
-10	E-23 & E-18	D-5 & B-4	East of HX-202
-11	E-18	B-5	South of HX-204
-12	E-19	F-5	Top of isobutane-storage Tank 602 south tank
-13	E-19	G-6	Top of Isobutane-storage tank 601 north tank
-14	E-22	F-3	North end of HX-204
-15	E-23	B-7	East of HX-203

vapor-compressor condenser, HX-601. The gas samples for AE-1 and AE-2 are obtained by sparging a small stream of water with air. Both the water and air streams are flow-controlled. The range for AE-1 and AE-2 is 0.1000 ppm isobutane. The sample stations are equipped with calibration connections to introduce known mixtures of isobutane and air.

10.8 Administrative Controls

10.8.1 Organization

(1) System preparation through normal operation (Modes 2 thru 10).

a. Minimum Staffing:

- o One Chief Operator
- o One Geothermal Power Plant Operator II (GPP0-II)
- o Two Geothermal Power Plant Operator I (GPP0-I)
- o Two Supply and Injection (S&I) System Operators.

b. Manning Stations:

- o The Chief Operator or the GPP0-II shall remain within the Raft River area and shall be capable of being reached immediately from the control room. The Chief Operator shall be in the control room during all planned transitions between operating Modes 2 thru 10.

- o The Chief Operator or the GPP0-II shall be in the control room in visual contact with the control panels at all times.
- o One GPP0-I Operator shall operate the Cooling Water Treatment System.
- o One roving watchstander shall be within the Raft River Geothermal Area at all times such that equipment can be monitored, alarms can be acted on, and he/she can readily respond when paged.
- o Two S&I Operators shall operate the Supply and Injection System.

(2) Lay-up (Mode 1)

a. Minimum Staffing:

- o One Chief Operator
- o One GPP0-I or II

b. Manning Stations:

- o The Chief Operator shall remain within the Raft River Geothermal Area and shall be capable of being reached immediately from the control room.
- o The Chief Operator or a GPP0-I or II shall be in the control room in visual contact with the control panels at all times.
- o One roving watchstander shall be within the Raft River Geothermal Area at all times such that

equipment can be monitored, alarms can be acted on, and he/she can readily respond when paged.

(3) Isobutane, Propane, and Sulfuric Acid Unloading

- a. The Chief Operator or GPP0-II shall be present at the Tank Farm/Cooling-Water Pump House during transfers from transport trucks to storage.
- b. A fire-watch shall be provided when unloading isobutane or propane.

(4) Relief

A watchstander must not leave his/her station unless officially relieved or unless given permission by the Chief Operator. Watch relief must be conducted on a face-to-face basis.

(5) Safety Engineer Manning

A Safety Engineer shall be present at the Raft River Geothermal Area at least once per week to review and assist the Plant Manager, Operations Supervisor, and operating crew in evaluating plant hardware, operations, and maintenance safety.

(6) 5 MW(e) RRPP Organization

- a. Authorization for operation of the 5 MW(e) RRRDP is the responsibility of the Plant Manager who shall be responsible for safe operation of the plant.

- b. The basic elements of the 5 MW(e) RRPP organization for the delegation of authority and technical support for safe operation of the plant are as shown in Table 10.6.

10.8.2 Operating Personnel

- o Chief Operator - The senior crew member who supervises and has responsibility for all activities conducted with the 5 MW(e) RRPP or that directly affect the RRPP and its related fire and safety hazards. This person is accountable for ensuring strict compliance with operating and test procedures, safety standards, and technical specifications covering plant operations.
- o Control-Room Watch - The Chief Operator or GPP0-II which is responsible for operation of all systems in the control room. The control-room watch reports to the Chief Operator.
- o Roving Watch - The GPP0-I or II responsible for the direct local monitoring of equipment performance and operation of equipment that is locally controlled. The roving watch reports to the Control Room Watch.
- o GPP0-I and II - A geothermal power plant operator is an individual who is trained and qualified for operation of the 5 MW(e) RRPP in accordance with the training manual.
- o S&I Operator - An S&I Operator is an individual who is trained and qualified for operation of the Supply and Injection System.

TABLE 10.6. ORGANIZATIONAL RESPONSIBILITY

10.8.3 Review and Audit

This section specifies the minimum requirements for EG&G review of 5 MW(e) RRRDP operational safety in accordance with EG&G Safety Manual 2020, NFPA-70, ID Appendix 0550, and DOE 5480.1 Chapter VII.

The following review and audit shall be performed to assess the operational and safety aspects of the plant and the degree of conformance to approved documents:

- o EG&G Safety Division shall review 5 MW(e) RRRDP operations at least once every 12 months to ensure compliance to ID Appendix 0550, NFPA-70, DOE 5480.1 Chapter VII, and EG&G Safety Manual 2020.

10.8.4 Technical Specification Violation

This section specifies the responsibilities and procedures for reporting of failures to comply with the Technical Specifications associated with the 5 MW(e) RRRDP.

- (1) Upon failure to comply with any safety limits in Section 10.3, the isobutane-process system shall be in standby (Mode 6) within 1 hour and in lay-up (Mode 1) within 71 hours (except as noted in Specification 10.8.4(4), and the system will remain in lay-up until approved for further operation by the Plant Manager.
 - a. The Chief Operator shall immediately notify the Operations Supervisor, who will immediately orally notify the following:
 - o Plant Manager

- o EG&G Safety Division
- o Branch Manager, Raft River Geothermal Area, or the designated representative, who will in turn notify the DOE-ID Raft River Geothermal Area Site Manager or the designated representative
- o DOE-ID Warning Communication Center
- b. After conducting a review, an Unusual Occurrence Report shall be prepared, in accordance with the requirements of EG&G Safety Manual 3080. Distribution shall include the following:
 - o Director, Energy and Technology Division, DOE-ID
 - o Director, Operational Safety Division DOE-ID
- c. Subsequent start-up shall be in accordance with disciplined logic and approved procedures.
- (2) Failure to comply with any limiting-control setting (Section 10.4), Limiting Condition for Operation (Section 10.5), or Surveillance Requirement (Section 10.6), subparagraphs entitled Specification, shall be orally reported in the following manner:
 - a. The Chief Operator shall notify the Operations Supervisor who will immediately orally notify:
 - o Plant Manager
 - o Branch Manager, Raft River Geothermal Area, or the designated representative, who in turn will

notify the DOE-ID Raft River Geothermal Area Site Manager or the designated representative.

- b. After review, an Unusual Occurrence Report shall be prepared, in accordance with the requirements of EG&G Safety Manual 3080. Distribution shall include the following:
 - o Director, Energy and Technology Division, DOE-ID
 - o Director, Operational Safety Division, DOE-ID
 - c. In the event progression to a lower mode of operation is required due to failure to comply with Technical Specification or in response to the action required for a Limiting Condition for Operation, subsequent operation in a higher mode requires approval of the Plant Manager, who may obtain advice of the Engineering Division and Safety Division.
 - d. Subsequent startup, following shutdown due to failure to comply with a technical specification including the applicable action statement will be in accordance with disciplined logic and approved procedures and requires approval by the Plant Manager.
 - e. Whenever it is required to follow the action specified for Limiting Conditions for Operation, the event and its circumstances shall be entered in the operations log.
- (3) Violation of two or more Safety Limits and Limiting Control setting in any combination will require the isobutane-process system to be placed in standby (Mode 6) within one hour and in lay-up (Mode 1) within 71 hours,

except as noted in Specification 10.8.4(5), and the system will remain in lay-up until approved for further operation by the Plant Manager.

- a. The Chief Operator shall immediately notify the Operations Supervisor who will immediately orally notify the following:
 - o Plant Manager
 - o EG&G Safety Division
 - o Branch Manager, Raft River Geothermal Area, who will in turn notify the DOE-ID Raft River Geothermal Area Site Manager
 - o DOE-ID Warning Communication Center.
- b. After conducting a review, an Unusual Occurrence Report shall be prepared, in accordance with the requirements of EG&G Safety Manual 3080. Distribution shall include the following:
 - o Director, Energy and Technology Division, DOE-ID
 - o Director, Operational Safety Division, DOE-ID.

(4) Failure to comply with the specifications in Section 10.8, Administrative Controls, shall be orally reported in the following manner:

- a. The Chief Operator shall immediately notify the Operations Supervisor who will immediately orally notify the following:

- o Plant Manager
 - o Branch Manager, Raft River Geothermal Area, or the designated representative.
- b. After review, EG&G Management shall determine the severity of the compliance failure and determine disciplinary action.
- (5) In the event a failure to comply with a specification is determined to have existed at some previous time but does not currently exist, an immediate assessment shall be made to determine if operation can continue safely, or if the plant should be placed in a lower mode of operation. A review shall be initiated to determine the effect of the compliance failure, and the appropriate corrective action to be taken.

10.8.5 Plant-Operating Procedures

Written and approved procedural control documents are required prior to plant operations. The minimum coverage shall involve four categories.

- (1) Control of propane and isobutane transfers from trucks to storage.
- (2) Operation, testing, and maintenance of all important equipment. The more significant are:
 - o Propane- and isobutane-storage system
 - o Vapor compressor-condensor

- o Flare system
 - o Isobutane-process system
- (3) An approved Emergency Action Plan shall be provided to control conduct of EG&G personnel during potential or actual emergency situations.
- (4) Changes to the procedures must be approved prior to implementation and upon approval, will be considered part of the approved procedures.

10.8.6 Plant-Operating Records and Reporting

The plant operations and facility records as itemized below shall be prepared and maintained. Retention shall be for the life of the plant, or as otherwise directed by the Department of Energy.

(1) Operating logs:

- o Control room log sheets
- o Chief Operator's written log
- o Roving Watch log sheets
- o Water treatment log sheets
- o Chemistry laboratory written log
- o Status of disabled plant equipment for systems required to be operational by the Technical Specifications. Also includes lockout and tag-out for all equipment.

- (2) Record of Unusual Occurrences, incidents and reviews
- (3) Facility modifications documentation
- (4) Records of personnel training and qualification
- (5) Maintenance and repair records
- (6) Isobutane and propane inventory, loading, and storage records.
- (7) Startup and Shutdown Operational check lists.
- (8) Records of certification of acceptance test completion.

Readings and checks required by Technical Specifications shall be formally recorded and evaluated.

10.8.7 Technical Specifications Review and Revision

- (1) The 5 MW(e) RRRDP Technical Specifications shall be reviewed by the Safety Division at intervals not to exceed 13 months, to determine their continued adequacy.
- (2) Revisions to the 5 MW(e) RRRDP Technical Specifications subparagraphs entitled Specifications, and any revision to Definitions shall have EG&G-management and DOE-ID approvals. The revision shall be submitted at least 15 calendar days prior to implementation except when the difference between the time of need for the revision to the time of need for implementation is not sufficient to allow for 15 days. The revision request shall be accompanied with adequate justification for the change and why the existing situation is inadequate.

- (3) Any revision to Bases, Applicability, Objectives, or Design Features (Section 10.7) shall be reviewed by the Safety Division to assess whether the revision decreases actual safety margins or changes the intent of the Specifications. If no decrease in the margin or if no change in the intent of Specifications results, these facts shall be shown in the request. If a reduced safety margin results or a revision changes the intent of a specification, the proposed revision shall receive Safety Division approval prior to implementation. Such approval request shall meet the requirements of 10.8.7(2).
- (4) The 5 MW(e) RRRDP Technical Specifications shall be released and controlled by Energy Programs Division Document Control Services (DCS). A controlled file shall be maintained by DCS for the documents referenced in the 5 MW(e) RRPP Technical Specifications and revisions thereto shall be incorporated upon approval of the Plant Manager.
- (5) Revisions will be submitted to DOE-ID for information within 14 days after incorporation.

10.8.8 Facility Modification

Revisions to the 5 MW(e) RRRDP shall be designed, installed, and documented in accordance with the following specifications:

- (1) Evaluations to detect potential unreviewed safety questions will be performed by the Safety Division on all modifications which could affect the plant safety. This evaluation will be reviewed by the Plant Manager.
- (2) Any modifications to the following portions of the facility shall receive review and approval by the Safety Division and DOE-ID approval prior to implementation.

- o Propane- and isobutane-storage area
 - o Isobutane-process area.
 - o Flare system
 - o Fire-protection system
 - o Electrical-power systems, including emergency-power sources, upon which the plant-flare system and control room are dependent.
 - o Any other system, subsystem, structure or component whose failure could result in an uncontrolled release of isobutane or propane.
- (3) Modifications to the 5 MW(e) RRRDP shall be to the codes and standards in the original plant specifications or equivalent.

10.8.9 Documentation Requirements for Operation

The following documents and changes thereto necessary to ensure that the plant can be operated safely within the Technical Specifications and without constituting an unreviewed safety question, shall be written and approved prior to integrated plant testing.

- o Safety Analysis Report
- o Facility Operating Procedures
- o System and Integrated Plant Tests.

10.8.10 Training

- (1) Training, qualification, and records of 5 MW(e) RRRDP operations personnel to satisfy Operator Training Requirements is the responsibility of the 5 MW(e) RRPP Plant Manager.
- (2) Practical training of operations personnel may be done at the Raft River Geothermal Area, providing the trainee is under the direct supervision and in the presence of a qualified operator.
- (3) Training of 5 MW(e) RRRDP operations personnel shall be in consideration of:
 - o Compliance with approved Technical Specifications
 - o Operating procedures and test plans
 - o Training policies and procedures
 - o Operator training requirements
 - o The need for an adequate Fire Brigade

10.8.11 Pressure Vessel Inspection

- (1) Pressure-vessel inspections shall be performed to the requirements of the inspection program for the unfired pressure vessels at the 5 MW(e) RRRDP.
- (2) Changes to the 5 MW(e) RRRDP Pressure Vessel Inspection Manual shall be approved by the Plant Manager, and the Safety Division.

(3) Pressure Vessels covered by this Technical Specification are:

o HX-201	o P-102
o HX-202	o HX-601
o HX-203	o TK-601
o HX-204	o TK-602
o HX-401	o TK-1201
o ES-401,402,403, & 404	o TK-1301
o TK-101	o TK-1302
o P-101	o WS-101

10.8.12 Fire Protection Equipment Inspection

(1) Inspections and tests on the fire protection system shall be in accordance with the standards in the NFPA Codes.

(2) Inspections and tests shall include:

<u>Item</u>	<u>Daily</u>	<u>Weekly</u>	<u>Monthly</u>	<u>Bi-Monthly</u>	<u>Semi-Annually</u>	<u>Annually</u>
Fire hazards	1	A				
Fire extinguishers (Portable)						
Building			2D			4A
Vehicles and equipment			2D (Quarterly PM)			4A
Fire doors			2D			5D
Fire-alarms systems						
Sprinkler systems			2C		5A	3B
Detection systems			2C			3B
Manual fire-alarm boxes				5C		
Supervisory devices					5B	
Fire-protection system control valves			2D			5D
Fire pumps		5D				5A
Water-supply systems						5A
Fire hydrants			2D			5A
Fire-sprinkler systems						
Deluge			2B,C		5A	
Wet, Dry, Pre-action			2B,C		5A	
Stand-pipe hose and outside hose houses			2D			5A
Special extinguishing systems						
Halon			2D		5A	
Dry chemical			2D		5A	

<u>Item</u>	<u>Daily</u>	<u>Weekly</u>	<u>Monthly</u>	<u>Monthly</u>	<u>Annually</u>	<u>Annually</u>
Self-contained breathing apparatus			2D			5A
Emergency lights			2D			
Emergency equipment			2D			

NOTE: Type of Inspection

- 1 = Visual inspection by all employees (not recorded)
- 2 = Recorded visual inspection (record findings)
- 3 = Preventive maintenance
- 4 = Breakdown (record findings)
- 5 = Performance test (record performance)
- A = By Safety Division
- B = By Communications and Power Branch
- C = Emergency Brigade
- D = By Maintenance or Operations

(3) Inspections and tests shall be performed by the Fire Protection Engineering Section of the Safety Division.

10.8.13 References

The references used in Chapter 10, in order of sequence made to them are:

- o Section 8, Division 1, ASME Boiler and Pressure Vessel Code.
- o C. J. Bliem, and D. J. Wiggins, Performance and Operability Study of the Raft River 5 MW(e) Pilot Geothermal Power Plant, Transient Behavior, EG&G Idaho, Inc. PG-G-80-028, February 1980.
- o O. J. Demuth, Preliminary Considerations of the Effects of Supply and Injection System Transients on Thermal Stress in Transite Pipes. OJD-7-79 Letter to N. Spang October 2, 1979.
- o D. J. Wiggins, Operations of the Raft River Pilot Plant, PG-G-80-037, June 1980.
- o Chapter 1.0 5MW(e) SAR
- o Chapter 3.0 5MW(e) SAR
- o Chapter 5.05 MW(e) SAR
- o FSEC Specifications For Raft River Geothermal Loop Facility
- o John Zink Operations and Maintenance Manual (Flare).
- o FSEC Drawings For Raft River Geothermal Loop Facility
- o Specifications for 5 MW(e) Flare System, August 29, 1978.

- o Automatic Sprinkler Corporation Vendor Data.
- o NFPA-70, National Electric Code
- o EG&G Safety Manual 2020, Independent Safety Review
- o ID Appendix 0550, Standard Operational Safety Requirements
- o ERDAM 0552 Fire Protection
- o SDD Chapter 1, General Plant Description (Westec Serv. Inc.)
- o SDD Chapter 3, Isobutane System (Westec Serv. Inc.)
- o SDD Chapter 8, Isobutane Flare System (Wastec Serv. Inc.)
- o SDD Chapter 13, Facilities and Utilities--Propane and Isobutane Storage. (Westec Serv. Inc.)