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INEEL/EXT-98-00938

December 1998

Conceptual Design Report for the Extreme Ecosystems Test Chambers

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Published December 1998

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**Prepared for the
U.S. Department of Energy
Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223**

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ABSTRACT

This conceptual design supports the creation of Extreme Ecosystems Test Chambers, which will replicate deep subsurface and subocean environments characterized by high pressure (2,000 psi) and subfreezing to high temperature (-4 to 300°F) with differing chemical and saturation conditions. The design provides a system to support research and development that includes heat transfer, phase change issues in porous media, microbiology in extreme environments, and carbon sequestration and extraction. The initial system design is based on the research needs to support the commercial production of methane hydrates from subsurface sediments. The design provides for three pressure vessels: a Down Hole Test Vessel, a Vertical Multi-phase Test Vessel, and a Horizontal Multi-phase Test Vessel.

SUMMARY

This report seeks funding for research and development at the Idaho National Engineering and Environmental Laboratory to support economic extraction of methane from methane hydrates on the ocean floor. These methane deposits, which are crystalline solids that are stable in ocean floor sediments at water depths greater than 1,000 ft, are potentially a significant source of energy for the United States. Indeed, the U.S. Geological Survey estimates that two areas, each about the size of the State of Rhode Island, contain more than 1,300 trillion cubic feet of methane gas. In connection with this discovery, the U.S. Department of Energy recently established a goal to begin commercial exploitation of methane hydrates by 2015.

To support this effort by DOE, INEEL researchers developed a conceptual design for facilities known as the Extreme Ecosystems Test Chambers. The facilities simulate subocean environments characterized by high pressure (2,000 psi), subfreezing to high temperature (-4 to 300°F), and differing chemical and saturation conditions. These facilities include the Down Hole Test Vessel, two Multiphase Test Vessels, and a storage and archival system, all enclosed within a new or existing structure. Some will test methane hydrate flow and production processes, others will test hydrate coring and extraction tools. If constructed, the facilities will provide the U.S. Department of Energy and other federal agencies with the ability to evaluate biological, geological, chemical, and physical interactions in controlled environments while developing and validating simulation models, which can be used to predict responses in natural systems.

The Down Hole Test Vessel, a large, hastelloy-lined vessel, is designed for high pressures (up to 2,000 psig) and severe corrosion environments. The vessel, which is approximately 6.5 ft inside diameter by 12 ft high, is designed specifically for full-scale testing of hydrate coring tools, hydrate extraction processes, and testing of acoustic processes to identify and characterize natural hydrate deposits. Systems to produce hydrate within the vessel to simulate in situ deposits are provided along with the drilling equipment to support testing of alternative coring devices.

The Down Hole Test Vessel, for full-scale testing of hydrate production technologies.

Core samples of methane hydrate will be removed from the Down Hole Test Vessel while maintaining vessel pressure on the sample.

Two Multiphase Test Vessels have been designed to support flow and production testing. One is oriented vertically while the other is horizontal to allow tests of multiphase (gas/liquid) flow in both directions relative to gravity. The vessels are approximately 12 in. in diameter and 16.4 ft long. They pump gas and/or liquid into one end and remove it at the other end while measuring the flows, temperatures, and phase compositions. The vertical vessel has provisions for upward and downward flow. Systems are also provided to produce simulated hydrate deposits in each of these vessels.

The two Multi-Phase Test Vessels, for testing methane hydrate production.

The storage and archival system has been designed to store hydrate samples produced in the facility and extracted from natural environments. The system provides storage for 100, 10-ft-long cores. The storage area is maintained at -4°F , with individual core-holding vessels pressurized to ensure the integrity of samples. A refrigerated room, designed to reduce core sample degradation due to sublimation, evaporation, etc., is provided for core sampling and analysis. This room has equipment that will move samples over 2,000 lb (including transport containers).

The hydrate storage facility will house 100 cored samples at specified temperature and pressure.

The Extreme Ecosystems Test Chambers may be housed in a new or in an existing facility. For the purposes of this conceptual design, it was assumed to be housed in a new facility. The conceptual floor plan occupies an area approximately 165 ft long and 104 ft wide. This includes space for all required vessels, hydrate production, sample storage, a control area, and several laboratories for small-scale experimentation. Due to the height of the DHV, the associated drilling equipment, clearances for crane access, etc., it is located in a bay that is 73 ft-6 in. high (top of parapet). This height is based on a design that provides a 16.4 ft total bed height and allows at least a 9.8-ft core to be drilled and extracted. These requirements establish a conservative basis for the conceptual design. Several alternatives to reduce this height are provided but have not been costed.

This conceptual design provides the first step in determining the research and development infrastructure needs to support development of advanced technologies in extreme environments, focusing specifically on methane hydrates production. Based on this design, both conceptual cost estimates and schedules have been developed to better understand the resources and time required to build such a facility. The Total Estimated Cost (TEC) for the equipment (test vessels, etc.) is \$20 million, and the TEC for the building is \$9.6 million.

CONTENTS

ABSTRACT	iii
SUMMARY	v
ACRONYMS	xiii
1. INTRODUCTION	1
2. DESIGN CRITERIA AND KEY ASSUMPTIONS	3
2.1 Process and Equipment Requirements	3
2.1.1 Pressure Vessels	3
2.1.2 Influent	4
2.1.3 Hydrate Production	5
2.1.4 Hydrate Storage and Archival System	5
2.1.5 Effluent and Emission Systems	6
2.1.6 Piping	6
2.1.7 Components	6
2.1.8 Materials	7
2.2 Process Instrumentation and Controls	7
2.2.1 Expansion	7
2.2.2 Remote Operation and Control	7
2.3 Power	8
2.3.1 Back-up Power	8
2.3.2 Uninterruptible Power	9
2.4 Space	9
2.4.1 Down Hole Test Area	9
2.4.2 Down Hole Hydrates Production Area	9
2.4.3 Multiphase Test Vessel Area	9
2.4.4 Multiphase Hydrates Production Area	9
2.4.5 Effluent Treatment Area	9
2.4.6 Control Area	9
2.4.7 Bench Test Area	10
2.5 Location	10
2.6 Access	10
2.7 Cranes	10
2.8 Occupancy Safety Requirements	10
2.9 Environmental Requirements	11
2.10 Key Assumptions	11
3. ALTERNATIVES	12
3.1 Hydrate Production Alternatives	12

3.2	Hydrate Production Vessel Room Height Alternatives	13
3.2.1	Installing the Full Height Vessel In a Pit.....	13
3.2.2	Reduced Vessel Height.....	13
3.2.3	Reduced Vessel Height Installed in a Pit.....	14
4.	DESIGN DESCRIPTION (RECOMMENDED ALTERNATIVE).....	15
4.1	Facility and Operational Overview	15
4.1.1	Operations Within the Down Hole Test Vessel Area.....	15
4.1.2	Operations Within the Vertical and Horizontal Multi-Phase Test Vessel Area.....	16
4.1.3	Sample Archiving.....	17
4.2	Process	17
4.2.1	Hydrate Production Process Description.....	17
4.2.2	Hydrate Bed Standby.....	20
4.2.3	Vessel Unloading and Effluent Treatment	20
4.3	Test Equipment.....	21
4.3.1	Pressure Vessels	21
4.3.2	Core Sampling of the Hydrate Bed in the DHV	22
4.3.3	Hydrate Storage and Archival System.....	27
4.4	Civil, Architectural, and Structural.....	29
4.5	HVAC Systems.....	30
4.6	Mechanical Utilities.....	30
4.7	Glycol Chilling System.....	30
4.8	Electrical Systems.....	30
4.9	Monitoring and Control	31
5.	RECOMMENDED DESIGN STUDIES AND RESEARCH TO SUPPORT FURTHER DESIGN	32
5.1	In-Vessel Tomography	32
5.2	Storage Stability of Hydrate Samples	32
5.3	Xenon as a Substitute for Hydrogen Sulfide	32
5.4	Hydrate Production Studies	33
5.4.1	Proposed Test Unit	33
5.4.2	Demonstration of Hydrate Production by Heat Conduction and Determination of Cooling Coil Duty Requirement	33
5.4.3	Demonstration of Hydrate Production by Water Circulation	34
5.4.4	Demonstration of Hydrate Production by CO ₂ and Hydrocarbon Circulation	34

5.5	Effluent Treatment Studies	34
5.5.1	H ₂ S Removal	34
5.5.2	Hydrocarbon Oxidation	35
6.	COST ESTIMATE AND FUNDING REQUIREMENTS	36
7.	SCHEDULE.....	38
8.	REFERENCES.....	40

Appendix A—Functional and Operational Requirements

Appendix B—Drawings

Appendix C—Hydrates Production Tables

Appendix D—Equipment List

Appendix E—Cost Estimate

FIGURES

1.	Down hole test vessel.....	21
2.	The multi-phase test vessels will be used to examine the properties of flow, hydrate formation, etc.	23
3.	Core samples of methane hydrate will be removed from the DHV while maintaining vessel pressure on the sample.	23
4.	Drilling equipment for extracting cores from the DHV.....	24
5.	Typical gate valve will be used to isolate the vessel from the drilling equipment.....	25
6.	The core preservation equipment spool maintains the vessel pressure conditions during retrieval and transport of the cores to a storage facility.....	26
7.	The hydrate storage facility will house approximately 100 cored samples at specified temperature and pressure.....	27
8.	The cored samples are each maintained within a separate vault and pressure vessel to maintain individual properties.....	28
9.	The pressure vessels that are located within each vault contain the cored samples at specified pressure.	29

TABLES

1.	Cost estimate for new EETC building.....	36
2.	Cost estimate for EETC equipment.....	37

ACRONYMS

ACFM	actual cubic feet per minute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
DHV	Down Hole Test Vessel
DI	deionized water
EETC	Extreme Ecosystems Test Chambers
HVAC	Heat, Ventilation, and Air Conditioning
INEEL	Idaho National Engineering and Environmental Laboratory
MPV	Multipurpose Test Vessel
MWD	measurement while drilling
NEC	National Electrical Code
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
OD	outside diameter
RTD	ranged thermistor
UBC	Uniform Building Code
UPS	Uninterruptible Power Supply

Conceptual Design Report for the Extreme Ecosystems Test Chambers

1. INTRODUCTION

The purpose of the Extreme Ecosystems Test Chamber project is to design and build several engineered environments of various sizes, shapes, and ecological complexities representative of extreme environments. This will provide the U.S. Department of Energy (DOE) and other federal agencies with the ability to evaluate biological, geological, chemical, and physical interactions in controlled environments while developing and validating simulation models, which can be used to predict responses in natural systems. Victor Kennedy, the director for the Multiscale Experimental Research Center, suggests that the ability to make predictions by extrapolating results from controlled laboratory experiments to natural ecosystems with known accuracy and precision is one of the most significant challenges facing the scientific community today.

The Functional and Operational Requirements (Appendix A) provide the basis for this conceptual design. The design is intended to provide the systems to replicate subsurface and subocean environments characterized by high pressure (2,000 psi), temperatures varying from -4 to 300°F, and with differing chemical and saturation conditions. Specifically, the systems will support research and development needs that include heat transfer and phase change issues in porous media, microbiology in extreme environments, and carbon sequestration and extraction. The design of systems to support this research is based on the needs identified for gas hydrates research and development. These systems will provide a broad array of capabilities that encompass the needs of many extreme environments.

Gas hydrates occur abundantly in nature, both in arctic regions and in marine sediments. They are crystalline solids consisting of gas molecules, usually methane, each surrounded by a cage of water molecules. Methane hydrate is stable in ocean floor sediments at water depths greater than 1,000 ft, and where it occurs, it is known to cement loose sediments in a surface layer several hundred meters thick. The United States Geological Survey estimates that two relatively small areas, each about the size of the State of Rhode Island, contain more than 1,300 trillion cubic feet of methane gas. This is more than 70 times the 1989 gas consumption in the United States. This potentially huge carbon reserve has significant potential to support our energy needs. In addition, the processes that have trapped these gasses may provide a potential method of carbon sequestration.

In the DOE Methane Hydrate Research and Resource Development Workshop, held in January 1998, DOE established a goal to begin commercial exploitation of methane hydrates by the year 2015. Through this workshop, experts identified science and technology issues that must be addressed for successful exploitation of the resource. These include:

- Characterization (Reservoirs). Technology does not presently exist to adequately
  - Determine the distribution of methane hydrates
  - Characterize methane hydrate reserves
  - Determine the volume of methane hydrate reserves
  - Understand why and how methane hydrates got where they are.

- Physical Chemistry. We presently do not have a thorough scientific understanding of
  - The physical chemistry of methane hydrates
  - The thermodynamics of methane hydrates
  - The effects of 2-phase to 3-phase transition associated with methane hydrates
  - The effects of differing sediment composition on the physical and chemical properties of methane hydrates.
- Production. Technology does not exist to
  - Economically produce methane from methane hydrates
  - Characterize the methane hydrate system (porosity, permeability, sediment effect, sample preservation, reproducibility)
  - Reproduce sub-sea methane hydrate samples for testing.
- Safety. Technology or science does not presently exist that can adequately
  - Detect and characterize methane hydrates
  - Determine how hydrates and hydrate processes affect sediment properties
  - Understand hydrate dissociation and its effects on sediments
  - Be able to predict mass movements and their consequences
  - Determine whether hydrate deposits can seal high-pressure gas accumulations and influence seafloor stability
  - Determine the quantities of hydrate that constitute a hazard
  - Understand the effects on hydrate beds from production wells
  - Determine if hydrate production will cause subsidence and catalogue subsidence effect from other causes.
- Global Change. The science does not exist to understand
  - How much methane hydrate is susceptible to climate change
  - The impact of these methane hydrates on global warming
  - The consequences from the release of methane from these hydrates
  - The role of methane release on global climate change.

2. DESIGN CRITERIA AND KEY ASSUMPTIONS

This section defines the requirements that will drive the advanced conceptual design for the Extreme Ecosystems Test Chambers project.

2.1 Process and Equipment Requirements

This section discusses the requirements for the pressure vessels, influent control, hydrate production, storage and archival systems, effluent and piping, components, and materials.

2.1.1 Pressure Vessels

Pressure vessels shall be designed, fabricated, and installed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2 as specified.

Pressure vessel welding shall be in accordance with the requirements of paragraphs UW-2(a) and UW-11 (lethal substances), of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code. Ultrasonic testing in accordance with UW-53 may be substituted for radiographic examination.

2.1.1.1 Down Hole Test Vessel (DHV). A vessel shall be provided that allows for testing of full-scale coring tools and down-hole instrumentation. Analysis shall be performed to determine the vessel size. Presently, the vessel shall be about 6.5 ft inside diameter with the ability to establish a hydrate bed height of a minimum 9.8 ft. To test coring tools, there shall be a way to position coring tools at the bed surface or 8 in. into the bed so that a 6 to 9.8-ft-long core can be extracted from the bed. To test instrumentation, there shall be a way of drilling or coring 6-in.-diameter vertical holes through the entire bed. The capability shall be provided to lower a 220-lb instrument into the hole. The vessel shall be designed to allow for remote techniques to evaluate the contents real-time.

Design conditions for the DHV are:

Test Mode	Design Pressure	Design Temp	Environment
Hydrate Test Mode	2,000 psig max.	-4°F to ambient	Simulated seawater, with methane, carbon dioxide, ethane, or hydrogen sulfide (H ₂ S). H ₂ S can be present in concentrations of up to 10 vol% concentrations.

The DHV shall be provided with a minimum of five penetrations in the upper head to allow access for coring tools and other instrumentation. The penetrations shall be nominal 8 in. pipe size with Grayloc or equivalent connections. Two additional penetrations (also 8 in. nominal pipe size) shall be provided in the upper head for pressure relief and vessel filling. A 24-in. OD manway shall be provided in the side of the vessel. At least one 8-in. penetration shall be provided in the lower head. Instrumentation taps shall be provided as required. Pressure vessel materials shall be compatible with the environment and service conditions.

2.1.1.2 Drilling Equipment. Drilling equipment shall simulate actual drilling operations and so should incorporate fluid pumping into and removal from the hole. The purpose of the fluid is to simulate the thermal and fluid effects on the surrounding hydrates, not to control pressure in the "well." Additionally, there shall be ways to measure the evolution of gas, water, and loose solids in the vessel during drilling or tool testing as well as during simulated production or well depressurization.

2.1.1.3 Acoustic Vessel. A vessel shall be provided for seismic studies. This vertical vessel is envisioned to be 3.2 ft in diameter and 13 ft high. Systems shall be provided for fabricating a layered hydrate bed. The ability to incorporate or inject free gas into the bed with the hydrates shall be provided. A number of fittings suitable for attaching acoustic transponders shall be incorporated in the lower head. An evaluation was performed to determine if this vessel's function could be integrated into the DHV. It was determined that the DHV shall provide this function and that a separate acoustic vessel will not be needed.

2.1.1.4 Multi-phase Test Vessels (MPV). Two vessels shall be provided for flow and production testing. They shall be alike in form and function. One shall be oriented vertically while the other shall be horizontal to allow tests of multiphase (gas/liquid) flow in both directions relative to gravity. The vessels shall be approximately 12 in. in diameter and 16.4 ft long. They shall have provisions for pumping gas and/or liquid into one end and removing it at the other end while measuring the flows, temperatures, and phase compositions. The vertical vessel shall have provisions for upward and downward flow. Low-temperature heat shall be provided at various locations on the outside of the vessels to encourage hydrate melting. Online tomographic analysis of hydrate, liquid, and gas shall be provided.

Design conditions for the MPVs are:

Test Mode	Design Pressure	Design Temp	Environment
Hydrate Test Mode	2,000 psig max.	-4°F to ambient	Simulated seawater, with methane, carbon dioxide, ethane, or hydrogen sulfide (H ₂ S). H ₂ S can be present in concentrations of up to 10 vol% concentrations.

The MPVs shall be provided with inlet and outlet penetrations on either end. Penetrations shall also be provided for pressure relief and instrumentation.

2.1.2 Influent

Systems shall provide alternative influent feeds of gasses, liquids, and solids into the vessels. These will include water, CO₂, methane, and other hydrocarbons. Systems shall be provided to mix and store solutions. Systems shall be provided for introducing and removing sediment over a range of particle sizes, porosity, density, and thermal conductivity.

The solids will be used to simulate sea-bottom sediments or permafrost layers. Liquid shall be representative of either seawater or the water found in permafrost regions. The gases shall be those found in natural hydrate zones or will be representative of carbon dioxide sequestration schemes.

2.1.2.1 Solids. For each experiment, the solids to be used shall normally be distributed homogeneously throughout a vessel. The system shall have the option of feeding two different kinds of solids to assist in forming layers of hydrates or to simulate (in a greatly scaled down way) differences in seafloor structure. The system shall use readily available solids as a substitute for actual ocean sediment: sieved sand, diatomaceous earth, or other essentially inert solids such as alumina that can be handled without producing large air pockets or excessive agglomeration. All of these materials are assumed to be available in bags or in bulk containers that can be loaded into storage hoppers with a forklift.

2.1.2.2 Liquids. The liquid to be used shall normally be synthetic seawater. Water is necessary to form hydrates, and the presence of dissolved salts is needed in these experiments because of its effect on

reducing the hydrate formation temperature. Since hydrate formation will leave behind a slightly concentrated salt solution, which inhibits further hydrate formation until it diffuses away, this shall be an important effect. In addition, the presence of salts in solution will greatly change the electrical properties of the water, which may have a major effect on the performance of experimental logging tools to be tested in this system. So, although the system shall replicate seawater's salt content, the effect does not require the complex chemical makeup of true seawater. In most experiments, a 3-wt% solution of NaCl shall be used for simplicity, although deionized water should also be available for experiments with fresh water or for equipment rinsing.

2.1.2.3 Gases. Methane shall be the material most commonly used, in one of two forms. Pure methane (the exact grade to be determined by the experiment, but likely 99.5% pure or higher) shall be used when the exact hydrate formation conditions must be predictable. A mixture of methane and other gases, with methane being 90–98% of the total, may also be used to determine the effects of incidental components. These other components (typically expected to be ethane, propane, carbon dioxide, perhaps nitrogen) shall be added from cylinders or they may be a custom gas mixture delivered by tank truck from a gas supplier. In addition, hydrogen sulfide will be of interest as a component because it can reasonably be generated biologically under conditions similar to those for methane generation. If the costs of dealing with the toxicity and corrosion problems of hydrogen sulfide are judged to be too great, it may be feasible to use xenon gas. A study shall be performed to determine if this is feasible. Carbon dioxide shall also be used in the systems to explore sequestration technologies. Pure CO₂ gas would be the expected feed until work in that area of technology better defines the possible impurities and their levels in the carbon dioxide.

2.1.3 Hydrate Production

A system shall be provided that can produce gas hydrates for each vessel. The systems to feed vessels shall be designed to produce the hydrates at different densities with different gas types (methane, carbon dioxide, and natural gas) and concentrations, and different sediments and sediment concentrations. For the DHV and MPV, this shall include fabricating layered hydrates with various concentrations of hydrates ranging from approximately 1 to 80 vol% of the pore space between the sediments. The hydrate production systems shall use various dry sediment solids as the major component of the bed. The systems shall have a way of flooding the formed hydrate bed with water or seawater to displace contained free gas. All systems shall have the ability to introduce simulated seawater.

2.1.4 Hydrate Storage and Archival System

A system shall be provided that can store hydrate samples produced in the facility and extracted from natural environments. The storage and archival system shall be designed to store 100 10-ft-long cores and maintain hydrate stability. It is presently anticipated that the storage areas shall be maintained at -4°F and individual core holding vessels will be pressurized to about 150 psig to ensure the integrity of samples. The hydrate storage and archival system shall consist of a refrigerated room. The room shall be designed to accommodate individual core samples collected both at this test facility and other locations. The room shall provide an environment that significantly reduces core sample degradation due to sublimation, evaporation, etc.

The refrigeration room shall provide features that can move samples over 2,000 lb (including transport containers). Sufficient space shall be provided to store up to 100 core samples. Each sample storage vessel shall provide space for a sample that is 6-in. in diameter × 10-ft long.

In addition, the refrigerated room shall be provided with tables, equipment, and space for sample preparation, inspection, analysis, and other necessary activities.

2.1.5 Effluent and Emission Systems

2.1.5.1 Liquid Effluent. The system shall be able to dispose of cooling water and other liquid effluents generated during testing and system clean-up. This shall include the processing of water that contains sodium salts. The design shall include storage for effluent from the vessels for sampling before release.

2.1.5.2 Gas Emission System. A gas emission system shall remove any hazardous components from the effluent of the system during pressure letdown (from 2,000 psi to near atmospheric). Gas vented to the atmosphere shall meet applicable emission standards. Gases expected in the effluent includes methane, ethane, hydrogen sulfide, carbon dioxide, water vapor, and air. The system shall be designed to handle expected off-gas during normal and off-normal conditions.

Dedicated process vents shall be provided for the Down Hole, Acoustic, and Multi-phase vessels.

2.1.5.3 Solid Effluent. The facility shall be able to dispose of solid effluent generated during testing and system clean up. This shall include the processing sediment removed prior to disposal. The design shall include storage for effluent from the vessels for sampling prior to release. A study shall be conducted to determine if the solid effluent will require sterilization before to release.

2.1.6 Piping

Piping shall be designed, fabricated, and installed in accordance with ANSI B31.3. Nonstandard piping components (those not included in Appendix D of ANSI B31.1) that are included in the piping flexibility analysis shall have flexibility and stress intensification factors based on experimental or theoretical analysis.

Design conditions for the test piping (that is, piping directly associated with generation of hydrate beds within the vessels) and associated components shall be as follows:

Test Mode	Design Pressure	Design Temp	Environment
Hydrate Test Mode	2,000 psig max.	-4°F to ambient	Simulated seawater, with methane, carbon dioxide, ethane, or hydrogen sulfide (H ₂ S). H ₂ S can be present in concentrations of up to 10 vol% concentrations.
Cleaning/Thermal Decontamination Mode	300 psig max. 10 in. of water vacuum, min.	400°F max.	Steam, noncorrosive cleaning solutions

Other portions of the piping systems (such as refrigerant coolant loops) may not be subjected to all the conditions and environments listed above. Design requirements for these subsystems shall be determined and documented separately.

2.1.7 Components

Components shall be designed, fabricated, and installed in accordance with nationally recognized codes and standards. The following codes apply: valves—ANSI B31.3; Relief device outlets shall be directed to containment vessels or headers to prevent uncontrolled discharge to the environment.

2.1.8 Materials

Materials used in the construction within pressure boundaries shall be those permitted by ANSI B31.1, ANSI 31.3, and ASME Section VIII, Division 1 or 2, as applicable. A technically justified corrosion allowance shall be specified for use in determining the minimum required wall thickness of each system component. Structural materials shall conform to American Institute of Steel Construction (AISC) requirements. The system shall be designed so that corrosion measurement areas and temperature sensors can be easily accessed.

2.2 Process Instrumentation and Controls

This section discusses the requirements for the instrumentation and control system, which shall provide system monitoring, control, and data acquisition and archiving.

2.2.1 Expansion

The system instrumentation and control system shall be designed to accommodate expansion of multiple sensors and control actuators for the system. The required number of instrumentation channels and interface requirements cannot be accurately specified at this time. The conceptual design process shall develop a generic instrumentation and control system that anticipate the number of channels and channel requirements over the life of the system.

2.2.2 Remote Operation and Control

The control instrumentation systems shall allow operators to remotely monitor and control the experimental systems and utilities from the control area. Start-up of the system to operating condition and remote shutdown shall be required. The data acquisition and control system shall include

- On-line laboratory analysis measurement equipment
- Process sensors
- Sensor signal conditioning
- Acquisition systems and interfaces
- Display, printing, and archiving devices
- Automatic/manual control systems and interfaces
- Control, display and data reduction algorithms.

The data acquisition and archival instrumentation systems shall allow operators to acquire selected system process measurements from a safe distance to meet data objectives.

The vessel Monitoring and Control Instrumentation shall

- Specify accuracy and resolution of all sensors so that operation or automatic control systems can adequately monitor and control the system.

- Ensure that sensor systems have sufficient range to indicate normal operating conditions and abnormal conditions without sensor saturation.
- Ensure that sensor system response time is adequate for system process control and accurate process monitoring.
- Provide acquisition equipment so that aliasing errors do not interfere with the ability to monitor and control the system.
- Provide sufficient spare channels to accommodate the expected needs for the design life of the system.
- Provide automatic control system responses that will attempt to mitigate an overpressure condition before a response from the relief devices.
- Provide time tagging and backup of data.
- Provide real-time online monitoring of as many selected channels as are required to ensure safe operation and control of the system.
- Provide trend displays for all analog inputs. Provide for online trend monitoring of as many selected channels as are required to ensure safe operation and control of the system.
- Provide audio and visual annunciation capability for all process parameters to alert operators of potential abnormal conditions.
- Provide alarm indicators to alert an operator of a pending over pressurization, gas releases, or other hazardous conditions.

The system shall monitor the process area through closed circuit television equipment. The system shall provide enough cameras to allow coverage of the entire operating area, and will provide full pan/tilt/zoom capabilities for all cameras.

2.3 Power

Analysis shall be performed to determine the power requirements for the systems and chambers. During operation, several systems shall require a 100% guaranteed supply of electrical power to maintain data integrity during and after any aberrations in the normal power supply. Present estimates of process load requirements indicate that a standby capacity of 180 kVA (including the building HVAC system) is necessary.

2.3.1 Back-up Power

Back-up power capabilities shall ensure safe shutdown of systems and/or maintenance of critical experiments. The emergency/backup system shall automatically transfer the source of power in case of a power fluctuation/outage. Manual power selection shall be provided to allow for periodic maintenance. All process shutdown procedures, whether normal or emergency, will allow for the maintenance and preservation of all data. Standby power shall supply 100% of its connected load for at least 12 hours.

2.3.2 Uninterruptible Power

Uninterruptible power shall be provided to ensure safe operation, maintenance of critical experiments, and archival of data.

2.4 Space

The Extreme Ecosystems Test Chambers (EETC) shall be located in an existing or new building at the INEEL. A new facility shall meet the requirements of the version of the Uniform Building Code in effect at the beginning of design. Existing facilities, if used, shall be suitable for the proposed area classifications. It is presently envisioned to be located in the proposed Environmental Engineering Sciences Center. Distance, walls, protective barriers, or other means to protect the operators and other personnel shall separate the control room and supporting administrative areas from the process equipment. The EETC shall provide the following areas:

2.4.1 Down Hole Test Area

The Down Hole Test Area (DHTA) shall provide sufficient vertical and floor space to house the DHV, drill strings, drilling equipment, and lifting equipment. The area shall be NEC Class 1 Division 2 construction because of the potential presence of flammable gases. The area shall also be equipped with explosion panels to relieve pressure resulting from the combustion of these flammable gases.

2.4.2 Down Hole Hydrates Production Area

An area shall be provided next to the DHTA to house the equipment that will produce hydrate and sediment layers in the DHV. This area shall be NEC Class 1 Division 2 construction due to the potential presence of flammable gases. This area shall also be equipped with explosion panels to relieve pressure resulting from the combustion of these flammable gases.

2.4.3 Multiphase Test Vessel Area

An area shall provide the vertical and floor space to house both the vertical MPV and the horizontal MPV.

2.4.4 Multiphase Hydrates Production Area

An area shall be provided next to the MPVs to house the equipment that will produce hydrate and sediment layers in the MPVs. This area shall be NEC Class 1 Division 2 construction because of the potential presence of flammable gases. The area shall also be equipped with explosion panels to relieve pressure resulting from the combustion of these flammable gases.

2.4.5 Effluent Treatment Area

An area shall be provided to house equipment and systems to treat the effluents from the test vessels under normal conditions.

2.4.6 Control Area

A control area shall contain the necessary elements of the data acquisition and control system that are required for remote operation and monitoring of the system. The control area shall afford operations personnel an ergonomically designed work space, which will allow for the remote monitoring and

operation of the process (via closed circuit television) for extended periods of time. The operation of the process may extend over periods ranging from several hours to several days.

The operations area shall have enough room to accommodate a primary and a secondary control/monitoring station; a separate instrument panel for the gas chromatography system, and a separate instrument panel for a tomography system. Expansion space shall be provided to allow for future additions as may be determined as the process progresses.

The range of operational humidity for the instrumentation and control equipment must be between 5 and 95%, non-condensing. Operational temperatures allowed for the instrument and control equipment will range from -40 to 158°F. Presumably the control area temperatures will allow for continual occupation by operations personnel, and no special temperature requirements for the instrumentation and control hardware will be required.

2.4.7 Bench Test Area

Two rooms shall be provided to accommodate small-scale testing of hydrates. These areas shall be provided with 120 VAC and 480 VAC power, ventilation, and water. Specialty gases, including methane, shall be provided by high-pressure gas bottles.

Mechanical and electrical areas shall be provided to house ventilation and other mechanical systems and electrical distribution equipment.

2.5 Location

The system shall be located indoors in an area that provides adequate space; is well lighted, heated, and ventilated; has necessary fire protection and alarm systems; has phone and communication systems; has adequate power available; and meet general requirements for industrial hygiene such as protection from hazardous materials, restrooms, and washroom facilities.

2.6 Access

The area where the system will be located shall be accessible by exterior doorways sized to accommodate a flatbed truck with a minimum vertical clearance of 16 ft. Through this doorway, equipment and materials shall be brought into the area by truck or other vehicles and unloaded and set in position.

2.7 Cranes

Cranes shall be provided to support loading, unloading, and positioning of equipment.

2.8 Occupancy Safety Requirements

The UBC occupancy classifications for the facility shall be as follows: the Down Hole Test Area, Multiphase Test Vessel Area, Hydrate Production Areas, and Core/Specimen Storage Areas will be classified as H Division 2 Occupancies. The rest of the building shall be classified as B Occupancy.

Requirements for the H Division 2 Occupancies shall be as follows:

- Total non-combustible construction for the building.

- A 2-hour-fire-rated separation shall be provided between the H-2 and B occupancies.
- The down hole test area shall have an explosive blow-out panel in one of the outside walls. (Explosion pressure relief panel).
- The total building shall be protected with an automatic fire sprinkler protection.
- Flammable gas leak detection shall be provided throughout all H-2 Occupancy areas.
- Ventilation shall be provided to keep methane concentrations below the lower flammable limit if there is a leak from the closed system.
- Electrical in H-2 occupancy areas shall be NFPA-70 “National Electric Code” Article 501 for Class I Division 2 locations.
- Bore hole equipment shall be designed to operate in a flammable gas atmosphere.

2.9 Environmental Safety Requirements

An analysis shall be performed to determine if any safety class items are required to ensure that hazardous materials are not released as a result of a design basis accident. Appropriate NEPA documentation shall be prepared to ensure the facility is in compliance with NEPA. A Hazards Classification shall be prepared to define the appropriate safety documentation for the system.

Based on a preliminary review of the emissions anticipated to be released from the system, methane, ethane, and carbon dioxide emissions are within acceptable levels. Hydrogen sulfide emissions are approximately 100 times greater than allowed by law and will require treatment before release. The system shall include removal efficiency of greater than 99%.

Containment of fluids shall be provided in the case of a spill or emergency condition.

2.10 Key Assumptions

The power requirements of this process are about 1,100 kVA. Of this total, the standby/emergency power requirement is assumed to be 200 kVA. This is connected load, and requirements are expected to be reduced after the application of the appropriate demand/diversity factors. However, experience dictates that future modifications, additions, and refinements will require substantial increases in the electrical service capacities. It is reasonable to conclude, then, that the presently configured process may well require most, if not all, of this capacity.

The municipal power authority is assumed to be able to serve the load requirements of this process.

A secure, readily available source of standby power is assumed. If the requirements for 200 kVA of standby capacity is not appreciably increased, a common off-the-shelf Uninterruptible Power Supply (UPS), with associated battery backup, shall be able to carry the standby load for up to 15 minutes.

A better solution would be an on-site generator. With sufficient fuel storage capacity, a generator would be able to supply standby power for any “practical” length of time that commercial power would be unavailable.

3. ALTERNATIVES

3.1 Hydrate Production Alternatives

Gas hydrates have been produced in laboratory-scale equipment by introducing water and hydrate-producing gases into a temperature- and pressure-controlled chamber. The temperature is controlled either by cooling coils or submersing the chamber in a temperature-controlled bath, while a high pressure feed gas or mechanical means provides the desired pressure.¹⁻⁵

Hydrate production processes at larger scale have been proposed as the means to desalinate sea water,^{6,7} store and transport natural gas,^{8,9,10} or store refrigeration.^{11,12} In contrast to the laboratory methods, larger-scale production methods utilize flow systems along with direct heat transfer between the hydrate forming materials and a heat transfer fluid, which is typically one or more of the hydrate forming fluids. However, these larger systems have made hydrates only in water, not in beds of sediment.

In one desalination proposal,⁶ circulating propane is used to remove the heat of formation of the hydrate. Liquid propane enters the hydrate formation vessel at a rate equal to the sum of that needed for hydrate formation and that needed to supply refrigeration. Propane, at the latter rate, exits as vapor, is compressed, condensed, and recirculated. Seawater is used in heat exchangers to condense the recirculated propane. Another desalination scheme⁷ proposes using either a hydrate-forming hydrocarbon, e.g., propane, for the circulating heat transfer fluid, or a hydrocarbon liquid, such as mineral oil, which will contain the hydrate-forming gas in solution. Brine and the heat transfer fluid, either the hydrate forming hydrocarbon or a hydrocarbon liquid, are pumped counter currently through the hydrate formation vessel.

Patents describing natural gas and other gas storage and or transport systems utilizing hydrates also propose circulating fluids, with or without supplemental heat removal by heat exchange, to produce hydrates.^{8,9,10} In one scheme,⁸ water and the hydrate-forming gas are pressurized and flow through the hydrate forming vessel. The vessel contains both a cooling jacket and cooling coils that remove the bulk of the heat of hydrate formation. Water, hydrate, and hydrocarbon gas contained in the vessel effluent are separated, with the water being recirculated to the feed water and the gas recompressed and reintroduced into the vessel. Other schemes^{9,10} do not use cooling coils in or cooling jackets on the hydrate formation vessel, but rely on circulating fluids through the vessel to provide all of the heat removal needed for hydrate formation. One scheme⁹ relies on the hydrate forming fluid (propane, n-butane, i-butane, CO₂, CHFCI₂, CFCl₃, or CF₃Br) for heat transfer, while another¹⁰ circulates water. In the latter scheme, hydrates form in a pipe in which the chilled water and hydrocarbon are mixed. The hydrate and excess water are separated in a tank, with the water then recirculated. In each of these schemes for storage and transport of gases via hydrates, heat is removed from the heat transfer fluid by a heat exchanger in the circulation loop. Proposed systems^{11,12} for producing hydrates for use as refrigeration storage systems are similar to those producing hydrates for use in gas storage and transport.

Based on a review hydrate production literature, the following general production methods were considered:

1. Production of hydrates in a separate vessel from the test vessel
2. Production of hydrates in the test vessel by indirect heat exchange
3. Production of hydrates in the test vessel by direct heat exchange using circulating water

4. Production of hydrates in the test vessel by direct heat exchange using circulating natural gas or CO₂.

The first scheme was considered because it would allow for a single production system to supply multiple test vessels and it would allow for production of hydrates of different types or properties that could be loaded into the test vessel in whatever layered configuration was desired. However, this scheme was rejected because it was unknown whether hydrates produced and then mixed with sediments would behave similarly to hydrates produced in sediments and because of potential difficulties transporting the hydrates from the production vessel to storage and then to test vessels.

The remaining three schemes differ only in how the hydrate heat of formation is removed during hydrate production. All three have been incorporated into the design of the hydrate production facilities.

For the DHV, hydrates can be produced by either circulation of water through the vessel or circulation of the hydrate-forming fluid (natural gas or CO₂). Because of the relatively low surface-area-to-volume ratio of the DHV (0.24), production of hydrates by a cooling jacket of cooling coils is not practical. The time required to produce a three foot bed of hydrates in the DHV, filling 80% of the pores of the sediments with hydrates, is estimated to be from a few weeks to over a year, depending on the types of hydrate and sediments used. In contrast, the hydrates can be produced by direct heat exchange in at most 2 days (see Tables 4-1 and 4-2).

The MPVs have a surface-area-to-volume ratio of 4.1, and thus hydrate production using a vessel cooling coil is feasible. Production times vary from minutes to about 1 day (see Table C-3, Appendix C). The design includes equipment for the vertical MPV to produce hydrates in any of the three methods—removing heat by cooling coils surrounding the vessel, removing heat by water circulation, or removing heat by hydrocarbon/CO₂ circulation. For the horizontal MPV, circulation of fluids through the bed would disturb horizontal layering of sediments. Thus for the horizontal MPV, hydrates are produced only by heat removal via the vessel cooling coil.

3.2 Hydrate Production Vessel Room Height Alternatives

To reduce the overall height of the building enclosure over the hydrate production vessel, a few alternative designs have been considered and are presented in the following paragraphs.

3.2.1 Installing the Full Height Vessel In a Pit

Installation of the full-height vessel into an excavated and concrete-lined pit allows for lowering the overall ceiling height from approximately 60 ft (Drawing A-2) to approximately 40 ft above grade. See Drawing 1584-68 (Preliminary and Dimensions) in Appendix B for details.

One advantage of this option is the lower overall ceiling height of the room wherein the vessel is located. This saves costs on the building structure, footings, and foundations. Another advantage allows for researcher-specified, full-length (10-foot) core samples to be extracted from the hydrate test vessel. A significant disadvantage to this option is that a below-grade pit will be required where the vessel will be placed, with additional costs for excavation and construction.

3.2.2 Reduced Vessel Height

Reduction of the hydrate production vessel tangent-to-tangent height from 12 ft to 5 ft 6 in. allows for an overall lowering of the ceiling from approximately 60 ft to approximately 50 ft. Because the vessel height has been reduced, the core sample preservation spools may also be reduced in their overall height

(less sample is available for drilling and subsequent capture). Therefore, the overall 10-foot reduction in height reflects a combined height reduction of the vessel and the core preservation spools. See Drawing 1584-78 (Preliminary and Dimensions) for details.

One advantage of this option is a lower building ceiling height and cost savings relative to equipment size as compared with the full-size concept. Storage of samples will require less space because of the reduced length of the core preservation spools. The impact of reducing the vessel height includes a smaller hydrate test bed, less material available for sampling, and samples that may be less representative of actual conditions, than from a larger vessel.

3.2.3 Reduced Vessel Height Installed in a Pit

Installation of the reduced-height vessel, described above, into an excavated and concrete-lined pit allows for further lowering of the room ceiling height to approximately 34 ft above grade. See Drawing 1584-88 (Preliminary and Dimensions) in Appendix B for details.

Advantages of this option are a much reduced building ceiling height and cost savings relative to equipment size as compared with the full-size concept. Storage of samples will require less space because of the reduced length of the core preservation spools. The impact of reducing the vessel height results in a smaller hydrate test bed, less material available for sampling, and samples that may be less representative of actual conditions, than from a larger vessel. A significant disadvantage of this option is that a below-grade pit will be required where the vessel will be placed, with additional costs for excavation and construction.

4. DESIGN DESCRIPTION (RECOMMENDED ALTERNATIVE)

4.1 Facility and Operational Overview

This facility has several capabilities and functions. To better understand them, this section outlines a set of operations that are envisioned to be done in each major area. These descriptions are not comprehensive and do not represent any particular experiments, only the general kinds of work that might be done.

4.1.1 Operations Within the Down Hole Test Vessel Area

4.1.1.1 Coring Tool and Seismic Interpretation Tests. To test the design and operation of new coring tools for downhole use, a bed of hydrates will be fabricated in the large vessel. This bed might be of uniform hydrates composition or be layered depending on the requirement of the planned test. With the bed under pressure, the experimental coring tool will be lowered until it just contacts the surface of the hydrates. The tool will then be triggered to take a core sample. The core will be captured within the tool, which would then be pulled back into the drill string pressure lock. The lock will be isolated from the main vessel and depressured, simulating the rise of the coring tool to the surface. The tool will then be withdrawn from the upper end of the pressure lock using the overhead crane and lowered down to a cart on the main floor level. The coring tool, with the core still inside, will be shuttled to the refrigerated core handling area to be opened so the performance of the tool in capturing and preserving an intact core can be assessed. After the core has been removed from the tool (and possibly repackaged for storage in the archive), the tool will be returned to the main vessel. It will be inserted in the main vessel again through a different port on the vessel's head so another core could be taken from the same bed of hydrate. This will be repeated until all the ports had been used, so no undisturbed hydrate was accessible in the bed. At that point the bed will be decomposed so a fresh bed could be made.

These coring tests naturally couple to seismic interpretation tests. When a fresh bed of hydrate is made, "seismic" readings using ultrasonic systems are made from transducers installed on the bottom head of the vessel. These upward directed readings are collected to determine the effect of layers of hydrates on the passage of acoustic waves. They do not affect the bed and take only an hour to collect. Interpretation of these readings using experimental analysis methods provides a picture of the bed that is confirmed using the coring results.

4.1.1.2 Drilling and Logging Tests. As part of a drilling and logging tool test, a layered bed of hydrates will be fabricated in the vessel. Before the start of the test, the bed will have been characterized both by knowing the protocol used to form the hydrate layers and by the use of tomography (an acceptable method for this tomography has not yet been identified) to assess the amount of hydrate as a function of position in the bed. At the start of the actual experiment, measurement-while-drilling (MWD) tool will be assembled onto the central drill port on the vessel head and will be lowered down to the bed surface. The flow of drilling fluid used to erode a hole through unconsolidated sediments such as this will be started and the drill string lowered gradually. Continuous vessel-mounted on-line tomography will monitor the change in diameter of the eroded hole and the dissociated hydrate cavity as the drill string progresses, while the MWD tool will send similar information to the "surface." This drilling fluid will be collected from the surface of the hydrate bed, cleaned of the major fraction of the sediment particles by cyclones or other solid-liquid separation, and recycled to the drill bit. (Alternatively, it may be allowed to pond on the surface of the hydrate bed until the experiment is done.) When the bit reaches the center of the vessel, the drilling fluid is shut off and the tendency of the sediments to collapse around the bit is recorded by the vessel and MWD devices.

A downhole test of a non-MWD logging tool will be the next step. The drilling tool is retracted, the drill bit removed, the experimental tool installed, and the drill string lowered back into the hole. During this change of tools, the bed will remain under pressure to prevent hydrate decomposition. The logging tool will record the amount of hydrates in the 3-ft radius of the bed, perhaps at two or more depths. Instrument readings from the tool will be fed back through the drill string. The tool is then removed from the vessel. To complete the test, core samples will be removed from off-axis locations in the bed to verify the amount of hydrates detected by the vessel and downhole detection systems. These will be pulled using the same procedures as for coring tool testing.

4.1.1.3 Production Tests. The DHV may also be used to examine the performance of potential production schemes. A typical test will first involve fabricating a new bed of hydrates, either layered or possibly homogeneous. A hole is punched into the center of the bed most likely using a coring tool (which will not have to retain the core in good condition) to minimize incidental damage to the bed which drilling or drilling fluid might cause. This hole might also be of reduced diameter, perhaps under an inch, to simulate a scaled down system. A casing of some kind will be inserted in the hole so that produced gases will only be collected at the lower end of the hole. Alternatively, to reduce gas bypassing up the outside of this casing after it is inserted, the bed may be fabricated with this casing in place. This casing will extend through the access ports on the upper head of the vessel and will be connected to offgas monitoring and control systems.

To begin the test, about 10 gal of a hydrate inhibitor chemical such as methanol is pumped into the bed through the production casing. It is allowed to sit for several minutes while the hydrate decomposes; the pressure in the vessel is carefully monitored during this time. Eventually, a mixture of methane gas and water is withdrawn from the casing by venting pressure through the offgas system. The temperature and relative amount of each phase is measured over time as the bed gradually dissociates. After several hours, the removal of fluid is stopped and another slug of methanol is added to stimulate methane production. Production resumes for several more hours. During all these steps, the vessel's tomography system is used to track the hydrate dissociation front, which is readily seen because of the gas generation occurring there. When the front approaches the walls of the vessel, the test ends.

In another test starting with a fresh bed of hydrate, two wells are drilled into the bed. Both are located along the same diameter of the vessel, but on opposite sides about halfway to the wall from the center. One well is used to inject warm water into the bed at a very low rate representing a scaled down reservoir. The other well is used to collect gas and produced fresh water being pushed ahead of the dissociation front. This test continues for about 60 hours because of the low rate of heat input, and ceases when the dissociation front approaches the production well as determined by tomography.

4.1.2 Operations Within the Vertical and Horizontal Multi-Phase Test Vessel Area

These two vessels are operated similarly, the only difference being that their orientations affect the way that two-phase mixtures of gas and water would potentially separate. In a representative test, a mixture of methane gas and water is fed through a bed of sediment (no hydrate) at various rates and relative ratios while the pressure drop is recorded. The gas and water are then pulsed in alternately to determine the stability of the displacement front at different velocities. This is monitored by tracking overall pressure drop, the instantaneous fractions of gas and water as each front breaks through, and the percentage of gas in the system by tomography.

A second test will track the rate of heat transfer to a hydrate dissociation front to verify heat transfer models. A bed of hydrate will be heated at one end by circulating heated air through external cooling coils at that end of the vessel. As the contained sediments warm, hydrate dissociates, absorbing some heat into the latent heat of the phase changes and carrying some heat away as sensible heat of the

product fluids. Thermocouples buried in the hydrate bed will track the position of the thermal front through this experiment.

In a third type of test, the feasibility of fracturing hydrate-bearing sediments will be tested by injecting water or sand slurry into a prepared bed of sediment and hydrate. Different experiments will use different flow rates, components, or component concentrations. On-line tomography will reveal the amount of fracturing, while pressure-drop measurements taken as a function of time as gas and/or water is forced through the bed will provide information about the stability of such fractures.

4.1.3 Sample Archiving

The archive will contain samples from several sources such as permafrost region wells, sub-sea sediments collected by the Ocean Drilling Program, the DHV in this facility, or specialty hydrate samples made on a smaller scale in INEEL and collaborating laboratories. However, the handling of all of them will be similar. These samples will arrive in pressurized vessels at ambient temperature or perhaps cooled by dry ice. They will be cooled by immersion in a bath of liquid nitrogen (LN₂) until the container and its contents are at close to LN₂ temperature; this will be evident by the cessation of boiling in the LN₂. The container will be removed from the liquid nitrogen and vented to an exhaust system suitable for handling a potentially large methane release. The sample will be removed from its original container and rapidly transferred to the archive's storage container, which will have been precooled to LN₂ temperature. The container is then sealed and pressurized to about 150 psig with methane or other gas depending on the sample through a quick-connect fitting. The archive's overhead crane lifts the steel storage vessel and carries to its position in the rack, where it is slid in and connected to a pressure sensor/transmitter. The container is then held at -4°F by the archive's refrigeration system.

The taking of samples from these stored cores follows similar procedures. The storage container is disconnected from its gas and pressure sensing systems and cooled to LN₂ temperature to minimize decomposition while at atmospheric pressure. The container is opened under an exhaust snorkel to remove any offgas and the hydrate is slid into an open pre-cooled tray. Working with non-sparking hand tools, researchers quickly remove the necessary sample(s) and package them into pre-cooled smaller vessels. The smaller vessels are sealed, pressurized, and readied for transport. The main hydrate sample is returned to its storage container, sealed, repressurized, returned to its storage slot, and reconnected to the monitoring and maintenance systems. The removal of subsamples is entered into the database for that archived core.

4.2 Process

4.2.1 Hydrate Production Process Description

Gas hydrates will be produced in three vessels, the DHV (V-101), the vertical MPV (V-201), and the horizontal MPV (V-301). The hydrate production processes for the DHV and vertical MPV are very similar, while production in the horizontal MPV uses a different method. Hydrates can be produced from methane, natural gas, or carbon dioxide. Deionized water, simulated seawater, ice, or any mixture of these can be used to supply the water needed for hydrate formation.

Drawing 507619 in Appendix B is a process flow diagram showing production of hydrates in the DHV, drawing 507620 shows production of hydrates in the vertical MPV, and drawing 507726 shows the horizontal MPV.

The general process of forming gas hydrates involves loading sediment into the test vessel; cooling the sediment; purging the vessel of oxygen; adding water; pressurizing the vessel with methane, natural

gas, or CO₂; and removing heat from the vessel. Flexibility has been built into the production process to allow for a range of sediment types, hydrate formation conditions, and means of removing the heat of hydrate formation.

4.2.1.1 Sediment Bed Preparation. Sediments to be used in the DHV are stored in B-101, Sediment Bin #1 and B-102, Sediment Bin #2. Sediments to be used in the MPVs are stored in B-201 and B-202. The sediment bins are equipped with external heating coils to dry the sediment, internal refrigeration coils to cool and chill the sediment, and mixers to improve heat transfer and avoid caking or creating air pockets in the bins. Air can be heated to a maximum temperature of 250°F and circulated in the heating coils. The air heater and blower are sized based on heating the sediment from 60 to 100°F and removing 10% moisture from the sediment within 24 hours.

Sediments are transferred by gravity into the test vessel. Distinct sediment layers can be built up in the vessel one by one, changing sediment types or moisture contents with each layer. The filling mechanism is equipped with internal blades to level sediment layers as they are added. Optionally, ice can be mixed with sediments during transfer to the test vessel or added separately to the test vessel. Equipment is available in the DHV production process to produce 1,450 lb/hr of ice, store 100 ft³ of ice, and crush 5,800 lb/hr. For the MPV production process, equipment is available to produce 210 lb/hr of ice, store 15 ft³ and crush 1,000 lb/hr.

Additional cooling or wetting of the sediment can be done after loading it into the bed. The sediment can be cooled by (1) circulating deionized water that has been chilled to 35°F through the bed, (2) passing vaporized CO₂ through the bed, or (3) by passing refrigerant through the vessel cooling/heating coil. Method (3) will only be effective for the MPVs, as heat is removed very slowly by conduction from the 2 m diameter DHV. Following cooling of the bed, additional water, if needed, is added as either de-ionized (DI) water or simulated seawater.

All bed preparation steps are performed at atmospheric pressure.

4.2.1.2 Vessel Purging and Pressurization. If a hydrocarbon gas is to be used in hydrate production and the vessel bed has residual air in sediment pores, the bed should be purged with nitrogen to avoid explosive hydrocarbon-air mixtures in the vessel. Purging can also be performed when producing CO₂ hydrates, but would be done for a different reason, namely to control the gas phase composition in the bed.

Following purging, the vessel is pressurized with the desired hydrate-forming gas. Methane, natural gas, and CO₂ are all received and stored as liquids, the former two in atmospheric, cryogenic tanks, and CO₂ at ambient temperature and a pressure of 700–1,000 psia. Depending on the desired vessel pressure for formation of CO₂ hydrate, the CO₂ pump may or may not be used. The process design pressure for formation of CO₂ hydrate is 750 psia and for CH₄ hydrate 1,500 psia. The pressure can be increased up to 2,000 psia to provide additional approach to hydrate equilibrium conditions.

Vaporizers, using ambient air as the heating medium, are supplied on the methane and natural gas supply lines. A chiller, utilizing 25°F refrigerant, is supplied on the CO₂ supply line.

4.2.1.3 Production of Hydrates in the DHV or Vertical MPV by Water Cooling. DI water or simulated seawater is pumped from the deionized water or Brine/Recycle Tank through the Water Chiller and into the test vessel. The chilled water flows through the bed from top to bottom and then is let down in pressure into the Brine Recycle Tank. Deionized water is chilled to 35°F, sea water to 32°F. As hydrates form, the vessel pressure is maintained by flow of CH₄, natural gas or CO₂ into the vessel.

Table C-1 (Appendix C) shows the amount of hydrate formed, duties, and times required to produce hydrates over a range of conditions. The sediment types shown in Table C-1 are intended to be representative of different porosities, with clay representing a low (~25%) porosity sediment, sand a medium (~50%) porosity sediment and diatomaceous earth a high (~85%) porosity sediment. In all cases the gas, methane or CO₂, was assumed to fill 70% of the cavities in the clathrate molecular structure. The difference between the total duty requirement and the heat removed by water is due to refrigeration supplied by the feed gas.

The water flow rates shown in Table C-1 are design flow rates for the water feed pump. Lower flow rates can be used, with a corresponding increase in the time required for hydrate formation. Table C-1 shows that the time required to remove the heat of hydrate formation varies in the DHV from about 2 minutes for 1% CH₄-hydrate in clay to about 49 hours for 80% CO₂ in diatomaceous earth. In the vertical MPV, the time of formation varies from about 8 minutes for 1% CH₄-hydrate in clay to about 160 hours for 80% CO₂ in diatomaceous earth.

4.2.1.4 Production of Hydrates in DHV or Vertical MPV by Gas Cooling. Equipment has been provided to remove the heat of formation by circulation of the hydrate gas. Testing will be needed to better determine the feasibility of this method. The primary advantages of gas circulation over water circulation is the potential for forming hydrates at temperatures below the freezing point of water and being able to deliver a large amount of gas relative to the water present as needed to make hydrates, as well as the capability of forming layers of gas hydrates.

Following purging of the vessel of oxygen, flow of CH₄, natural gas, or methane would be started into the vessel. When the vessel pressure reaches the desired hydrate formation pressure, flow through the circulation loop is started by allowing vessel off-gas to enter the methane recycle compressor. Gas discharged from the compressor is chilled by -22°F refrigerant and then reenters the test vessel. Table C-2 (Appendix C) shows the time required for producing hydrates for various cases using the design circulation gas flowrate of 1000 SCFM.

Table C-2 shows that hydrates can be produced by gas cooling in the DHV in times from about 10 minutes to 54 hours, and in the vertical MPV from less than a minute to about 2.4 hours. The gas recycle loop equipment is the same size for both vessels, since the methane flow rate is small, about 10 ACFM.

4.2.1.5 Production of Hydrates in the MPVs by Indirect Cooling. Hydrates can be produced in the MPVs by removing heat of formation with refrigeration circulating in the external cooling coil. Table C-3 (Appendix C) shows the time required to produce hydrates using refrigeration.

The times shown in Table C-3 were calculated using the following equation:

$$Q = k A \Delta T / x \quad (1)$$

where

Q = heat transfer rate, Btu/hr

K = thermal conductivity of sediment/hydrate bed, Btu/hr-ft-°F

ΔT = temperature difference between bed and refrigerant

x = linear distance from refrigerant to vessel center line.

A thermal conductivity of 3 W/m-K (1.7 Btu/hr-ft-°F) was assumed based on reported conductivities in hydrates.¹³ The temperature difference of 57°F was assumed, based on hydrate formation at 35°F and a refrigerant temperature of -22°F. Thermal resistances other than the hydrate bed itself were neglected (coil tube wall, vessel wall, vapor spaces on either side of the vessel wall); thus the times shown in Table C-3 should be considered minimum times. The heat flux determined by this equation will be proportional to the rate at which hydrate will be formed in the bed.

4.2.2 Hydrate Bed Standby

Once the bed of hydrates has been formed in the test vessel, the bed can be kept in a standby mode by maintaining an appropriate flow of refrigerant in the vessel cooling coil and maintaining pressure in the bed. The refrigerant flow would be set to match the expected heat leak into the vessels, or alternatively, maintained at a higher rate to subcool the hydrates.

4.2.3 Vessel Unloading and Effluent Treatment

Following tests performed using the hydrate bed, the vessel would be depressurized and the bed removed. A process flow diagram showing effluent treatment equipment is given in the Appendix B, Drawing 507726.

4.2.3.1 Vessel Depressurization and Offgas Treatment. Valves on the vessel offgas line would be opened to begin depressurization of the bed. Flow of refrigerant through the vessel chilling coil would be stopped or replaced with air flow.

Offgas from the test vessel is filtered to remove entrained sediment particles, and then enters an accumulator. The purpose of the accumulator is to provide a more constant flow of methane or natural gas to the oxidation unit. If the hydrate bed contains H₂S, the offgas is heated to 60–100°F and passed through a bed of ferric oxide hydrate to remove the H₂S. Iron oxide will react with H₂S to produce iron sulfide and water vapor. A bypass of the H₂S reactor is provided.

Air is added to the offgas downstream of the H₂S reactor. Air is needed to either provide oxygen for the oxidation of hydrocarbons or avoid the oxygen-devoid emission that would result from CO₂ hydrate beds. Under normal operating conditions, if the offgas contains hydrocarbons, it then passes through a thermal oxidation unit, in which the hydrocarbons are oxidized to CO₂ and H₂O.

When the pressure in the bed has reached atmospheric pressure, nitrogen is passed through the bed to remove residual hydrocarbon gases.

4.2.3.2 Sediment Removal. The remaining contents of the vessel are then washed out of the vessel into the Waste Bin using the DI Water pump. The vessel design will include the means to spray water jets into the vessel to remove the sediment.

Water in the Waste Bin is drained to the sewer. Sediment is then transferred to containers and transported to the disposal site.

4.3 Test Equipment

The test equipment associated with the EETC is listed in Appendix D.

4.3.1 Pressure Vessels

4.3.1.1 Down Hole Test Vessel. The DHV (Figure 1) is a large, lined vessel designed for high pressures (up to 2,000 psig) and severe corrosion environments. A study was performed to evaluate various materials for this application (EDF-EES-001). For this conceptual design, Hastelloy C-276 was chosen as the best material for this application. Considering the cost and complexity of this vessel, additional evaluation of materials and fabrication methods should be performed early in the following design phase. Hastelloy C-276 is a nickel-chrome-molybdenum material originally developed for high temperature applications. It is also extremely corrosion resistant. It is, however, also quite costly. Given the size and the pressure rating of the DHV, fabrication of the DHV completely of Hastelloy C-276 would be prohibitively expensive. Therefore, a lined vessel will be used. The pressure retaining part of the vessel will be constructed of carbon steel meeting the requirements of ASME specification SA 516, grade 70. A Hastelloy liner (assumed to be 0.25 in. thick) will be bonded (roll or explosion bonded) to the pressure vessel. Other methods of attaching the liner to the bulk of the vessel were considered, (plug welding and weld overlay) but were rejected. Plug welding was eliminated due to concerns with adequate attachment, possible cracking, etc. Completely lining the vessel using a weld overlay method was deemed to be too expensive based on conversations with fabricators, although penetrations and other smaller areas will be lined using a weld overlay technique.

Figure 1. Down hole test vessel.

The use of carbon steel in the low-temperature service required of the DHV (as low as -4°F) does present concerns with respect to brittle fracture. The SA-516 material will be impact tested to ensure that it will not present problems at these temperatures.

The DHV has an outside diameter of 120 in. and a height of 16 ft-5 in., tangent to tangent, that is, between the heads. There are a total of seven penetrations in the upper head, five that are available for inserting drilling equipment or instrumentation.

4.3.1.2 Acoustic Vessel. An evaluation was performed and it was determined that the DHV will provide the functions required for the Acoustic Vessel. Therefore, it was determined that a separate acoustic vessel was not required.

4.3.1.3 MPVs. Two MPVs will be provided for flow and production testing. They will be alike in form and function. One will be oriented vertically while the other will be horizontal to allow tests of multiphase (gas/liquid) flow in both directions relative to gravity. The vessels will be approximately 12 in. in diameter and 16.4 ft long. They will have provisions for pumping gas and/or liquid into one end and removing it at the other end while measuring the flows, temperatures, and phase compositions. The vertical vessel will have provisions for upward and downward flow. The ability to supply low temperature heat at various locations on the outside of the vessels to encourage hydrate melting will be provided. The ability to perform online tomographic analysis of hydrate, liquid, and gas will be provided.

The vessels will be fabricated from Hastelloy C-276 plate to a 12-in., schedule 100 size. The vessels will be connected to their service and discharge piping using Grayloc fittings, also constructed from Hastelloy materials. The adapters will allow the vessels to be connected to a variety of pipe sizes, as required by testing scenarios. The vessels will be in the horizontal and vertical orientation as shown in Figure 2.

4.3.2 Core Sampling of the Hydrate Bed in the DHV

Associated with the DHV is drilling equipment that can drill bore holes and extract core samples from the simulated methane hydrate bed. Appropriate interfaces between the drilling equipment and the vessel are required to maintain the simulated ocean depth conditions of the retrieved cores. Figure 3 provides a concept of the basic vessel and drilling equipment layout.

The system consists of a commercial drilling system that is normally mounted on a truck, trailer, or other type of mobile vehicle. Because the drilling equipment will be located over the top of the vessel, only the drilling system is required for this application. The major parts of a typical drilling system consists of a basic tower, drilling head, chuck assembly, drill rod, core barrel, and some miscellaneous equipment (water/mud swivels, foot clamps, etc.) The modified version of this equipment, resting on a platform above the vessel, is shown in Figure 4.

A brief description of the drilling system individual components is as follows:

Drilling tower—The drilling tower provides support for the drilling head (including chuck assembly) and the backbone for the drilling stroke mechanism. That is, the mechanism for adding (or removing) drilling pipe sections at the drill. The length of the stroke mechanism varies with the drill unit selected. Some have stroke lengths as long as 12 ft while others have stroke lengths of 2 ft or less. The unit being considered for this effort has a 6 ft stroke length. The drilling tower design should include equipment and procedures for resisting expulsion of the drill string by the 2,000 psig vessel pressure.

Figure 2. The multi-phase test vessels will be used to examine the properties of flow, hydrate formation, etc.

Figure 3. Core samples of methane hydrate will be removed from the DHV while maintaining vessel pressure on the sample.

Figure 4. Drilling equipment for extracting cores from the DHV.

Drilling head—The hydraulics-driven rotational head assembly (with hydraulic chuck assembly) clamps onto, rotates (assisted by the drilling stroke mechanism), and drives the drill string down into the medium being drilled. The unit may be single-speed or multiple-speed depending on the unit selected. The unit will be designed to safely hold the drill rod experiencing the 2,000 psi rejection forces from the vessel pressure.

Drill rod—The drill rod (or drill string) provides the connection between the drilling head and the cutting head at the base of the drill. Additionally, the drill rod provides a conduit for cooling fluids or drilling mud. The drill rod is commercially available in a variety of sizes and materials.

Core barrel—The core barrel is the bottom section of drill pipe that contains a “core catcher” mechanism composed of a split tube assembly, seals, bearings, and a sample keeping mechanism. Core barrels come in a variety of diameters and lengths. For this application, a core barrel of nominal 6-in. diameter has been selected.

Associated with the drilling equipment are the equipment interfaces to the hydrate vessel. These consist of vessel penetrations on the vessel head that allow for drilling of the hydrate test bed without relieving vessel pressure. These are described below:

Vessel penetration—The penetrations consist of 8-in. schedule 160 pipe. Each pipe section penetrates (and is welded into) the vessel head and extends down into it (see Figure 3). During drilling operations, the in-vessel pipe extension serves as a guide for the drill string.

Connections and shutoff—Each vessel penetration pipe has an 8-in., Class 900, gate type shutoff valve welded to the top of the pipe and outside the vessel. A typical gate valve is shown in Figure 5. The valve discharge port includes RE Flange (Grayloc) connections for economy of space and ease of assembly.

Core preservation equipment—Connected above the vessel gate valve is a specially designed spool that will serve as the core and environmental capture equipment. This is as shown in Figure 6. The spool consists of a lower valve (same type as the vessel valve), 8-in. schedule 160 pipe, and a sealing gland at the top of the pipe. The gland will require special design and manufacture to allow sealing during rotation and translation of the drill string. The valve is connected to the vessel valve by a Grayloc fitting.

The drilling head is connected to the core barrel (inside the spool) by the drill rod. The drill rod goes from the drill head through the upper seal gland and attached to the core barrel. The drill rod may be solid or hollow dependant on the need for coolant during drilling. The hollow rod will require an inline check valve to prevent escape of the vessel pressure. Special mud and/or coolant pumping equipment may be required to overcome the 2,000 psig vessel pressure.

Overhead crane system—An overhead crane moves the drill unit to vessel penetration locations around the vessel head. It supports pieces of drill rod as they are assembled and disassembled from the drill. The crane is also used for removing loaded spools (core samples) to a storage facility and returning the empty spools back to the vessel to be reloaded.

Figure 5. Typical gate valve will be used to isolate the vessel from the drilling equipment.

Figure 6. The core preservation equipment spool maintains the vessel pressure conditions during retrieval and transport of the cores to a storage facility.

Operating Description

The drilling system will provide boreholes for down-hole instrumentation placement, for core drill experimentation, and for core preservation exercises. A typical scenario will proceed as follows:

1. A drill/core barrel will be placed inside a core preservation spool.
2. The spool will be placed onto the vessel penetration adapter and secured in place by tightening the Grayloc hub.
3. A drill rod will be placed into the drilling head and connected to the core preservation spool.
4. The vessel penetration valve will be opened.
5. The valve at the base of the core preservation spool will be opened.
6. The drill/core drill will be advanced down into the vessel by the drilling stroke mechanism (additional sections of drill rod will be added, as necessary, during this exercise).

7. When the desired elevation is achieved, the drilling head will be turned on and drilling will commence in the hydrate bed. Drilling will proceed to the desired depth.
8. When the desired depth is achieved, the drill/core drill will be extracted from the hydrate bed.
9. The drill rod will be extracted and removed until the drill/core barrel is inside the core preservation spool.
10. Both the vessel gate valve and the spool gate valve will be closed and the pressure bled off between the two gates.
11. The spool Grayloc will be disconnected and the spool removed for tool change-out or core sample storage.
12. A similar scenario will exist for placement of down hole instrumentation or for drilling additional core holes.

4.3.3 Hydrate Storage and Archival System

The hydrate storage and archival system includes a refrigerated room that is approximately 30 ft wide by 50 ft long by 16 ft tall. The room is divided into two parts as shown in Figure 7.

One part of the room is an open area, with tables, that is used for cored sample transport, movement, bench testing, sampling, and handling. The remaining part of the room contains a large bank of vaults. The vaults ensure that temperature variations in the room do not affect the core samples. Each vault contains a pressure vessel (see Figures 8 and 9) wherein the cored sample is stored under 150 psig of pressure and at -4°F.

Figure 7. The hydrate storage facility will house approximately 100 cored samples at specified temperature and pressure.

Samples are transported into the room on the monorail hoist. Sample integrity is maintained inside the core preservation equipment during transport into the refrigerated room. Using the hoist, the core preservation vessel is oriented with the desired storage vault, the vault and storage vessel doors opened, the valve on the core preservation equipment opened, and the core sample slid into the storage vessel. At this time, the storage vessel door is closed and the bolts tightened to the specified torque. The vessel is then pressurized to a value that, when coupled with the cold room, will maintain the sample integrity. The core preservation equipment is returned to the DHV for reuse on another core extraction. Each core sample will be monitored by the use of a pressure switch, which will measure the pressure of each core sample through the valve stem (or the gauge connection). Software will adjust each pressure set-point for the particular gas involved in the sample, and each sample alarm point will be monitored.

Figure 8. The cored samples are each maintained within a separate vault and pressure vessel to maintain individual properties.

Figure 9. The pressure vessels that are located within each vault contain the cored samples at specified pressure.

4.4 Civil, Architectural, and Structural

The Extreme Ecosystems Test Chambers (EETC) may be housed in a new or in an existing facility. For the purposes of this conceptual design, it is assumed to be a new facility.

The EETC is shown in drawings A-1 (plan view) and A-2 (sections), which are included in Appendix B. It is approximately 165 ft long and 104 ft wide. It is made of non-combustible materials, predominantly steel with metal siding type construction. The down hole test area and the multiphase test area are located at one end of the facility. Both areas are classified as Group H Division 2 Occupancies, as defined in the Uniform Building Code.

The down hole test area is 54 ft long and 62 ft wide and contains the DHV and some of the equipment needed for generating the hydrate and sediment beds with the DHV. A 10-ton crane services it. Due to the height of the DHV, the associated drilling equipment, clearances for crane access, etc., it is located in a bay that is 73 ft-6 in. high (top of parapet). This height is based on a design that provides a 16.4 ft total bed height and allows at least a 9.8 ft core to be drilled and extracted. These requirements establish a conservative (more expensive) basis for the conceptual design. Additional investigation into the needs of the potential users will be conducted to more firmly establish these criteria. Also, it may be feasible to place part (or all) of the DHV below grade, thereby reducing the overall building height. This feasibility will be determined by items such as cost of excavation (soil vs. rock), concerns about entrapment of gases in sub-grade areas, etc. These issues will be addressed in more detail in subsequent design efforts. The multiphase test area is located adjacent to the down hole test area.

The control area, located in a UBC Group B Occupancy area, is about 28 ft long and 16 ft wide. It houses process control and data acquisition equipment. An office space (20 ft-8 in. by 15 ft-9 in.) is provided for general use.

4.5 HVAC Systems

Separate ventilation systems will be provided for the Group H-2 occupancy areas (down hole, multiphase, hydrate preparation, and effluent treatment areas) and the Group B occupancy areas (control area, offices, rest rooms). The ventilation systems for the H-2 areas will maintain a slight negative pressure (relative to atmospheric) and sufficient air flow to maintain the concentrations of methane or natural gas below flammability limits.

4.6 Mechanical Utilities

The following utilities are provided as part of the process and facility design of the EETC:

- Potable water is assumed to be provided at the boundary of the facility (e.g., a city water supply). Costs are not included for wells, potable water treatment, etc.
- Sanitary and storm sewer service are also assumed to be provided at the boundary of the facility.
- Heat for the HVAC systems is assumed to be electrically generated. Costs are not included for steam boilers, gas heaters, etc.
- In some cases liquid nitrogen (LN2) may be required for cooling or inerting vessels and pipe. An insulated LN2 storage tank will be provided. A vaporizer will be used to generate gaseous nitrogen. The tank can also be used to fill dewars that will be transported to the points of local use for specific cooling operations.

4.7 Glycol Chilling System

A propylene glycol/water chilling system is used to cool sediments and fluids in the production of gas hydrates. The chilling system is sized to allow simultaneous production of hydrates in all three vessels—the DHV, the horizontal and vertical MPVs. The chilling system has a capacity of 1 million Btu/hr chilling duty, and can deliver 120 gpm of -40°F process coolant. The process coolant is a 60 wt% propylene glycol/40 wt% water solution. The process coolant return is chilled by a refrigerant. To allow control of the process coolant supply temperature, the refrigerant chiller has a bypass line.

4.8 Electrical Systems

The project will involve a connected load of 1,100 kVA, of which approximately 200 kVA will require a source of standby power. Using an estimated demand factor of 50%, a 600 kVA service, with a full-load standby/UPS capacity of 200 kVA, will be the baseline service requirements for the project. Lighting load will be about 25 kW.

Power will be distributed through a main service power panel. Motor loads will be supplied by a motor control center, fed from the main service panel.

An UPS will supply emergency/standby load, with an automatic transfer switch to allow for a smooth transfer between normal and emergency power. The UPS will be sized to supply its connected load for at least 15 minutes. A source of standby power (supplied from an on-site generator, or from an off-site source) should be available for longer power maintenance, and to provide for an orderly shutdown of the process.

The facility will have electrical construction complying with NFPA -70 Class I, Division 2 requirements.

4.9 Monitoring and Control

Measurement of vessel parameters will be made through the use of flanged penetrations and nozzles in the vessel. Instruments for measuring temperature and pressure will be installed and connected to provide continuous readouts of analog data. This data will be routed into the control area, which will provide remote monitoring, operation, and control of the process. Hydrate bed temperatures can be measured using appropriately ranged thermistor or RTD probes, installed in any of several of the vessel flanges.

Pressure measurements can likewise be obtained from pressure transmitters installed in these flanges. All signals from the transmitters will be 4–20 mADC, and can be grouped together and routed into the control area where they will be monitored and archived. Any required flow measurements may be obtained using similar techniques.

Fluid emissions will be routed out of the process vessel through piping, and common measuring techniques may be used to determine these fluid pressures, temperatures, and flows. Commonly used industrial practices will be able to provide for data trending, alarming, mitigation of off-normal process excursions, and for remote operation and safe shutdown.

Down-hole instrument packages will be provided. This will allow real-time monitoring of the process vessel beds while drilling operations are in progress. A data baseline can be developed so that trends in the hydrate beds can be logged.

Rosemount Analytical manufactures the GCX, a stand-alone gas chromatograph transmitter that can be mounted on the support structure above the process vessel. A flanged connection can be made to attach the GCX to sample lines in the down-hole instrument package. A wide variety of different gases can be analyzed by this instrument, depending upon the concentration for each particular gas in question.

5. RECOMMENDED DESIGN STUDIES AND RESEARCH TO SUPPORT FURTHER DESIGN

This facility is intended to allow large-scale experimentation on hydrate-cemented sediments (as opposed to pipeline plugs) that before have only been manufactured in laboratories at the scale of less than one liter. There are several novel technologies assumed in this conceptual design that would profit from additional research before construction of this facility begins.

5.1 In-Vessel Tomography

The ability to track on-line the in-situ evolution of gas from layers of decomposing hydrates, the possible segregation of gas and water flowing through porous media, and the erosion of sediments and decomposition of hydrates during the drilling process would be extremely valuable to evaluate results. In principle, one or more of acoustic, x-ray, or electrical tomography should allow this. However, the thick vessel walls (5.5 in.) required by the pressure rating of the drilling vessel makes externally generated acoustic and x-ray tomography difficult. The rather low difference in properties between hydrate and either water or solids may make detecting hydrate difficult too. Acoustic scattering from the bed particles will further complicate the problem. The feasibility of getting 0.2–1.0 cm resolution from electrical tomography in this large vessel is not known either. A separate preliminary line of work to do technology selection and testing of an on-line tomography system applicable to all the major vessels in this facility would be very useful.

5.2 Storage Stability of Hydrate Samples

A significant part of this facility design is for a hydrate core and sample storage facility. However, the practically obtainable conditions that will ensure stability of hydrates are not known. Several key issues are

- The rate at which hydrates exchange guest molecules with a pressurizing gas that is not of the identical composition as that which formed the hydrate
- Whether residual water frozen into ice during storage below 0°C affects hydrate chemically or physically while in storage or when raised back above 0°C
- The amount of sample degradation that occurs during sample handling in the field or in the lab if cores are cooled to dry ice or liquid nitrogen temperatures (since the equilibrium pressure of methane hydrate is still greater than one atmosphere at those temperatures)
- How to take subsamples of an archived material so as not to contaminate or degrade the remaining material.

Developing answers to these questions through laboratory testing of hydrate handling protocols will allow more confidence that the hydrate sample storage system will perform as required.

5.3 Xenon as a Substitute for Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a highly toxic and corrosive gas that is a relatively common component of natural gas and therefore is a likely component of hydrates. These undesirable properties may impose significant equipment and operational limitations on experiments that would use it. However, it appears that xenon, an inert noble gas like helium or argon, may substitute for hydrogen sulfide because it has the

identical molecular size of 4.58Å, and many of the hydrate-related properties of gases depend primarily on their molecular size and how well they stabilize the cages in the hydrate's water lattice. To verify this conclusion, a literature study, reinforced with a modest amount of experimental work, would be quite useful. This work could also suggest other relatively safe gases that might practically be used in place of H₂S (even if the resulting properties are not identical to H₂S mixtures) to study how sour gases behave under hydrate-forming conditions.

5.4 Hydrate Production Studies

To confirm design assumptions used in the hydrate production equipment data, a test unit is needed. While numerous reports describe laboratory-scale hydrate production apparatus, these systems are significantly different from the design of larger-scale production units. A literature search resulted in only one document¹⁴ describing a larger system, namely, a 10-gal hydrate crystallization vessel in which propane hydrate was produced. In comparison, the MPVs have a volume of about 93 gal, and the DHV has a volume of about 555 gal.

The two major areas of uncertainty in the design are thermodynamic and heat transfer properties of hydrate-sediment mixtures, both before and during formation, and the fluid dynamics in the test vessels for the various scenarios that involve circulating fluids. Thermal conductivities of deep-sea sediments and hydrates can vary by over an order of magnitude, depending on the type and porosity of the sediment being used.^{15,16} The change in thermal conductivity with percentage of hydrate in the pore space is unknown. Patterns of temperature change over time within the sediment bed as hydrates form are also unknown. To adequately design the cooling coil for the MPVs, this data is needed.

Adequate flow and mixing of fluids in and through the test vessels is crucial to ensure adequate heat transfer needed to reach temperatures needed for hydrate formation and to form hydrates throughout the test vessel. Tests are needed to ensure adequate design of flow distributors of vessel feeds and means to retain sediments and hydrate particles in the vessels. Production of CO₂ hydrates offers additional challenges, since over much of the region of CO₂ hydrate formation, CO₂ exists in two phases.

5.4.1 Proposed Test Unit

The proposed test vessel is the same diameter as the Multi-Phase Test Vessel, 12 in., and one-fifth the length, 36 in. Equivalent diameter is important for both the thermal properties and fluid dynamics. The vessel would be designed for a maximum pressure of about 750 psia (5.2 MPa) to be able to run tests with CO₂. Hydrates of ethane, propane, butane, or higher hydrocarbons could also be produced at lower pressures. In addition to being used to obtain data for design of large test vessels, the proposed test unit could be used for hydrate production and testing in the EETC.

5.4.2 Demonstration of Hydrate Production by Heat Conduction and Determination of Cooling Coil Duty Requirement

These tests would demonstrate the production of CO₂ hydrate with external cooling and determine design parameters for the cooling coil. The test vessel would be loaded with sediment. Thermocouples would be placed in the bed to be able to record temperature changes during hydrate production. Following purging the bed with an inert gas, a measured amount of water would be added. Refrigerant would be introduced into the cooling coil and the vessel pressurized with CO₂. Bed temperatures, the refrigerant flow rate and temperature in and out, CO₂ flow into the bed, and vessel pressure would be recorded until, at constant pressure, the CO₂ flow ceased. Data would be obtained for CO₂ hydrate production with several different sediments, and with both pure water and simulated seawater.

5.4.3 Demonstration of Hydrate Production by Water Circulation

For these tests, the cooling coil would not be used, but the heat of formation of hydrate would be removed by circulating chilled water through the bed. Water would be pumped to a high-pressure tank that would serve as the water feed tank and the receiving tank for effluent from the reactor. The pressure of this tank needs to be close to the test vessel pressure to avoid stripping the test bed of CO_2 . The tank would be stirred to avoid separation of two liquid phases (water and liquid CO_2). After loading the bed with sediment, purging the bed of air and pressurizing it with CO_2 , water would be pumped from the high pressure tank through a chiller and through the sediment bed. Flow rates, pressure drops, pressures, and temperatures would be recorded, and used to determine (1) if adequate flow distribution was achieved throughout the bed for both vertical and horizontal configurations, (2) the optimum temperature to which the circulating water is chilled, (3) time required to produce hydrates, (4) the required or optimum water circulation rate, (5) the minimum approach needed to the hydrate formation equilibrium curve and (6) the degree of control of hydrate composition (moles water per mole CO_2) achievable at different bed temperatures and pressures.

5.4.4 Demonstration of Hydrate Production by CO_2 and Hydrocarbon Circulation

Design of equipment for production of hydrates by circulation of the hydrocarbon or CO_2 is highly dependent on the hydrate-forming species. At hydrate formation conditions, CO_2 is a liquid, highly soluble in water, while light hydrocarbons are supercritical fluids with relatively low densities and low solubilities in water. Requirements for equipment in the circulation loop, the compressor or pump, separator, and chiller will be unique to the fluid. Devices needed for flow distribution in the test vessel may differ as well. Also, the designs of the recirculation loop for the horizontal and vertical vessels for a single fluid will be different. The major advantage of CO_2 or hydrocarbon cooling as compared to water cooling is that temperatures below the freezing point of water are possible, allowing for a lower operating pressure.

For the demonstration of CO_2 hydrate production by CO_2 circulation in a vertical vessel, the test would be very similar to the water circulation test, except for reversing the flow through the test bed (upflow rather than downflow). However to demonstrate ethane- or propane-hydrate production, additional equipment would be needed. Entrained liquid in the effluent from the test bed would be separated in a knock-out drum, the vapor from the drum being compressed, chilled and recirculated to the test bed.

Test data from these tests would be used for the same purposes as for the water circulation demonstration. For tests in which a hydrocarbon gas is used, tests may be needed of different gas distributors to ensure hydrate production throughout the bed.

5.5 Effluent Treatment Studies

5.5.1 H_2S Removal

Hydrogen sulfide is commonly removed from industrial offgases by a variety of methods. Many of these methods use absorption systems where the H_2S is either absorbed into a liquid or reacted to form a soluble metal sulfide. To avoid liquid effluent containing H_2S or sulfide, and because quantities of H_2S are expected to be small, the design includes a solid bed of hydrated ferric oxide. The ferric oxide reacts with H_2S to produce ferric sulfide and water. Data is needed to determine the efficiency of this process for the removal of H_2S and the optimum operating temperature and residence time of the reactor. An initial study is recommended to evaluate different solid absorbents for H_2S , such as molecular sieves and

dolomite in addition to ferric oxide. Following this study, small-scale tests are recommended to demonstrate the process for the expected maximum H₂S concentration in the hydrate vessel offgas.

5.5.2 Hydrocarbon Oxidation

It is recommended that both catalytic and thermal oxidation systems be evaluated to provide a better basis for the selection of an offgas oxidation unit.

6. COST ESTIMATE AND FUNDING REQUIREMENTS

This planning cost estimate for the EETC has been prepared in two parts: building and equipment. Total Estimated Cost (TEC) for the building is \$9.6 million. TEC for the equipment is \$20 million. The Cost Estimate Summary and Detail Sheets for cost breakdowns are contained in Appendix E. A summary of the cost estimate is contained in the two tables below.

This estimate is based on present-day costs that have been escalated to the approximate midpoints of the major activities, i.e., design and construction. A Contingency Analysis has been prepared to determine the approximate amount of contingency that may be required to complete this project.

Table 1. Cost estimate for new EETC building.

Cost Element	Total Unescalated	Escalation	Total Including Escalation
Engineering, Design and Inspection	709,534	88,966	\$798,500
Management Costs	876,184	175,237	\$1,051,421
Construction	4,243,892	848,780	\$5,092,672
Government Furnished Equipment	39,423	8,673	\$48,096
G&A/PIF	523,538	104,708	\$628,246
Procurement Fees	128,499	25,724	\$154,223
Subtotal Including Escalation	--	--	\$7,773,158
Management Reserve	--	--	\$592,324
Contingency	--	--	\$1,234,518
Total Estimated Cost	--	--	\$9,600,000

Table 2. Cost estimate for EETC equipment.

	Total Unescalated	Escalation	Total Including Escalation
Engineering, Design and Inspection	958,111	114,247	\$1,072,358
Management Costs	734,076	131,979	\$866,055
Construction	10,677,949	1,708,472	\$12,386,421
G&A/PIF	867,456	138,793	\$1,006,249
Procurement Fees	320,338	51,254	\$371,592
Subtotal Including Escalation	--	--	\$15,702,675
Management Reserve	--	--	\$0
Contingency	--	--	\$4,297,325
Total Estimated Cost	--	--	\$20,000,000

Engineered Ecosystems Schedule

7. SCHEDULE

8. REFERENCES

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Appendix A

Extreme Ecosystems Test Chamber Functional and Operational Requirements

Functional and Operational Requirements

For

Extreme Ecosystems Test Chambers

Developed by:
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7/20/98
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TBD

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Date

Functional and Operational Requirements

For

Extreme Ecosystems Test Chambers

I Project Requester and End User

This document establishes the functional and operational requirements (F&ORs) for the Extreme Ecosystem Test Chambers project. These F&ORs are being developed at the request of the Verification, Validation and Engineering Analysis (VV &EA) Program in support of the Department of Energy's (DOE) Environmental Management Program (EM) and the Idaho National Engineering and Environmental Laboratory's (INEEL) Long Range Plan.

II Purpose of Performing Project

The purpose of the Extreme Ecosystems Test Chamber project is to design and build several engineered environments of various size, shape and ecological complexity representative of extreme environments. This will provide the DOE and other Federal Agencies with the ability to evaluate biological, geological, chemical, and physical interactions in controlled environments while developing and validating simulation models, which can be used to predict responses in natural systems. Victor Kennedy, the director for the Multiscale Experimental Research Center, suggests that the ability to make predictions by extrapolating results from controlled laboratory experiments to natural ecosystems with known accuracy and precision, is one of the most significant challenges facing the scientific community today. These F&ORs will provide the basis for the design and fabrication of systems to replicate subsurface and sub-ocean environments characterized by high pressure (2000psi) subfreezing (-20C) to high temperature (150C), and with differing chemical and saturation conditions. Specifically, systems will support areas of research and development needs which will include heat transfer and phase change issues in porous media, microbiology in extreme environments, and carbon sequestration and extraction. The design of systems to support the above mentioned research is based on the needs identified for gas hydrates research and development. This will provides a broad array of capabilities that will encompass the needs of many extreme environments.

Gas hydrates occur abundantly in nature, both in arctic regions and in marine sediments. They consist of a crystalline solid consisting of gas molecules, usually methane, each surrounded by a cage of water molecules. Methane hydrate is stable in ocean floor sediments at water depths greater than 300 meters, and where it occurs, it is known to cement loose sediments in a surface layer several hundred meters thick. The United States Geological Survey estimates that two relatively small areas, each about the size of the State of Rhode Island, contain more than 1,300 trillion cubic feet of methane gas. This is more than 70 times the 1989 gas consumption in the United States. This potentially huge carbon reserve has significant potential to support our energy needs. In addition, the processes that have trapped these gasses may provide a potential method of carbon sequestration.

DOE has established a goal to begin commercial exploitation of methane hydrates by the year 2015 (Methane Hydrate Research and Resource Development Workshop, January 1998). Through this workshop, experts identified science and technology issues that must be addressed for successful exploitation of the resource. These include:

Characterization (Reservoirs)

Technology does not presently exist to adequately;

- determine the distribution of methane hydrates,
- characterize methane hydrate reserves,
- determine the volume of methane hydrate reserves, and
- understand why and how methane hydrates got where they are.

Physical Chemistry

We presently do not have a scientific understanding of;

- the physical chemistry of methane hydrates,
- the thermodynamics of methane hydrates,
- the effects of 2 phase to 3 phase transition associated with methane hydrates, and
- the effects of differing sediment composition on the physical and chemical properties of methane hydrates.

Production

Technology does not exist to;

- economically produce methane from methane hydrates,
- characterize the methane hydrate system (porosity, permeability, sediment effect, sample preservation, reproducibility), and
- reproduce sub-sea methane hydrate samples for testing.

Safety

Technology or science does not presently exist which can adequately;

- detect and characterize methane hydrates,
- determine how hydrates and hydrate processes affect sediment properties,
- understand hydrate dissociation and its effects on sediments,
- be able to predict mass movements and their consequences,
- determine whether hydrate deposits can seal high-pressure gas accumulations and influence seafloor stability,
- determine the quantities of hydrate that constitute a hazard,
- understand the effects on hydrate beds from production wells, and
- determine if hydrate production will cause subsidence and catalogue subsidence effect from other causes.

Global Change

The science does not exist to understand;

- how much methane hydrate is susceptible to climate change,
- the impact of these methane hydrates on global warming,
- the consequences from the release of methane from these hydrates, and
- the role of methane release on global climate change.

III Function

These F&ORs will provide the basis for the design and fabrication of systems to replicate subsurface and sub-ocean environments. This will concentrate on areas of research and development needs which will include heat transfer and phase change issues in porous media, microbiology in extreme environments, and carbon sequestration and extraction research and development. The research and development activities to be performed in this facility will include:

Development of properties associated with subsurface and sub-ocean environments

- Physical (porosity, permeability, sediment effect)
- Thermodynamic properties
- Multiphase properties, and flow phenomenon
- Determine effects of hydrates and hydrate processes on sediment properties

Understand biological and geological processes associated with subsurface and sub-ocean environments

- Extremophilic bacteria, effects of physical and chemical conditions on chemolithotropic and heterotrophic bacteria.
- Subsurface transport
- Biological Influences on Hydrate Formation

Develop/Test sensors for subsurface and sub-ocean environments

- Exploration
- Characterization
- Production

Develop/Test Production Technology for subsurface and sub-ocean extraction of or sequestration of carbon resources.

- Sampling (collecting and packaging cores)
- Drilling
- Extraction

Produce samples for subsurface and sub-ocean research activities

- Significant volumes
- Differing characteristics
- In sediment beds

Archive Samples to maintain sample integrity

IV Operational Requirements

1. General Codes and Standards

This project shall meet the requirements of the following documents, codes, and standards.

- DOE-ID Architectural Engineering Standards

2. Structural

Structures shall be designed and constructed in accordance with the Uniform Building Code. Structural supports will be provided to adequately support equipment. Supports shall be designed in accordance with the AISC Steel Construction Manual or the American Concrete Institute. The supports will allow for flexibility in positioning equipment modules so that different configurations can be supported during testing.

3. Mechanical

Code boundaries and design conditions shall be established for all components. Outside of the boundaries of pressure vessels, all structural welding with steel shall be in accordance with American Welding Society (AWS) D1.1 Structural Welding Code-Steel, and AWS D1.3 Structural Welding Code-Sheet Metal. All structural welding with aluminum will be in accordance with AWS D1.1, Structural Welding Code-Aluminum.

Pressure Vessel welding shall be in accordance with the requirements of paragraphs UW-2(a) and UW-11 (lethal Substances) of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. The requirements of 122.8.1 and .2 in ANSI B31.1 shall be met for all toxic fluids. Analysis shall be performed to determine if category M fluid rules shall apply.

Maintain air flow from inhabited portions of the facility to the test areas.

Maintain flammable gas concentrations below flammability limits where practical

Utility systems shall be provided as necessary to support the test programs. These utilities will include, at a minimum,:

- Refrigeration systems for cooling vessels and generating hydrate

- Cooling water

- Deionized water

- Potable water

- Instrument air

- Electricity

- Simulated seawater production and storage system

4. Fire Protection

A fire Hazard analysis shall be performed on the systems to be installed to ensure that the requirements of the facility meet DOE Order 5480.8 and "Operational Design Criteria Manual" (ID-12044) are met.

5. Electrical

The design and installation of the system electrical system shall comply with the National Electrical Code, National Fire Protection Associations/ANSI and National Electrical Safety Code, ANSI C-2.

All System electrical equipment shall comply with Underwriter's Laboratories standards. The electrical system shall be designed so that an interruption of power will not create a safety hazard during process equipment of operation.

6. Architectural

6.1 Facility Classification: Analysis shall be performed to determine the occupancy classification for the facility.

V. Process Requirements

1. Design Life: The process systems shall be designed for a 5 year design life.

2. Process Requirements

2.1 Pressure Vessels

2.1.1 General Requirements

Pressure vessels shall be designed, fabricated, and installed in accordance with nationally recognized codes and standards. The following codes shall apply; ASME, Section VIII, Division 1 and 2 Where specified.

ASME stamps are required for components constructed in accordance with the ASME Boiler and Pressure Vessel Code. Stamped vessels shall be registered with the National Board of Boiler and Pressure Vessel Inspectors of Columbus, Ohio.

Pressure vessel welding shall be in accordance with the requirements of paragraphs UW-2(a) and UW-11 (lethal substances), of Section VIII, Division 1 of ASME Boiler Code and Pressure Vessel Code. Ultrasonic testing in accordance with UW-53 may be substituted for radiographic examination. All piping butt welds shall be volumetrically examined. The requirements of 122.8.2 in ANSI B31.1 shall be met for toxic fluids.

2.1.2 Down Hole Test Vessel: A vessel shall be provided that allows for testing of full scale coring tools and down-hole instrumentation. Analysis will need to be performed to determine the vessel size. Presently it is estimated that the vessel will be 2 meters inside diameter with the ability to establish a hydrate bed height of a minimum of 3 meters. To test coring tools, there shall be a way to position coring tools at the bed surface or 20 cm into the bed so that a 2 – 3 meter long core can be extracted from the bed. To test instrumentation, there shall be a way of drilling or coring 6 inch diameter vertical holes through the entire bed. The capability shall be provided to lower a 100kg instrument into the hole. The vessel shall be

designed to allow for evaluation of the contents real-time remote techniques.

This drilling would preferably simulate actual drilling operations and so should incorporate fluid pumping into and removal from the hole. The purpose of the fluid is to simulate the thermal and fluid effects on the surrounding hydrates, not to control pressure in the "well". Additionally, there shall be ways to measure the evolution of gas, water, and loose solids in the vessel during drilling or tool testing as well as during simulated production or well depressurization.

2.1.3 Acoustic Vessel: A vessel shall be provided for seismic studies. This vertical vessel is envisioned to be one meter in diameter and four meters long. Systems shall be provided for fabricating a layered hydrate bed. The ability to incorporate or inject free gas into the bed with the hydrates shall be provided. A number of fittings suitable for attaching acoustic transponders shall be incorporated in the lower head. *This vessel's function may be possible to integrate into the Down Hole Test Vessel.*

2.1.4 Multi-phase Test Vessels: Two vessels shall be provided for flow and production testing. They are to be similar in form and function with one vertical while the other is horizontal to allow tests of multiphase (gas/liquid) flow in both directions relative to gravity. A single vessel that can swivel between the two orientations is an acceptable alternative. The vessels are estimated to be approximately 0.3 meters in diameter and 5 meters long with provisions for pumping gas and/or liquid into one end and removing it at the other end while measuring the flows, temperatures, and phase compositions. The vertical vessel shall have provisions for upward and downward flow. The ability to supply low temperature heat at various locations on the outside of the vessel to encourage hydrate melting is needed. Online tomographic analysis of hydrate, liquid and gas is needed.

2.1.5 Pressure: All vessels shall have operating pressures of 2000 pound per square inch.

2.1.6 Temperature: All vessels shall have operating temperatures of from -20°C to 150°C.

2.2 Influent

Systems shall be provided to allow for alternative influent feeds of both gasses and liquids into the vessels. These may include; methylamines, acetate, formate, water, CO₂, etc. Systems shall be provided for the ability to mix and store solutions. Systems shall be provided for the introduction and removal of sediment (sand, soil, etc.) within the vessel. The throughput and storage requirements shall be identified as part of the conceptual design effort.

2.3 Hydrates Production System

A system shall be provided capable of producing gas hydrates for each vessel. The systems to feed vessels shall be designed with the capability to produce the hydrates at different densities with different gas (methane, carbon dioxide, and natural gas) types and concentrations, and sediments and sediment concentrations. This shall include fabricating layered hydrates with various concentrations of hydrates ranging from approximately 1-80 vol% of the pore space between the sediments. The system shall be able to use various dry sediment solids as the major component of the bed. The system shall have a way of flooding the formed hydrate bed with water or sea water to displace contained free gas. All systems shall have the ability to introduce simulated sea water.

2.4 Hydrate Sample Storage and Archival System

A system shall be provided that is capable of storing hydrate samples produced in the facility and extracted from natural environments. The storage and archival system designed to store 100 2 meter long cores. The storage areas shall be maintained at -20C and pressure to ensure the integrity of samples.

2.5 Effluent and Emission Systems

2.5.1 Liquid Effluent: The system shall have the capabilities to dispose of cooling water and effluent generated during testing and system clean up. This shall include the processing of water that contains sodium salt and other elements that must be removed prior to disposal. The design shall include storage for effluent from the vessels for sampling prior to release.

✓ A Study shall be performed to determine if the effluent will require sterilization prior to release.

2.5.2 Gas Emission System: A gas emission system is required to remove any hazardous components from the effluent of the system during pressure letdown (from 2000 psi to near atmospheric). Gas vented to the atmosphere shall meet applicable emission standards. Gasses that may be expected to be in the effluent include methane, ethane, hydrogen sulfide, carbon dioxide, water vapor, and air. The system shall be designed to handle expected off gas during normal and off-normal conditions.

Dedicated process vents shall be provided for the Down Hole and Acoustic and Multi-phase vessels.

2.5.3 Solid Effluent: The facility shall have the capabilities to dispose of solid effluent generated during testing and system clean up. This shall include the processing sediment removed prior to disposal. The design shall include storage for effluent from the vessels for sampling prior to release. A study shall be conducted to determine if the solid effluent will require sterilization prior to release.

2.6 Piping

Piping shall be designed, fabricated and installed in accordance with ANSI B31.3. Nonstandard piping components (those not included in Appendix D of ANSI B31.1) that are included in the piping flexibility analysis must have flexibility and stress intensification factors based on experimental or theoretical analysis.

2.7 Components

Components shall be designed, fabricated, and installed in accordance with nationally recognized codes and standards. The following codes apply: valve – ANSI, B31.1/B16.34, and pumps ASME Section VIII, Divisions 1 and 2 where specified. Code boundary and design conditions shall be established for all components. Design conditions shall include design pressure, design temperature, and where applicable, a description of pressure and thermal transients. Relief device outlets shall be directed to containment vessels or headers to prevent uncontrolled discharge to the environment. Containment vessels shall be designed to accept total system blow-down upon venting.

2.8 Materials of Construction

Materials used in the construction within pressure boundaries shall be those permitted by ANSI B31.1, ANSI 31.3, and ASME Section VIII, Division 2. A technically justified corrosion allowance shall be specified for use in determining minimum required wall thickness of each system component. Structural materials shall conform to American Institute of Steel Construction (AISC) requirements. The system shall be designed so that corrosion measurement areas and temperature sensors can be easily accessed.

3. Process Instrumentation and Controls

The instrumentation and control system shall provide for system monitoring, control and for data acquisition and archiving.

3.1 Expansion

The system instrumentation and control system shall be designed to accommodate expansion of multiple sensors and control actuators for the system. The required number of instrumentation channels and interface requirements cannot be accurately specified at this time. The conceptual design process shall develop a generic instrumentation and control system requirements that anticipate the number of channels and channel requirements over the life of the system.

3.2 Remote Operation and Control

The system instrumentation and control instrumentation systems shall be provided to allow operators to remotely monitor and control the experimental systems and utilities from a safe distance. Remote start-up of the system to operating condition and remote shutdown shall be required. The control system shall include:

- a) Process sensors
- b) Sensor signal control conditioning
- c) Automatic/manual control systems and interfaces
- d) Control and display algorithms

- e) Display and printing devices

3.3 Data Acquisition

The data acquisition and archival instrumentation systems shall be provided to allow operators to acquire selected System process measurements from a safe distance to meet data objectives. These systems shall include:

- f) On-line laboratory analysis measurement equipment
- g) Process sensors
- h) Sensor signal conditioning
- i) Acquisition systems and interfaces
- j) Display and data reduction algorithms
- k) Display, printing and archiving devices

3.4 Vessel Monitoring and Control Instrumentation Functions

The design shall provide a system that monitors and controls the systems (vessels) and collects data during experimental runs. The systems shall be designed to allow for flexibility and safe operation. The system shall meet the following performance requirements.

3.4.1 Monitoring and Control and Data Acquisition Sensor Requirements

- a) Specify absolute pressure rating for all process sensors so that the maximum credible pressure applied to the sensing element shall not cause a rupture of the pressure boundary or damage to the sensor.
- b) Specify accuracy and resolution of all sensors so that operation or automatic control systems can adequately monitor and control the System.
- c) Ensure that sensor systems have sufficient range to indicate normal operating conditions and abnormal conditions without sensor saturation.
- d) Ensure that sensor system response time is adequate for System process control and accurate process monitoring.

3.4.2 Control and Data Acquisition System

- a) Provide an analog and digital system capable of monitoring and controlling all process variables necessary for remote monitoring and control.
- b) Provide an analog and digital acquisition system with channels and bandwidth sufficient to control the System.
- c) Provide acquisition equipment so that aliasing errors do not interfere with the ability to monitor and control the System.

- d) Provide sufficient spare channels to accommodate the expected needs for the design life of the system.
- e) Provide automatic control system responses that will attempt to mitigate an overpressure condition before a response from the relief devices.
- f) Provide time tagging and backup of data.

3.4.3 Control and Data Acquisition System Display

A data acquisition and control system shall be designed to:

- a) Provide real-time online monitoring of as many selected channels as are required to ensure safe operation and control of the system.
- b) Provide trend displays for all analog inputs. Provide for online trend monitoring of as many selected channels as are required to ensure safe operation and control of the System.
- c) Provide audio and visual annunciation capability for all process parameters to alert operators of potential abnormal conditions
- d) Provide alarm indicators to alert an operator of a pending over pressurization, gas releases, or other hazardous conditions.

4. Power Requirements

Analysis shall be performed to determine the power requirements for the systems and chambers.

4.1 Back-up Power: Back-up power capabilities shall be provided to ensure safe shutdown of systems and/or maintenance of critical experiments.

4.2 Uninterruptible Power: Uninterruptible power shall be provided to ensure safe operation, maintenance of critical experiments, and archival of data.

5. Space Requirements

The Hydrates facility shall be located in an existing or new building at the INEEL. It is presently envisioned to be located in the proposed Environmental Engineering Sciences Center. Distance, walls, protective barriers, or other means to protect the operators and other personnel shall separate the control room and supporting administrative areas from the process equipment.

5.1 Location

The system shall be located indoors in an area that provides adequate space; is well lighted, heated, and ventilated; has necessary fire protection and alarm systems; phone and communication systems; adequate power available; a deionized water supply; and meet general requirements for industrial hygiene such as protection from hazardous materials, restrooms, and washroom facilities.

5.2 Control Area

A control area shall be provided containing the necessary elements of the data acquisition and control system that are required for remote operation and monitoring of the System.

5.3 Access

The area where the Center will be located shall be accessible by exterior doorways sized to accommodate a flatbed truck with a minimum vertical clearance of 16 ft. Through this doorway, equipment and materials shall be brought into the area by truck or other vehicles and unloaded and set in position.

5.4 Cranes

Cranes shall be provided to support loading, unloading, and positioning of equipment.

5.5 Hazardous Materials Storage

Storage of hazardous materials shall be provided for.

6. Safeguards and Security

Physical security of the facility will be consistent with the requirements for the facility in which the chambers are sited.

7. Environmental and Safety

Release of hazardous materials postulated to occur as a result of design basis accidents (DBAs) shall be limited by design such that a single failure does not result in the loss of a safety class item to accomplish its required safety function. Appropriate NEPA documentation shall be prepared to ensure the facility is in compliance with NEPA. A Hazards Classification shall be prepared to the appropriate safety documentation for the system.

8. Facility Use Category

The facility use category will be defined by the safety analysis report (SAR). (not to be prepared with FY-98 funds)

9. Quality System

Quality requirements for this project shall be in accordance with the Lockheed Martin Idaho Technologies Quality Assurance Program Requirements Document PDR 101, rev. 0 8/96.

Appendix B

Drawings

D

C

B

A

MAIN FLOOR

AN

FOR DRAWING INDEX SEE DRAWING NO.		SUBCONTRACT NO.		LOCKHEED MARTIN EXTREME ECOSYSTEMS TEST FACILITY			
REQUESTER: JM BELLER DESIGNER: WH LANDMAN DRAWN: LANDMAN / BEHM PROJECT NO. SPEC CODE		FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. EFFECTIVE DATE:					
DESIGN PHASE: CONCEPTUAL QUALITY LEVEL: 3		SCALE: 1/8" = 1'-0"		MAIN FLOOR PLAN SIZE: D 01MF3 AREA: 1530 DWG- SHEET A-1			

8

7

6

5

D

C

B

A

T.O. PARAPET

SLOPE

HIGH BAY CRANE

V-107

FULL SCALE
VESSEL
TEST AREA

73'-6"

EAVE

20'-0"

MEZZININE

REI

CORE /
SPECIMEN
STORAGE

SECTION

A
A-1

User: ASE
Date: 12/01/98 - 12:58 P.M.

File: hyd-2.dwg
Path: P:\london

8

7

6

5

SECTION B
A-1

FOR DRAWING INDEX SEE DRAWING NO.		SUBCONTRACT NO.		LOCKHEED MARTIN EXTREME ECOSYSTEMS TEST FACILITY	
REQUESTOR: JIM BELLER DESIGNER: WH LANDMAN DRAWING: CA BEHM PROJECT NO. SPEC CODE		FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO. EFFECTIVE DATE			
DESIGN PHASE: CONCEPTUAL QUALITY LEVEL: 3		SCALE: 1/8" = 1'-0"		SECTIONS SIZE: D 01MF3 AREA: 1128 G: 1082 530 DWG- SHEET A-2	

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE

FOR DRAWING INDEX SEE DRAWING NO.	SUBCONTRACT NO.	LOCKHEED MARTIN	
NO SCALE	REQUESTER: JM BELLER	EXTREME ECOSYSTEMS TEST FACILITY	
	DESIGNER: WH LANDMAN	GAS HYDRATE PRODUCTION	
	DRAWN: J.TULLIS	DOWN HOLE TEST VESSEL	
	PROJECT NO.	PROCESS FLOW DIAGRAM	
DESIGN PHASE: CONCEPTUAL	SPEC CODE	SIZE: D	CAGE CODE: 01MF3
QUALITY LEVEL: 3	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	INDEX CODE NUMBER: AREA TYPE CL L ORG	DWG-507619
EFFECTIVE DATE:	SCALE: 1/1	530	REV 1 OF 1

TO V-103, GAS ACCUMULATOR
SEE DWG 507726

TO B-108, WASTE BIN
SEE DWG 507726

TO FLARE STACK
SEE DWG 507726

FROM V-301 HORIZONTAL MPT VESSEL
SEE DWG 507726

E-201 A.B.
SOLIDS FILTER
202

COIL
WATER
KW

2F REF

25F COOLANT

E-202 A.B.
GAS COOLER
1000 BTU/HR
2 FT²

BL-202
VMPTV
AIR BLOWER

AIR

HEATED AIR TO V-301
SEE DWG 507726

N₂ CYLINDERS

N₂ TO V-301
SEE DWG 507726

METHANE, NATURAL GAS OR CO₂
FROM E-106A, E-106B, OR E-101
SEE DWG 507619

TO P-209 VMPT VESSEL
SLURRY PUMP
SEE DWG 507726

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE

FOR DRAWING INDEX SEE DRAWING NO.		SUBCONTRACT NO.		LOCKHEED MARTIN											
NO SCALE		REQUESTER: JIM BELLER		EXTREME ECOSYSTEMS TEST FACILITY											
		DESIGNER: WH LANDMAN													
		DRAWN: J.TULLIS													
		PROJECT NO.													
SPEC CODE		FOR REVIEW/APPROVAL SIGNATURES		SIZE		CAGE CODE		INDEX CODE NUMBER		DWG-507620		REV			
DESIGN PHASE: CONCEPTUAL		SEE DAR NO.		D		01MF3		AREA		TYPE		G		530	
QUALITY LEVEL: 3		EFFECTIVE DATE:		SCALE: 1/1								SHEET 1 OF 1			

FOR DRAWING INDEX SEE DRAWING NO.		SUBCONTRACT NO.		LOCKHEED MARTIN	
NO SCALE		REQUESTER: JM BELLER		EXTREME ECOSYSTEMS TEST FACILITY GAS HYDRATE EFFLUENT TREATMENT AND HORIZONTAL MP TEST VESSEL PROCESS FLOW DIAGRAM	
		DESIGN: WH LAMOWAN			
		DRAWING: F.A. HAYNER			
		PROJECT NO.			
SPEC CODE		FOR REVIEW/APPROVAL SIGNATURES		INDEX CODE NUMBER	
DESIGN PHASE: CONCEPTUAL		SEE DAR NO.		D 01MF3	
QUALITY LEVEL: 3		EFFECTIVE DATE:		SCALE: 1/1	
				DWG-507726	
				SHEET 1 OF 1	

8

7

6

5

8

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6

5

TO NORMAL
 POWER SUPPLY
 600KVA
 480/277
 1000NA
 P

P-1
 1200A, 1022KVA
 SEE NOTE 5

MCC--
 600A, 384KVA
 SEE NOTE 6

CUBICAL SCHEDULE

CKT NO.	NAMEPLATE LABEL	HP	STARTER SIZE	
A1	SPARE			
A2	BL-201	5	1	SEDIMENT DRYING AIR BLOWER (MPTV)
A3	MX-101	20	2	SOLIDS MIXER
A4	MX-102	5	1	SEDIMENT BIN #1 MIXER (DHTV)
A5	MX-103	5	1	SEDIMENT BIN #2 MIXER (DHTV)
A6	MX-201	5	1	SOLIDS MIXER
B1	SPARE			
B2	MX-204	5	1	SEDIMENT BIN #2 (MPTV)
B3	P-309	10	1	SLURRY PUMP (HMPTV)
B4	P-103	15	2	DI WATER PUMP
B5	P-105	1	1	BRINE PUMP
B6	P-108	3	1	CO2 RECYCLE PUMP
C1	SPARE			
C2	P-201	7.5	1	RECYCLE WATER PUMP
C3	P-203	1	1	DI WATER PUMP
C4	P-205	0.1	1	BRINE PUMP
C5	P-208A	3	1	CO2 RECYCLE PUMP
C6	P-209	10	1	SLURRY PUMP (VMPTV)
D1	SPARE			
D2	GLYCOL PUMP	5	1	E-X01, X02A, X02B, X04A, X04B COOLERS (10 TOTAL)
D3	GLYCOL PUMP	15	2	E-X03A, X03B CHILLER, X-10 COOLER (6 TOTAL)
D4	BL-101	15	2	SEDIMENT DRYING AIR BLOWER
D5	MX-202	5	1	SEDIMENT BIN #1 (MPTV)
D6	P-109	10	1	SLURRY PUMP (DHTV)
E1	SPARE			
E2	P-106	30	3	METHANE PUMP
E3	SPARE			
E4	P-102	10	3	CO2 PUMP
F1	SPARE			
F2	BL-____	30	3	AMBIENT AIR BLOWER
F3	SPARE			
F4	P-101	75	4	RECYCLE WATER PUMP
G1	SPARE			
G2	BL-102	10	1	METHANE PUMP
G3	BL-202	5	1	NATURAL GAS PUMP
G4	MX-104	5	1	CO2 PUMP
G5	P-110	2	1	CO2 PUMP
H1	SPARE			
H2	SPARE			
H3	SPARE			
H4	SPARE			
H5	P-108B	3	1	CO2 RECYCLE PUMP
H6	P-208B	3	1	CO2 RECYCLE PUMP

4

3

2

1

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE

13'-4"

A	B	C	D	E	F	G	H
A1	B1	C1	D1	E1	F1	G1	H1
A2	B2	C2	D2	E2	F2	G2	H2
A3	B3	C3	D3			G3	H3
A4	B4	C4	D4	E3	F3	G4	H4
A5	B5	C5	D5	E4	F4	G5	H5
A6	B6	C6	D6				H6

7'-6"

MOTOR CONTROL CENTER ELEVATION

FOR DRAWING INDEX SEE DRAWING NO.		SUBCONTRACT NO.			
SCALE: 1" = 1'-0"		REQUESTER: DESIGN: K. CALDWELL DRAWN: M. WINTERS PROJECT NO. SPEC CODE			
DESIGN PHASE:		FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.		SIZE: D CAGE CODE: 01MF3 INDEX CODE NUMBER: 1530 AREA: TYPE: CL: ORG: DWG- REV:	
QUALITY LEVEL: 3		EFFECTIVE DATE:		SCALE: 1"=1'-0" SHEET 1 OF 2	

4

3

2

1

DETAIL

3/16"=1'-0"

4

3

2

1

REVISIONS

REV DESCRIPTION EFFECTIVE DATE

D

C

B

A

#16 TSP SHELDED

MOTOR
CONTROL
CENTER

FOR DRAWING INDEX SEE DRAWING NO.		SUBCONTRACT NO.		LOCKHEED MARTIN					
NO SCALE		REQUESTER:		EXTREME ECOSYSTEMS TEST FACILITY INSTRUMENT FLOW DIAGRAM					
		DESIGN: K. CALDWELL							
		DRAWN: M. WINTERS							
		PROJECT NO.							
SPEC CODE		FOR REVIEW/APPROVAL SIGNATURES		SIZE	CAGE CODE	INDEX CODE NUMBER		DWG-	REV
DESIGN PHASE:		SEE DAR NO.		D	01MF3	AREA	TYPE		
QUALITY LEVEL: 3		EFFECTIVE DATE:		SCALE: NOTED		530		SHEET 1 OF 3	

4

3

2

1

Appendix C

Hydrates Production Tables

Appendix C

Hydrates Production Tables

Table C-1. Hydrate formation using water to remove heat of hydrate formation.

Vessel	Sediment	Pores Filled with Hydrates (%)	Gas	Hydrate (lb)	Total Dut (Btu)	Btu Removed by Water	Water Flow (gpm)	Hydrate Formation Time (hr)
DHV	Clay	1	CH ₄	154	2.10E+04	1.63E+04	50	0.13
DHV	Clay	80	CH ₄	12,300	1.68E+06	1.30E+06	50	10.4
DHV	Sand	1	CH ₄	308	4.19E+04	3.26E+04	50	0.26
DHV	Sand	80	CH ₄	24,600	3.36E+06	2.61E+06	50	20.9
DHV	Diatom. Earth	1	CH ₄	523	7.13E+04	5.54E+04	50	0.44
DHV	Diatom. Earth	80	CH ₄	41,821	5.70E+06	4.43E+06	50	35.5
DHV	Clay	1	CO ₂	189	7.33E+04	7.26E+04	50	0.6
DHV	Clay	80	CO ₂	15,098	5.87E+06	5.81E+06	50	46.5
DHV	Sand	1	CO ₂	377	1.47E+05	1.45E+05	50	1.2
DHV	Sand	80	CO ₂	30,196	1.17E+07	1.16E+07	50	93.0
DHV	Diatom. Earth	1	CO ₂	642	2.49E+05	2.47E+05	50	2.0
DHV	Diatom. Earth	80	CO ₂	51,334	1.99E+07	1.98E+07	50	158.1
Vert. MPV	Clay	1	CH ₄	1.8	2.41E+02	1.87E+02	5	0.01
Vert. MPV	Clay	80	CH ₄	141.8	1.93E+04	1.50E+04	5	1.2
Vert. MPV	Sand	1	CH ₄	3.5	4.82E+02	3.75E+02	5	0.03
Vert. MPV	Sand	80	CH ₄	283.5	3.86E+04	3.00E+04	5	2.4
Vert. MPV	Diatom. Earth	1	CH ₄	6.0	8.20E+02	6.37E+02	5	0.05
Vert. MPV	Diatom. Earth	80	CH ₄	482.0	6.56E+04	5.10E+04	5	4.1
Vert. MPV	Clay	1	CO ₂	2.2	8.43E+02	8.35E+02	5	0.07
Vert. MPV	Clay	80	CO ₂	174.0	6.74E+04	6.68E+04	5	5.3
Vert. MPV	Sand	1	CO ₂	4.4	1.69E+03	1.67E+03	5	0.13
Vert. MPV	Sand	80	CO ₂	348.0	1.35E+05	1.34E+05	5	10.7
Vert. MPV	Diatom. Earth	1	CO ₂	7.4	2.87E+03	2.84E+03	5	0.23
Vert. MPV	Diatom. Earth	80	CO ₂	591.7	2.29E+05	2.27E+05	5	18.2

Table C-2. Hydrate formation using gas to remove heat of hydrate formation.

Vessel	Sediment	Fill (%)	Gas	Hydrate (lb)	Btu Removed by Circ. Gas	Methane Flow (scfm)	CO ₂ Flow (gpm)	Hydrate Formation Time (hr)
DHV	Clay	1	CH ₄	154	1.63E+04	1,000	—	0.17
DHV	Clay	80	CH ₄	12,300	1.30E+06	1,000	—	13.5
DHV	Sand	1	CH ₄	308	3.26E+04	1,000	—	0.34
DHV	Sand	80	CH ₄	24,600	2.61E+06	1,000	—	27.0
DHV	Diatom. Earth	1	CH ₄	523	5.54E+04	1,000	—	0.57
DHV	Diatom. Earth	80	CH ₄	41,821	4.43E+06	1,000	—	45.9
DHV	Clay	1	CO ₂	189	7.26E+04	—	40	0.20
DHV	Clay	80	CO ₂	15,098	5.81E+06	—	40	15.8
DHV	Sand	1	CO ₂	377	1.45E+05	—	40	0.40
DHV	Sand	80	CO ₂	30,196	1.16E+07	—	40	31.6
DHV	Diatom. Earth	1	CO ₂	642	2.47E+05	—	40	0.7
DHV	Diatom. Earth	80	CO ₂	51,334	1.98E+07	—	40	53.7
								Minutes
Vert. MPV	Clay	1	CH ₄	2	1.87E+02	1,000	—	0.1
Vert. MPV	Clay	80	CH ₄	142	1.50E+04	1,000	—	9.3
Vert. MPV	Sand	1	CH ₄	4	3.75E+02	1,000	—	0.2
Vert. MPV	Sand	80	CH ₄	284	3.00E+04	1,000	—	18.6
Vert. MPV	Diatom. Earth	1	CH ₄	6	6.37E+02	1,000	—	0.4
Vert. MPV	Diatom. Earth	80	CH ₄	482	5.10E+04	1,000	—	31.7
Vert. MPV	Clay	1	CO ₂	2	8.35E+02	—	40	0.5
Vert. MPV	Clay	80	CO ₂	174	6.68E+04	—	40	41.6
Vert. MPV	Sand	1	CO ₂	4	1.67E+03	—	40	1.0
Vert. MPV	Sand	80	CO ₂	348	1.34E+05	—	40	83.1
Vert. MPV	Diatom. Earth	1	CO ₂	7	2.84E+03	—	40	1.8
Vert. MPV	Diatom. Earth	80	CO ₂	592	2.27E+05	—	40	141.3

Table C-3. Hydrate formation using refrigeration to remove heat of hydrate formation.

Sediment	Fill (%)	Gas	Hydrate (lb)	Total Duty (Btu)	Time (hr)
Clay	1	CH ₄	1.8	187	0.0
Clay	80	CH ₄	141.8	14,987	1.5
Sand	1	CH ₄	3.5	375	0.0
Sand	80	CH ₄	283.5	29,973	3.0
Diatom. Earth	1	CH ₄	6.0	637	0.0
Diatom. Earth	80	CH ₄	482.0	50,954	5.1
Clay	1	CO ₂	2.2	835	0.1
Clay	80	CO ₂	174.0	66,834	6.7
Sand	1	CO ₂	4.4	1,671	0.2
Sand	80	CO ₂	348.0	133,667	13.3
Diatom. Earth	1	CO ₂	7.4	2,840	0.3
Diatom. Earth	80	CO ₂	591.7	227,235	22.7

Appendix D

Equipment List

Extreme Ecosystems Test Facility Equipment List
(Mechanical Process Equipment Only)

11/11/98

Equip type	Equip No	Tag	Description	Capacity	Diameter or Rating	Length or add'l rating	Pressure Rating (psig)	Material	Power	Drawing
V	101		Down Hole Test Vessel	4,150 gal	6.56 ft	16.40 ft	2000	SA 516 / Hast 276C		507619
V	201		Vertical Multiphase Test Vessel	93 gal	0.98 ft	16.40 ft				507620
V	301		Horizontal Multiphase Test Vessel	93 gal	0.98 ft	16.40 ft				507726
BL	101		Sediment Drying Air Blower	2,000 scfm					15 hp	507619
EH	101		Sediment Drying Air Heater	40 kw					10 hp	507619
EH	102		DHTV Coil Air Heater	16 kw						507619
B	101		Sediment Bin #1	320 ft3	6.5 ft ID	10 ft T-T	atm	CS	N/A	507619
MX	102		Sediment Bin #1 Mixer						15 hp	507619
E	110		Sediment Bin #1 Cooling Coil	120,000 Btu/hr	31 ft2	-22 F			N/A	507619
B	102		Sediment Bin #2	320 ft3	6.5 ft ID				N/A	507619
MX	103		Sediment Bin #2 Mixer						10 hp	507619
E	111		Sediment Bin #2 Cooling Coil	120,000 Btu/hr	31 ft2	-22 F				507619
V	107		Sediment Water Accumulator	360 gal	3 ft ID	7 ft T-T			10 hp	507619
E	108		Ice Maker	220,000 Btu/hr						507619
CR	101		Ice Crusher/Shaver	5,800 lbm/hr					3 kw	507619
B	103		Ice Storage Bin		4 ft ID	8 ft high			5 hp	507619
E	109		Ice Storage Bin Cooling Coil	(ADD)						507619
MX	101		Solids Mixer	150 ft3/hr						507619
T	101		DI Water Tank	2,600 gal	6	12			5 kw	507619
T	102		Brine / Recycle Water Tank	2,600 gal	6	12				507619
T	103		Methane Tank	1,000 gal	4	10				507619
T	104		Natural Gas Tank	1,000 gal	4	10				507619
T	105		CO2 Tank	3,400 gal	6	16				507619
MX	104		Brine Mixer							507619
P	101		Recycle Water Pump	50 gpm	4600 ft head					507619
P	102		CO2 Pump	10 gpm	3200 ft head					507619
P	103		DI Water Pump	8 gpm	4600 ft head					507619
P	105		Brine Pump	8 gpm	230 ft head					507619
P	106		CH4 Pump	15 gpm	11000 ft head					507619
E	101		CO2 Cooler	24 ft2	24000 Btu/hr					507619

Equip type	Equip No	Tag	Description	Capacity	Diameter or Rating	Length or add'l rating	Pressure Rating (psig)	Material	Power	Drawing
E	106 A		CH4 Vaporizer	140 ft2	800000 Btu/hr					507619
E	106 B		CH4 Vaporizer	140 ft2	800000 Btu/hr					507619
E	104 A		Water Chiller	260 ft2	160000 Btu/hr					507619
E	104 B		Water Chiller	260 ft2	160000 Btu/hr					507619
E	105		Vessel Heating/Cooling Coil	320 ft2						507619
F	101 A		Solids Filter							507619
F	101 B		Solids Filter							507619
E	102 A		Gas Cooler	2 ft2	1000 Btu/hr					507619
E	102 B		Gas Cooler	2 ft2	1000 Btu/hr					507619
BL	102		DHTV Air Blower							507619
V	102		Liquid Knock out drum	900 gal	3.5 ft	7 ft				507619
C	101		Methane Recycle Compressor	10 acfm	110 psid					507619
P	108		CO2 Recycle Pump	50 gpm	250 ft head					507619
P	108		CO2 Recycle Pump	50 gpm	250 ft head					507619
E	103 A		Gas Chiller	120 ft2	325000 Btu/hr					507619
E	103 B		Gas Chiller	120 ft2	325000 Btu/hr					507619
BL	201		Sediment Drying Air Blower	100 scfm						507620
EH	201		Sediment Drying Air Heater	2 kw						507620
EH	202		MPTV Coil Air Heater	16 kw						507620
B	201		Sediment Bin #3	12 ft3	2 ft ID	4 ft T-T	atm			507620
MX	201		Sediment Bin #3 Mixer							507620
E	210		Sediment Bin #3 Cooling Coil	12,000 Btu/hr	3 ft2	-22 F				507620
B	202		Sediment Bin #4	12 ft3	2 ft ID	4				507620
MX	202		Sediment Bin #4 Mixer							507620
E	211		Sediment Bin #4 Cooling Coil	12,000 Btu/hr	3 ft2	-22 F				507620
V	207		Sediment Water Accumulator	30 gal	1.5 ft ID	2.5 ft T-T				507620
E	208		Ice Maker	32,000 Btu/hr						507620
CR	201		Ice Crusher/Shaver	1,000 lbm/hr						507620
B	203		Ice Storage Bin		2.5 ft ID	3 ft high				507620
E	209		Ice Storage Bin Cooling Coil							507620
MX	203		Solids Mixer	15 ft3/hr						507620
T	201		DI Water Tank	100 gal	2	4				507620
T	202		Brine / Recycle Water Tank	100 gal	2	4				507620
P	201		Recycle Water Pump	5 gpm	4600 ft head					507620
P	203		DI Water Pump	1 gpm	4600 ft head					507620

Equip type	Equip No	Tag	Description	Capacity	Diameter or Rating	Length or add'l rating	Pressure Rating (psig)	Material	Power	Drawing
P	205		Brine Pump	1 gpm	230 ft head					507620
E	204 A		Water Chiller	260 ft2	160000 Btu/hr					507620
E	204 B		Water Chiller	260 ft2	160000 Btu/hr					507620
E	205		Vessel Heating/Cooling Coil	320 ft2						507620
F	201 A		Solids Filter							507620
F	201 B		Solids Filter							507620
E	202 A		Gas Cooler	2 ft2	1000 Btu/hr					507620
E	202 B		Gas Cooler	2 ft2	1000 Btu/hr					507620
BL	202		VMPTV Air Blower							507620
V	202		Liquid Knock out drum	90 gal	2 ft	3 ft				507620
C	201		Methane Recycle Compressor	10 acfm	110 psid					507620
P	208		CO2 Recycle Pump	50 gpm	250 ft head					507620
P	208		CO2 Recycle Pump	50 gpm	250 ft head					507620
E	203 A		Gas Chiller	120 ft2	325000 Btu/hr					507620
E	203 B		Gas Chiller	120 ft2	325000 Btu/hr					507620
B	108		Waste Bin	10,575 gal	10 ft	18 ft				507726
V	103		Gas Accumulator	220 gal	2.5 ft	6 ft				507726
EH	102		Offgas heater	80 kw						507726
V	104		H2S Reactor	576 gal	3.5 ft	8 ft				507726
V	105		Gas/Liquid Separator	220 gal	2.5 ft	6 ft				507726
BL	103		Oxidizer Air Blower	6,000 scfm						507726
V	106		Thermal Oxidizer		3 ft	6 ft				507726
P	110		H2S Decomposition Water Pump	50 gpm	100 ft head					507726
P	109		DHTV Slurry Pump							507726
P	209		VMTV Slurry Pump							507726
P	309		HMTV Slurry Pump							507726
V	107		Drilling Mud Storage Tank	120 gal	2 ft	5 ft				507726
P	111		Drilling Mud Pump	10 gpm	200 ft head	5 ft				507726
			Cryo Storage Facility							not shown
			LN2 Storage Tank	500 gal						not shown
			N2 Gas Bottles	220 scf						507619
			Process Chiller							not shown
			Flare Stack							507726

Appendix E

Cost Estimate

Lockheed Martin Idaho Technologies Company**INTERDEPARTMENTAL COMMUNICATION**

Date: December 15, 1998

To: J. M. Beller MS 2213 6-1205

From: S. M. Bradford MS 3655 6-0121

Subject: EXTREME ECOSYSTEMS TEST FACILITY – EQUIPMENT – SMB-43-98

Reference: S. M. Bradford letter to J. M. Beller, SMB-36-98, EXTREME ECOSYSTEMS TEST FACILITY, dated October 14, 1998

Cost Estimating has revised their Planning Cost Estimate for the Extreme Ecosystems Test Facility to incorporate new equipment prices and additional pieces of equipment. The revised Total Estimated Cost (TEC) for the equipment is \$20,000,000. Please refer to the attached Cost Estimate Summary and Detail Sheets for cost breakdowns. The TEC for the building was previously estimated as \$9,600,000. A copy of the Cost Estimate Summary and Detail Sheets for the building is available if you should request it.

This estimate is based on present day costs that have been escalated to the approximate midpoints of the major activities, i.e., design and construction. A Contingency Analysis has been prepared to determine the approximate amount of contingency that may be required to complete this project.

A Cost Estimate Support Data Recapitulation sheet has been prepared for your information also. This should adequately identify the scope and assumptions upon which this estimate has been based. If we can be of further assistance, please do not hesitate to call on us.

smb

Attachments

cc: Estimate File #8477-1
S. M. Bradford File

Lockheed Martin Idaho Technologies Co.

Rev. 6-96

COST ESTIMATE SUMMARY

 PROJECT NAME: **Extreme Ecosystems Test Fac
Equipment**
 LOCATION 1: **INEEL**
 REQUESTOR: **J. M. Beller**

 TYPE OF ESTIMATE: **Planning**
 PROJECT NO: **8477**
 PREPARED BY: **S. M. Bradford**
 REPORT NAME: **Cost Estimate Summary**

 DATE: **14-Oct-1998**
 TIME: **08:36:44**
 CHECKED BY:
 APPRD BY:

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
1.1	<u>ENGINEERING, DESIGN AND INSPECTION</u>			>> <u>\$1,072,358</u>
1.1.1	DESIGN ENGINEERING TITLE I & II	781,020	85,912	866,932
1.1.2	QUALITY ASSURANCE	177,091	28,335	205,426
1.2	<u>MANAGEMENT COSTS</u>			>> <u>\$866,055</u>
1.2.1	PROJECT MANAGEMENT	363,159	72,632	435,791
1.2.2	CONSTRUCTION MANAGEMENT	370,917	59,347	430,264
1.3	<u>CONSTRUCTION</u>			>> <u>\$12,469,678</u>
1.3.1	GENERAL CONDITIONS	123,390	19,742	143,132
1.3.2	SITWORK	0	0	0
1.3.3	CONCRETE	81,861	13,098	94,959
1.3.4	MASONRY	0	0	0
1.3.5	METALS	60,638	9,702	70,340
1.3.6	WOOD & PLASTICS	0	0	0
1.3.7	THERMAL & MOISTURE PROTECTION	0	0	0
1.3.8	DOORS & WINDOWS	0	0	0
1.3.9	FINISHES	0	0	0
1.3.10	SPECIALTIES	0	0	0
1.3.11	EQUIPMENT	6,973,297	1,115,728	8,089,025
1.3.12	FURNISHINGS	0	0	0
1.3.13	SPECIAL CONSTRUCTION	516,583	82,653	599,236
1.3.14	CONVEYING SYSTEMS	64,191	10,271	74,462
1.3.15	MECHANICAL	711,970	113,915	825,885
1.3.16	ELECTRICAL	2,217,792	354,847	2,572,639
1.5	<u>G&A/PIF</u>			>> <u>\$1,010,814</u>
1.5.1	G&A/PIF ADDER	871,391	139,423	1,010,814
1.5.2	PROCUREMENT FEES	322,492	51,599	>> <u>\$374,091</u>
	SUBTOTAL INCLUDING ESCALATION	13,635,792	2,157,204	>> \$15,792,996
	PROJECT CONTINGENCY			
	MANAGEMENT RESERVE			>> \$0
	CONTINGENCY			>> \$4,207,004
	TOTAL ESTIMATED COST			>> \$20,000,000

PROJECT COST PARAMETERS

 EDI AS A % OF CONST. + GFE= **9.00%**

 CONTINGENCY= **26.64%**

Lockheed Martin Idaho Technologies Co.

COST ESTIMATE SUMMARY

Rev. 6-96

PROJECT NAME: **Extreme Ecosystems Test Fac
New Building**
LOCATION 1: **INEEL / Idaho Falls**
REQUESTOR: **J. M. Beller**

TYPE OF ESTIMATE: **Planning**
PROJECT NO: **8477**
PREPARED BY: **S. M. Bradford**
REPORT NAME: **Cost Estimate Summary**

DATE: **14-Oct-1998**
TIME: **08:42:52**
CHECKED BY:
APPRD BY:

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
1.1	<u>ENGINEERING, DESIGN AND INSPECTION</u>			>> \$798,500
1.1.1	DESIGN ENGINEERING TITLE I & II	529,402	52,940	582,342
1.1.2	QUALITY ASSURANCE	180,132	36,026	216,158
1.2	<u>MANAGEMENT COSTS</u>			>> \$1,051,421
1.2.1	PROJECT MANAGEMENT	445,265	89,053	534,318
1.2.2	CONSTRUCTION MANAGEMENT	430,919	86,184	517,103
1.3	<u>CONSTRUCTION</u>			>> \$5,092,672
1.3.1	GENERAL CONDITIONS	142,013	28,403	170,416
1.3.2	SITWORK	805,297	161,059	966,356
1.3.3	CONCRETE	363,409	72,682	436,091
1.3.4	MASONRY	0	0	0
1.3.5	METALS	529,062	105,812	634,874
1.3.6	WOOD & PLASTICS	0	0	0
1.3.7	THERMAL & MOISTURE PROTECTION	48,362	9,672	58,034
1.3.8	DOORS & WINDOWS	26,864	5,373	32,237
1.3.9	FINISHES	143,764	28,753	172,517
1.3.10	SPECIALTIES	159,800	31,960	191,760
1.3.11	EQUIPMENT	0	0	0
1.3.12	FURNISHINGS	16,323	3,265	19,588
1.3.13	SPECIAL CONSTRUCTION	510,873	102,175	613,048
1.3.14	CONVEYING SYSTEMS	93,043	18,609	111,652
1.3.15	MECHANICAL	326,319	65,264	391,583
1.3.16	ELECTRICAL	1,078,763	215,753	1,294,516
1.4	<u>GOVERNMENT FURNISHED EQUIP.</u>			>> \$48,096
1.4.1	GOVERNMENT FURNISHED EQUIP.	39,423	8,673	48,096
1.5	<u>G&A/PIF</u>			>> \$628,246
1.5.1	G&A/PIF ADDER	523,538	104,708	628,246
1.5.2	PROCUREMENT FEES	128,499	25,724	\$154,223
SUBTOTAL INCLUDING ESCALATION		6,521,070	1,252,088	>> \$7,773,158
PROJECT CONTINGENCY				
MANAGEMENT RESERVE				>> \$592,324
CONTINGENCY				>> \$1,234,518
TOTAL ESTIMATED COST				>> \$9,600,000

PROJECT COST PARAMETERS

EDI AS A % OF CONST. + GFE= 16.00%

CONTINGENCY= 23.50%

COST ESTIMATE SUPPORT DATA RECAPITULATION

Project Title: Extreme Ecosystems Test Facility
Estimator: S. M. Bradford
Date: October 14, 1998
Estimate Type: Planning
File: 8477
Approved By:

I. **SCOPE OF WORK:** *Brief description of the proposed project.*

Design and construction of an Extreme Ecosystems Test Facility to be located in Idaho Falls. The project is divided into two parts: building and equipment. There is the possibility that the equipment could be located in an existing facility, such as the EESC, and a new building would not have to be constructed to house the equipment/process.

II. **BASIS OF THE ESTIMATE:** *Drawings, Design Report, Engineers Notes and/or other documentation upon which the estimate is originated.*

Preliminary drawings, sketches, vendor information, and project information from the engineers supporting this effort.

III. **ASSUMPTIONS:** *Conditions statements accepted or supposed true without proof of demonstration. An assumption has a direct impact on total estimated cost.*

1. The new building will be located near the IRC; the utility run will be approximately a half mile to the tie-in.
2. The city will be responsible for the new transformer, this project will have the responsibility of installing the conduit and cable between the new building and the transformer.
3. There are no cost allowances for encountering rock or other underground obstructions during excavation activities.
4. The design and construction of the building will be in accordance with the requirements of Quality Level 3, and the design and installation of the process equipment will be in accordance with the requirements of Quality Levels 2 and 3.

COST ESTIMATE SUPPORT DATA RECAPITULATION

- Continued -

Project Title: Extreme Ecosystems Test Facility

File: 8477

Page 2

- IV. CONTINGENCY GUIDELINE IMPLEMENTATION: *The percentage used for contingency as determined by the contingency allowance guidelines can be altered to reflect the type of construction and conditions that may impact the total estimated cost.*

The overall contingency for this project, 24% for the building and 27% for the equipment, is reflective of the minimal amount of information about the facility and process. As better design information is presented, the contingency level will be lower.

V. OTHER COMMENTS/CONCERNS SPECIFIC TO THE ESTIMATE

1. This project will be a FY02 new start; Design will commence in October of 2002, with construction and procurement activities anticipated to start in January 2004.
2. This project has been estimated for LMITCO design and typical subcontracted construction.
3. The two parts of this project, building and equipment, may be combined into one project. The costs associated with administrative areas including Project Management, Quality Assurance, Construction Management, and field supervision will decrease, due to some economies of scale. It is not anticipated that design or the costs associated with the construction and the fabrication and installation of equipment will not decrease.

Lockheed Martin Idaho Technologies Co.

Rev. 6-96

COST ESTIMATE SUMMARY

PROJECT NAME: Extreme Ecosystems Test Fac
 New Building
 LOCATION 1: INEEL / Idaho Falls
 REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning
 PROJECT NO: 8477
 PREPARED BY: S. M. Bradford
 REPORT NAME: Cost Estimate Summary

DATE: 14-Oct-1998
 TIME: 08:42:52
 CHECKED BY:
 APPRD BY:

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
<u>1.1</u>	<u>ENGINEERING, DESIGN AND INSPECTION</u>			>> <u>\$798,500</u>
1.1.1	DESIGN ENGINEERING TITLE I & II	529,402	52,940	582,342
1.1.2	QUALITY ASSURANCE	180,132	36,026	216,158
<u>1.2</u>	<u>MANAGEMENT COSTS</u>			>> <u>\$1,051,421</u>
1.2.1	PROJECT MANAGEMENT	445,265	89,053	534,318
1.2.2	CONSTRUCTION MANAGEMENT	430,919	86,184	517,103
<u>1.3</u>	<u>CONSTRUCTION</u>			>> <u>\$5,092,672</u>
1.3.1	GENERAL CONDITIONS	142,013	28,403	170,416
1.3.2	SITEWORK	805,297	161,059	966,356
1.3.3	CONCRETE	363,409	72,682	436,091
1.3.4	MASONRY	0	0	0
1.3.5	METALS	529,062	105,812	634,874
1.3.6	WOOD & PLASTICS	0	0	0
1.3.7	THERMAL & MOISTURE PROTECTION	48,362	9,672	58,034
1.3.8	DOORS & WINDOWS	26,864	5,373	32,237
1.3.9	FINISHES	143,764	28,753	172,517
1.3.10	SPECIALTIES	159,800	31,960	191,760
1.3.11	EQUIPMENT	0	0	0
1.3.12	FURNISHINGS	16,323	3,265	19,588
1.3.13	SPECIAL CONSTRUCTION	510,873	102,175	613,048
1.3.14	CONVEYING SYSTEMS	93,043	18,609	111,652
1.3.15	MECHANICAL	326,319	65,264	391,583
1.3.16	ELECTRICAL	1,078,763	215,753	1,294,516
<u>1.4</u>	<u>GOVERNMENT FURNISHED EQUIP.</u>			>> <u>\$48,096</u>
1.4.1	GOVERNMENT FURNISHED EQUIP.	39,423	8,673	48,096
<u>1.5</u>	<u>G&A/PIF</u>			>> <u>\$628,246</u>
1.5.1	G&A/PIF ADDER	523,538	104,708	628,246
1.5.2	PROCUREMENT FEES	128,499	25,724	>> <u>\$154,223</u>
	SUBTOTAL INCLUDING ESCALATION	6,521,070	1,252,088	>> \$7,773,158
	PROJECT CONTINGENCY			
	MANAGEMENT RESERVE			>> \$592,324
	CONTINGENCY			>> \$1,234,518
	TOTAL ESTIMATED COST			>> \$9,600,000

PROJECT COST PARAMETERS

EDI AS A % OF CONST. + GFE= 16.00%

CONTINGENCY= 23.50%

Lockheed Martin Idaho Technologies Co.
Rev 8-96
PROJECT NAME: **Extreme Ecosystems Test Fac**
NEW BUILDING
INHEEL / Idaho Falls
J. M. Baller

[illegible]

Lockheed Martin Idaho Technologies Co.
 Rev 6-90
 PROJECT NAME: Extreme Ecosystems Test Fac
 New Building
 LOCATION 1: INEEL / Idaho Falls
 REQUESTOR: J. M. Boller

DETAILED COST ESTIMATE SHEET

PAGE # 2

TYPE OF ESTIMATE: Planning
 PROJECT NO.: 8477
 PREPARED BY: S. M. Bradford
 DATE 14-Oct-1998
 TIME: 08:42:54
 REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
1.1.2	QUALITY ASSURANCE Management Support @ 10%	1	lot		Z-7250	368.000	368	16,457				16,457
	QUALITY ASSURANCE S/T						4,028	\$180,132				\$180,132
1.2.1	PROJECT MANAGEMENT											
	Project Management and Support - .75 FTE	45	mnth		Z-6310	100.000	4,500	332,865				332,865
	Miscellaneous Project Support - Allowance	1	lot		Z-6310	228.000	228	16,717				16,717
	Cost Estimating - CID Support	18	mnth		Z-6330	8.000	144	8,844				8,844
	Environmental Compliance Support - .05 FTE	33	mnth		Z-7332	8.000	264	14,792				14,792
	Management Support @ 20%	1	lot		Z-6310	974.000	974	72,047				72,047
	PROJECT MANAGEMENT S/T						6,108	\$445,265				\$445,265
1.2.2	CONSTRUCTION MANAGEMENT											
	CC/OE Activities during Bid/Award, Close Out - .25 FTE	3	mnth		Z-6340	40.000	120	8,876				8,876
	CC/OE Activities during Construction - 1 FTE	18	mnth		Z-6340	160.000	2,880	213,034				213,034
	- Back Shift to Support Outage	1	fte		Z-6340	20.000	20	1,479				1,479
	CC Activities during FPT	9	mnth		Z-6340	40.000	360	26,629				26,629

Lockheed Martin Idaho Technologies Co.

Rev 6-98

PROJECT NAME: Extreme Ecosystems Test Fac

LOCATION 1: INEEL / Idaho Falls

REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477

PREPARED BY: S. M. Bradford

PAGE # 3

DATE 14-Oct-1998

TIME: 08:42:54

REPORT NAME: Detail Cost Estimate Sheet

DETAILED COST ESTIMATE SHEET

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.2.2	CONSTRUCTION MANAGEMENT Constructability Reviews and Special Conditions	1	lot		Z-6340	120.000	120	8,876				8,876
	Safety Engineering	18	mnth		Z-7120	27.000	486	29,981				29,981
	- Back Shift to Support Outage	1	fte		Z-7120	20.000	20	1,234				1,234
	Miscellaneous Third Party Support - Allowance	20	mnth		Z-6340	12.000	240	17,753				17,753
	Site Survey	1	lot		Z-6341	120.000	120	5,864				5,864
	Materials Test Lab	1	lot		Z-6340	280.000	280	20,712				20,712
	Pool Account	1	lot		Z-OTH	4020.00	4,020	98,480				98,480
	CONSTRUCTION MANAGEMENT S/T						8,666	\$430,919				\$430,919
1.3.1	GENERAL CONDITIONS											
	Full Time Non-Working Supervisor	18	mnth		ZT-IW GEN	180.000	2,880	88,733				88,733
	Training	1	lot		ZT-SM GEN	120.000	120	2,351				2,351
	Mob/Demob	1	lot	2,500.00	ZT-IW GEN	80.000	80	2,465		2,500		4,965
	Construction Aids, Barricades, Safety Devices	1	lot	3,000.00	GEN	0.000				3,000		3,000
	Vendor Data, As-Built, Misc. Submittals	1	lot		ZT-IW GEN	340.000	340	10,475				10,475
	Punchlist, Project Closeout	1	lot		ZT-IW GEN	80.000	80	2,465				2,465
	GENERAL CONDITIONS S/T						3,500	\$108,489		\$5,500		\$111,989

Lockheed Martin Idaho Technologies Co.
 Rev 6-98
 PROJECT NAME: Extreme Ecosystems Test Fac
 LOCATION 1: INEEL / Idaho Falls
 REQUESTOR: J. M. Beller

DETAILED COST ESTIMATE SHEET

PAGE # 4

TYPE OF ESTIMATE: Planning
 PROJECT NO.: 8477
 PREPARED BY: S. M. Bradford

DATE 14-Oct-1998
 TIME: 08:42:54
 REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.2	<u>SITework</u>											
	<u>SITE CLEARING</u>											
	- Surveying and Layout	1	lot	500.00	ZT-LB GEN	160.000	180	1,472		500		1,972
	- Clear and Grub	30,000	sf	0.05	GEN	0.000				1,500		1,500
	<u>EARTHWORK</u>											
	- Import Fill / Final Grade	300	cy		GEN	0.000					4,320	4,320
	- Structural Excavation and Backfill	1,620	cy		GEN	0.000					33,615	33,615
	- Rock Excavation				GEN							
	- Sand Levelling Coarse	120	cy	25.00	GEN	0.000				3,000	1,366	4,366
	<u>WATER SYSTEMS</u>											
	- 8" and Fillings	2,640	ft	22.20	PIPE	0.000				58,608		58,608
	- 8" and Fillings	250	ft	17.53	PIPE	0.000				4,383		4,383
	- Hydrant	4	ea	1,892.00	ZT-PF PIPE	5.600	22	604		7,568		8,172
	- PIV	3	ea	1,662.00	ZT-PF PIPE	7.500	23	615		4,986		5,601
	- Cleaning and Sterilization	1	lot	200.00	ZT-PF PIPE	80.000	80	2,167		200		2,367
	- Excavation and Backfill	4,000	cy	16.00	GEN	0.000				64,000		64,000
	- Rock Excavation and Import Fill		cy		GEN							
	<u>NATURAL GAS SYSTEM</u>											
	- Piping	2,640	ft	4.66	ZT-PF PIPE	0.154	407	10,961		12,302		23,263

DETAILED COST ESTIMATE SHEET

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.2	SITework SEWAGE AND DRAINAGE											
	- 6" w/ Fittings	2,640	ft	5.11	GEN	0.000				13,490		13,490
	- Excavation and Backfill	3,168	cy	16.00	GEN	0.000				50,688		50,688
	- Rock Excavation and Import Fill		cy		GEN							
	- 12" w/ Fittings	2,640	ft	10.32	GEN	0.000				27,245		27,245
	- Catch Basins	2	ea	1,550.00	GEN	0.000				3,100		3,100
	- Excavation and Backfill	3,960	cy	16.00	GEN	0.000				63,360		63,360
	- Rock Excavation and Import Fill		cy		GEN							
	- Asphalt Cut and Repair	3,100	sf	12.00	GEN	0.000				37,200		37,200
	- Supervision	4	wks		21-PF GEN	40.000	160	4,314				4,314
	ROADS / PARKING											
	- Clear and Grub - Assume 4"	80,000	sf	0.04	GEN	0.000				3,200		3,200
	- Excavation		cy		GEN							
	- Fill Run	5,000	cy	7.00	GEN	0.000				35,000	10,000	45,000
	- Crushed Gravel	1,700	cy	10.00	GEN	0.000				17,000	11,560	28,560
	- Asphalt	1,800	ton	32.00	GEN	0.000				57,600	13,500	71,100
	- Seal Coat	8,111	sy	1.00	GEN	0.000				8,111		8,111
	- Painting	5,000	ft	0.50	GEN	0.000				2,500		2,500
	- Signage	1	lot	4,000.00	GEN	0.000				4,000		4,000

Rev 6-98
PROJECT NAME: **Extreme Ecosystems Test Fac**
New Building
LOCATION 1: **INEEL / Idaho Falls**
REQUESTOR: **J. M. Beller**

DATE 14-Oct-1998
TIME: 08:42:54
NAME: Detail Cost E

REPORT NAME: Detail Cost Estimate Sheet

[illegible]

Lockheed Martin Idaho Technologies Co.

Rev 6-98

PROJECT NAME: Extreme Ecosystems Test Fac

LOCATION 1: INEEL / Idaho Falls

REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477

PREPARED BY: S. M. Bradford

DETAILED COST ESTIMATE SHEET

PAGE # 7

DATE 14-Oct-1998

TIME: 08:42:54

REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
<u>1.3.4</u>	<u>MASONRY</u>											
	MASONRY S/T						0					
<u>1.3.5</u>	<u>METALS</u>											
	METAL FABRICATIONS											
	- Guard Posts	4	ea	165.00	STEEL	0.000				660		660
	- Crane Rails	150	ft	14.70	ZT-IW	0.200	30	924		2,205		3,129
	- Mezzanine	6,700	sf	45.00	STEEL	0.375	2,513	77,410		301,500		378,910
	- Stairs	3	sets	5,275.00	ZT-IW	40.000	120	3,697		15,825		19,522
	METALS S/T						2,683	\$82,032		\$320,180		\$402,222
<u>1.3.6</u>	<u>WOOD & PLASTICS</u>											
	WOOD & PLASTICS S/T						0					
<u>1.3.7</u>	<u>THERMAL & MOISTURE PROTECTION</u>											
	BUILDING INSULATION											
	- Foundation Wall Insulation	2,160	sf	0.68	ZT-CP GEN	0.012	26	388		1,469		1,857
	- Building Insulation - Batt - Walls	21,700	sf	0.30	ZT-CP GEN	0.007	162	2,274		6,510		8,784
	- Building Insulation - Batt - Roof	17,220	sf	0.84	ZT-CP GEN	0.015	258	3,867		14,465		18,332

DETAILED COST ESTIMATE SHEET

Lockheed Martin Idaho Technologies Co.

Rev 0-00

PROJECT NAME: Extreme Ecosystems Test Fac

LOCATION 1: INEEL / Idaho Falls

REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477

PREPARED BY: S. M. Bradford

DATE 14-Oct-1998

TIME: 08:42:54

REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
1.3.7	THERMAL & MOISTURE PROTECTION - Roof Insulation Support System	17,220	sf	0.45	GEN	0.000				7,749		7,749
							436	\$6,529		\$30,193		\$36,721
1.3.8	THERMAL & MOISTURE PROTECTION S/T											
	DOORS & WINDOWS											
	STANDARD STEEL DOORS AND FRAMES											
	- Steel Doors and Frames - 3 x 7	19	ea	514.00	ZT-CP GEN	5.000	96	1,422		9,766		11,188
	- Steel Doors and Frames - 6 x 7	9	ea	890.00	ZT-CP GEN	8.000	72	1,078		8,010		9,088
	ALUMINUM WINDOWS											
	- Single Hung 4 x 4	2	ea	30.00	ZT-CP GEN	0.294	1	8		60		69
	DOORS & WINDOWS S/T						168	\$2,509		\$17,836		\$20,345
1.3.9	FINISHES											
	GYPSUM BOARD ASSEMBLIES											
	- Non Load-Bearing Steel Framing - 3 5/8"	10,800	sf	0.29	ZT-CP GEN	0.019	205	3,072		3,132		6,204
	- Load-Bearing Steel Framing - 6"	18,600	sf	1.04	ZT-CP GEN	0.024	446	6,683		19,344		26,027
	- Gypsum Board Assemblies - Walls	14,300	sf	0.26	ZT-CP GEN	0.022	315	4,710		3,575		8,285
	- Gypsum Board Assemblies - Fire Walls	18,600	sf	0.49	ZT-CP GEN	0.040	744	11,138		9,114		20,252
	- Gypsum Board Assemblies - Ceilings	560	sf	0.33	ZT-CP GEN	0.021	12	176		185		361

DETAILED COST ESTIMATE SHEET

Lockheed Martin Idaho Technologies Co.

Rev 6-98

PROJECT NAME: Extreme Ecosystems Test Fac

New Building

LOCATION #: INEEL / Idaho Falls

REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477

PREPARED BY: S. M. Bradford

DATE 14-Oct-1998

TIME: 08:42:54

REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.9	FINISHES											
	TILE											
	- Unglazed Porcelain Mosaic Tile	560	sf	3.28	ZT-CP GEN	0.089	50	746		1,837		2,583
	- Glazed Wall Tile	540	sf	3.23	ZT-CP GEN	0.087	38	542		1,744		2,286
	ACOUSTICAL PANEL CEILINGS											
	- Acoustical Panel Ceiling - 2 x 2	3,200	sf	1.38	ZT-CP GEN	0.023	74	1,102		4,416		5,518
	RESILIENT TILE FLOORINGS											
	- Vinyl Floor Tile	2,400	sf	3.00	ZT-CP GEN	0.025	60	898		7,200		8,098
	- Carpet Tile Mats	24	sf	8.27	ZT-CP GEN	0.013		5		198		203
	CARPET											
	- Carpet	36	sy	14.60	ZT-CP GEN	0.140	6	76		526		601
	PAINTING											
	- Ceilings	560	sf	0.07	ZT-PT GEN	0.009	5	100		39		139
	- Walls	32,900	sf	0.07	ZT-PT GEN	0.007	230	4,562		2,303		6,865
	- Piping, Steel, Iron Work	1	lot	5,000.00	ZT-PT GEN	0.000				5,000		5,000
	- Steel Doors and Frames	28	ea	4.93	ZT-PT GEN	0.941	26	522		138		660
	- Sealed Concrete Floors	13,500	sf	0.25	ZT-PT GEN	0.006	81	1,805		3,375		4,980
	- Epoxy Floors	5,000	sf	2.00	ZT-PT GEN	0.020	100	1,981		10,000		11,981
	FINISHES S/T						2,390	\$37,915		\$72,126		\$110,041

DETAILED COST ESTIMATE SHEET

DATE 14-Oct-1998
 TIME: 08:42:54
 REPORT NAME: Detail Cost Estimate Sheet

Lockheed Martin Idaho Technologies Co.

Rev 6-90
 PROJECT NAME: Extreme Ecosystems Test Fac

LOCATION 1: New Building
 REQUESTOR: INEEL / Idaho Falls

PREPARED BY: J. M. Beller
 PROJECT NO.: 8477

TYPE OF ESTIMATE: Planning
 PREPARED BY: S. M. Bradford

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.10	SPECIALTIES											
	TOILET AND BATH COMPARTMENTS, ACCESSORIES											
	- Toilet Compartments and Privacy Screens	1	lot	6,082.00	ZT-CP GEN	44.000	44	669		6,082		6,741
	- Toilet and Bath Accessories	1	lot	3,971.00	ZT-CP GEN	24.000	24	369		3,971		4,330
	LOUVERS AND VENTS											
	- Fixed Metal Wall Louvers	1	lot	3,200.00	ZT-IW STEEL	2.000	2	62		3,200		3,262
	SIGNS											
	- Panel Signs	12	ea	20.00	ZT-CP GEN	0.500	6	90		240		330
	- Dimensional Letters and Numbers	20	ea	113.00	ZT-CP GEN	1.000	20	299		2,260		2,559
	FIRE EXTINGUISHER CABINETS AND ACCESSORIES											
	- Fire Extinguisher Cabinets	2	ea	55.00	ZT-CP GEN	2.000	4	60		110		170
	METAL LOCKERS											
	- Single-Tier Lockers and Benches	1	lot	3,395.00	ZT-CP GEN	22.000	22	329		3,395		3,724
	MISC											
	- Explosion Panels	2	ea	5,000.00	ZT-CP GEN	0.000						
	- Computer Access Flooring	500	sf	24.00	ZT-CP GEN	0.320	160	2,395		10,000		10,000
										12,000		14,395

Rev 6-98
PROJECT NAME: **Extreme Ecosystems Test Fac
New Building**
LOCATION 1: **INEEL / Idaho Falls**
REQUESTOR: **J. M. Beller**

[illegible]

Lockheed Martin Idaho Technologies Co.
 Rev 6-98
 PROJECT NAME: Extreme Ecosystems Test Fac
 LOCATION 1: New Building
 REQUESTOR: INEEL / Idaho Falls
 J. M. Beller

DETAILED COST ESTIMATE SHEET

PAGE # 12

TYPE OF ESTIMATE: Planning
 PROJECT NO.: 8477
 PREPARED BY: S. M. Bradford

DATE 14-Oct-1998
 TIME: 08:42:54
 REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
1.3.13	SPECIAL CONSTRUCTION - Pre-Engineered Metal Building	17,220	sf	15.00	STEEL	0.000				258,300		258,300
	- Erection of Red Iron and Sheet Metal	17,220	sf		ZT-IW STEEL	0.250	4,305	132,637				132,637
	SPECIAL CONSTRUCTION S/T						4,305	\$132,637		\$258,300		\$390,937
1.3.14	CONVEYING SYSTEMS											
	Crane - 10 Ton, 50' span, Floor Op	1	ea	66,120.00	ZT-IW STEEL	168.000	168	5,176		65,120		70,296
	CONVEYING SYSTEMS S/T						168	\$5,176		\$65,120		\$70,296
1.3.15	MECHANICAL											
	FIRE PROTECTION SYSTEM											
	- Wet Pipe Sprinkler System, Main Floor	17,220	sf	2.00	PIPE	0.000				34,440		34,440
	- Wet Pipe Sprinkler System, Above Ceilings	17,220	sf	1.25	PIPE	0.000				21,525		21,525
	- Back Flow Check Valve	1	ea	2,200.00	ZT-PF PIPE	8.000	8	216		2,200		2,416
	PIPING											
	- Potable Water System	2,000	ft	2.50	ZT-PF PIPE	0.144	288	7,764		5,000		12,764
	- Waste and Vent System	1,500	ft	8.00	ZT-PF PIPE	0.309	464	12,496		12,000		24,496

DETAILED COST ESTIMATE SHEET

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.15	MECHANICAL - Misc (Hangers, Valves, Specialties, Identification)	1	lot	15,000.00	ZT-PF PIPE	640.000	640	17,254		15,000		32,254
	- Insulation	1	lot	5,000.00	PIPE	0.000				5,000		5,000
	PLUMBING FIXTURES											
	- Floor Drains	8	ea	62.00	ZT-PF PIPE	4.000	32	863		486		1,359
	- Water Closets	5	ea	700.00	ZT-PF PIPE	12.000	60	1,618		3,500		5,118
	- Urinals	2	ea	600.00	ZT-PF PIPE	8.000	16	431		1,200		1,631
	- Lavatories	4	ea	555.00	ZT-PF PIPE	10.000	40	1,078		2,260		3,338
	- Service Sinks	1	ea	1,175.00	ZT-PF PIPE	16.000	16	431		1,175		1,606
	- Drinking Fountain	1	ea	785.00	ZT-PF PIPE	8.000	8	216		785		1,001
	WATER HEATER											
	- Water Heater - Restrooms	1	ea	260.00	ZT-PF PIPE	6.000	6	162		250		412
	HEATING AND COOLING UNITS											
	- Air Handling Unit - 12 Ton, Roof Mounted	1	lot	7,000.00	ZT-SM HVAC	80.000	80	1,567		7,000		8,567
	- Cabinet Heater - 2 kw	1	ea	170.00	ZT-SM HVAC	3.000	3	59		170		229
	POWER VENTILATORS											
	- Exhaust Fans - Restrooms	2	ea	60.00	ZT-SM HVAC	4.000	8	157		120		277
	- Outside Air Intake	1	ea	2,400.00	ZT-SM HVAC	16.000	16	313		2,400		2,713

DETAILED COST ESTIMATE SHEET

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
<u>1.3.15</u>	<u>MECHANICAL</u> DUCTWORK											
	- Ductwork and Fittings	17,220	sf	0.80	ZT-SM HVAC	0.040	689	13,494		13,776		27,270
	- Duct Accessories, Identification	1	lot	30,000.00	ZT-SM HVAC	300.000	300	5,877		30,000		35,877
	- Controls, Testing, Balancing	1	lot	10,000.00	HVAC	0.000				10,000		10,000
	- Insulation	1	lot	3,000.00	ZT-CP HVAC	120.000	120	1,796		3,000		4,796
	REFRIGERANT PIPING											
	- Piping and Accessories	1	lot	7,200.00	ZT-PF PIPE	176.000	176	4,745		7,200		11,945
	MECHANICAL S/T						2,969	\$70,537		\$178,497		\$249,034
<u>1.3.16</u>	<u>ELECTRICAL</u>											
	UNDERGROUND DUCTS AND UTILITY STRUCTURES											
	Ductbank - Power and Communications											
	- Excavation and Backfill	1,600	cy	12.00	ELEC	0.000				19,200		19,200
	- Red Mud	320	cy	125.00	ELEC	0.000				40,000		40,000
	- Reinforcing	2,500	lb	0.20	ELEC	0.000				500		500
	- Manholes	13	ea	2,845.00	ZT-EL ELEC	12.000	156	4,822		36,985		41,807
	- 4" PVC - 6 ea	10,560	ft	2.82	ZT-EL ELEC	0.070	739	22,849		29,779		52,628
	- 500 KCM	42,240	ft	6.38	ZT-EL ELEC	0.050	2,112	65,282		269,481		334,773
	- Multiduct	2,640	ft	3.00	ZT-EL ELEC	0.100	264	8,160		7,920		16,080

DATE 14-Oct-1998

TIME: 08:42:54

REPORT NAME: Detail Cost Estimate Sheet

DETAILED COST ESTIMATE SHEET

Lockheed Martin Idaho Technologies Co.

Rev 6-98

PROJECT NAME: Extreme Ecosystems Test Fac

LOCATION 1: INEEL / Idaho Falls

REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477

PREPARED BY: S. M. Bradford

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
1.3.16	ELECTRICAL	7	ea	3,638.00	ZT-EL ELEC	12.000	84	2,596		25,452		28,048
	- Handholes	2,640	ft	2.21	ZT-EL ELEC	0.200	528	16,320		5,834		22,155
	- 100 Pair Telephone Wire	2,640	ft	1.73	ZT-EL ELEC	0.020	53	1,632		4,597		6,199
	- 12 Fiber FO Cable											
	TRANSFORMERS											
	- 800 kVA - Provided and Installed by City											
	GROUNDING	1	lot	1,100.00	ZT-EL ELEC	60.000	60	1,855		1,100		2,955
	- Ground Loop											
	PANEL BOARDS and MOTOR CONTROL CENTERS											
	- Main Distribution Panel	1	lot	17,500.00	ZT-EL ELEC	80.000	60	1,855		17,500		19,355
	- Mini Power Zone - 480 V, 30 KVA	1	lot	7,300.00	ZT-EL ELEC	18.000	18	558		7,300		7,858
	LIGHTING AND RECEPTACLES											
	- Lighting - Interior	17,220	sf	2.50	ZT-EL ELEC	0.050	861	26,614		43,050		1,371
	- Lighting - Exterior	2	ea	500.00	ZT-EL ELEC	6.000	12	374		1,000		3,301
	- Lighting - Parking Area	3	ea	915.00	ZT-EL ELEC	6.000	18	558		2,745		23,060
	- Receptacles and Switches	17,220	sf	0.35	ZT-EL ELEC	0.032	551	17,033		6,027		
	LIFE SAFETY SYSTEMS											
	- Fire Alarm System	17,220	sf	1.70	ZT-EL ELEC	0.030	617	15,988		29,274		45,242
	- Telephone Distribution System	17,220	sf	1.60	ZT-EL ELEC	0.050	861	26,614		27,552		54,166

PROJECT NAME: Extreme Ecosystems Test Fac
 LOCATION 1: INEEL / Idaho Falls
 REQUESTOR: J. M. Beller

DETAILED COST ESTIMATE SHEET

TYPE OF ESTIMATE: Planning
 PROJECT NO.: 8477
 PREPARED BY: S. M. Bradford

DATE 14-Oct-1998
 TIME: 08:42:54
 REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
<u>1.3.16</u>	ELECTRICAL - Public Address System	17,220	sf	0.50	ZT-EL ELEC	0.050	861	26,614		8,610		35,224
	ELECTRICAL S/T						7,755	\$239,896		\$583,887		\$823,583
<u>1.4.1</u>	GOVERNMENT FURNISHED EQUIP.											
	Telecommunications / Data Tie-Ins	1	lot	26,000.00	Z-2430	250.000	250	12,123		26,000		38,123
	GOVERNMENT FURNISHED EQUIP. S/T						250	\$12,123		\$26,000		\$38,123
<u>1.5.1</u>	G&A/PIF ADDER											
	G&A on Construction, Procurement Fee	1	lot			0.000					304,376	304,376
	PIF on Construction, Procurement Fee	1	lot			0.000					210,401	210,401
	G&A on GFE (Materials Only), Procurement Fee	1	lot			0.000					7,231	7,231
	PIF on GFE (Materials Only), Procurement Fee	1	lot			0.000					1,530	1,530
	G&A/PIF ADDER S/T						0				\$523,538	\$523,538
	PROJECT SUBTOTAL						51,713	\$2,269,677	\$0	\$2,510,438	\$597,899	\$5,378,014

CONTINGENCY ANALYSIS

PROJECT NAME: Extreme Ecosystems Test Fac
New Building
LOCATION 1: INEEL / Idaho Falls
REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning
PROJECT NO: 8477
PREPARED BY: S. M. Bradford

DATE: 14-Oct-1998
TIME: 08:42:40

REPORT NAME: Contingency Analysis

PROBABLE % VARIATION									PROJECT CONTINGENCY		SUMMARY
WBS Element	Cost Estimate Element	Total Cost w/o Contingency	% Total Cost	Prob. % Var. From Est.		Wt. % of Prob.		Contingency	%	Cost	Total Cost by Element
				-	+	-	+				
1.1.1	DESIGN ENGINEERING TITLE I & II	529,402	6.81	5	20	0.34	1.36	1.192%	5.21%	95,093	624,495
1.1.2	QUALITY ASSURANCE	180,132	2.32	5	20	0.12	0.46	0.406%	1.77%	32,356	212,488
1.2.1	PROJECT MANAGEMENT	445,265	5.73	5	20	0.29	1.15	1.002%	4.38%	79,980	525,245
1.2.2	CONSTRUCTION MANAGEMENT	430,919	5.54	5	20	0.28	1.11	0.970%	4.24%	77,403	508,322
1.3.1	GENERAL CONDITIONS	142,013	1.83	5	30	0.09	0.55	0.484%	2.11%	38,628	180,641
1.3.2	SITEWORK	805,297	10.36	5	30	0.52	3.11	2.745%	11.99%	219,042	1,024,339
1.3.3	CONCRETE	363,409	4.68	5	30	0.23	1.40	1.239%	5.41%	98,848	462,257
1.3.4	MASONRY	0	0.00	5	25	0.00	0.00	0.000%	0.00%	0	0
1.3.5	METALS	529,062	6.81	5	25	0.34	1.70	1.497%	6.54%	119,469	648,531
1.3.6	WOOD & PLASTICS	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.7	THERMAL & MOISTURE PROTECTION	48,362	0.62	5	25	0.03	0.16	0.137%	0.60%	10,921	59,283
1.3.8	DOORS & WINDOWS	26,864	0.35	5	25	0.02	0.09	0.076%	0.33%	6,066	32,930
1.3.9	FINISHES	143,764	1.85	5	25	0.09	0.46	0.407%	1.78%	32,464	176,228
1.3.10	SPECIALTIES	159,800	2.06	5	25	0.10	0.51	0.452%	1.98%	36,085	195,885
1.3.11	EQUIPMENT	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.12	FURNISHINGS	16,323	0.21	5	20	0.01	0.04	0.037%	0.16%	2,932	19,255
1.3.13	SPECIAL CONSTRUCTION	510,873	6.57	5	30	0.33	1.97	1.742%	7.61%	138,958	649,831
1.3.14	CONVEYING SYSTEMS	93,043	1.20	5	30	0.06	0.36	0.317%	1.39%	25,308	118,351
1.3.15	MECHANICAL	326,319	4.20	5	30	0.21	1.26	1.112%	4.86%	88,759	415,078
1.3.16	ELECTRICAL	1,078,763	13.88	5	30	0.69	4.16	3.678%	16.06%	293,425	1,372,188
1.4.1	GOVERNMENT FURNISHED EQUIP.	39,423	0.51	5	20	0.03	0.10	0.089%	0.39%	7,081	46,504
1.5.1	G&A/PIF ADDER	523,538	6.74	5	25	0.34	1.68	1.482%	6.47%	118,221	641,759
1.5.2	PROCUREMENT FEES	128,499	1.65	5	20	0.08	0.33	0.289%	1.26%	23,081	151,580
	ESCALATION	1,252,088	16.11	5	25	0.81	4.03	3.544%	15.48%	282,722	1,534,810
SUBTOTAL		7,773,158	100.00					22.897%			
CALCULATED CONTINGENCY		1,779,834									
RESULTANT TEC		9,552,992									
ROUNDED TEC		9,600,000									
PROJECT CONTINGENCY		1,826,842						23.50%			
MANAGEMENT RESERVE		592,324									
CONTINGENCY		1,234,518									
TOTAL ESTIMATED COST		9,600,000								1,826,842	9,600,000

CONFIDENCE LEVEL AND ASSUMED RISKS:

The Lockheed Martin Idaho Technologies Co. Cost Estimate Contingency Analysis Model is based on the applied contingency and the assumptions upon which the estimate was predicated. The model is applied with a suggested risk level of 18% and a level of confidence of 90% the estimate will fall within the bid range. The Contingency Analysis is based on a weighted average to provide a 90 % probability of underrun and a 10% probability of overrun.

CONTINGENCY ANALYSIS GUIDE BY TYPE OF ESTIMATE

Guidelines established by DOE/FM 50, Cost Estimating Guide, Vol. 6, Cost Guide, and as presented in the INEL Cost Estimating Guide.

PLANNING 20% - 30%
Experimental/Special Conditions.....Up to 50%
Conceptual 15% - 25%
Experimental/Special Conditions.....Up to 40%
TITLE I 10% - 20%
TITLE II 5% - 15%
TITLE II/AFC Market Conditions

FY-99 G&A/PIF ADDER CALCULATION SHEET

PROJECT: Extreme Ecosystems Test Facility - Building

DATE: 10/14/98

PROCUREMENT FEE:

CONSTRUCTION =	\$4,243,894		
FEE @ 3.0% =	\$4,243,894	* 0.03 =	\$127,317
GFE =	\$26,000		
FEE @ 3.0% =	\$26,000	* 0.03 =	\$780

G&A @ 27% (with a ceiling of \$500,000 imposed per year)

CONSTRUCTION \$ OR CEILING * # OF YEARS

YEARS OF CONST. =	\$2	\$1,000,000	
PROCUREMENT FEE =		<u>\$127,317</u>	
FEE @ 27% =	\$1,127,317	* 0.27 =	\$304,376
GFE =	\$26,000		
PROCUREMENT FEE =	<u>\$780</u>		
FEE @ 27% =	\$26,780	* 0.27 =	\$7,231

PIF @ 4.5%

CONSTRUCTION =	\$4,243,894		
PROCUREMENT FEE =	\$127,317		
G&A =	<u>\$304,376</u>		
FEE @ 4.5% =	\$4,675,586	* 0.045 =	\$210,401
GFE =	\$26,000		
PROCUREMENT FEE =	\$780		
G&A =	<u>\$7,231</u>		
FEE @ 4.5% =	\$34,011	* 0.045 =	\$1,530

Lockheed Martin Idaho Technologies Co.

Rev. 6-96

COST ESTIMATE SUMMARY

 PROJECT NAME: **Extreme Ecosystems Test Fac
Equipment**
 LOCATION 1: **INEEL**
 REQUESTOR: **J. M. Beller**

 TYPE OF ESTIMATE: **Planning**
 PROJECT NO: **8477-1**
 PREPARED BY: **S. M. Bradford**
 REPORT NAME: **Cost Estimate Summary**

 DATE: **15-Dec-1998**
 TIME: **08:02:30**
 CHECKED BY:
 APPRD BY:

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
1.1	<u>ENGINEERING, DESIGN AND INSPECTION</u>			>> \$1,072,358
1.1.1	DESIGN ENGINEERING TITLE I & II	781,020	85,912	866,932
1.1.2	QUALITY ASSURANCE	177,091	28,335	205,426
1.2	<u>MANAGEMENT COSTS</u>			>> \$866,055
1.2.1	PROJECT MANAGEMENT	363,159	72,632	435,791
1.2.2	CONSTRUCTION MANAGEMENT	370,917	59,347	430,264
1.3	<u>CONSTRUCTION</u>			>> \$12,386,421
1.3.1	GENERAL CONDITIONS	123,390	19,742	143,132
1.3.2	SITWORK	0	0	0
1.3.3	CONCRETE	81,861	13,098	94,959
1.3.4	MASONRY	0	0	0
1.3.5	METALS	60,638	9,702	70,340
1.3.6	WOOD & PLASTICS	0	0	0
1.3.7	THERMAL & MOISTURE PROTECTION	0	0	0
1.3.8	DOORS & WINDOWS	0	0	0
1.3.9	FINISHES	0	0	0
1.3.10	SPECIALTIES	0	0	0
1.3.11	EQUIPMENT	6,901,524	1,104,244	8,005,768
1.3.12	FURNISHINGS	0	0	0
1.3.13	SPECIAL CONSTRUCTION	516,583	82,653	599,236
1.3.14	CONVEYING SYSTEMS	64,191	10,271	74,462
1.3.15	MECHANICAL	711,970	113,915	825,885
1.3.16	ELECTRICAL	2,217,792	354,847	2,572,639
1.5	<u>G&A/PIF</u>			>> \$1,006,249
1.5.1	G&A/PIF ADDER	867,456	138,793	1,006,249
1.5.2	PROCUREMENT FEES	320,338	51,254	>> \$371,592
SUBTOTAL INCLUDING ESCALATION		13,557,930	2,144,745	>> \$15,702,675
PROJECT CONTINGENCY				
MANAGEMENT RESERVE				>> \$0
CONTINGENCY				>> \$4,297,325
TOTAL ESTIMATED COST				>> \$20,000,000

PROJECT COST PARAMETERS

 EDI AS A % OF CONST. + GFE= **9.00%**

 CONTINGENCY= **27.37%**

COST ESTIMATE SUPPORT DATA RECAPITULATION

Project Title: Extreme Ecosystems Test Facility - Equipment
Estimator: S. M. Bradford
Date: December 15, 1998
Estimate Type: Planning
File: 8477-1
Approved By:

I. **SCOPE OF WORK:** *Brief description of the proposed project.*

Design and construction of an Extreme Ecosystems Test Facility to be located in Idaho Falls. The project is divided into two parts: building and equipment. There is the possibility that the equipment could be located in an existing facility, such as the EESC, and a new building would not have to be constructed to house the equipment/process.

The equipment costs were revised to incorporate the reduced cost of the thermal oxidizer, and the addition of heating/cooling coils on two test vessels, a drilling mud storage tank, and a drilling storage pump.

II. **BASIS OF THE ESTIMATE:** *Drawings, Design Report, Engineers Notes and/or other documentation upon which the estimate is originated.*

Preliminary drawings, sketches, vendor information, and project information from the engineers supporting this effort.

III. **ASSUMPTIONS:** *Conditions statements accepted or supposed true without proof of demonstration. An assumption has a direct impact on total estimated cost.*

1. The new building will be located near the IRC; the utility run will be approximately a half mile to the tie-in.
2. The city will be responsible for the new transformer, this project will have the responsibility of installing the conduit and cable between the new building and the transformer.
3. There are no cost allowances for encountering rock or other underground obstructions during excavation activities.
4. The design and construction of the building will be in accordance with the requirements of Quality Level 3, and the design and installation of the process equipment will be in accordance with the requirements of Quality Levels 2 and 3.

COST ESTIMATE SUPPORT DATA RECAPITULATION

- Continued -

Project Title: Extreme Ecosystems Test Facility - Equipment
File: 8477-1

Page 2

- IV. **CONTINGENCY GUIDELINE IMPLEMENTATION:** *The percentage used for contingency as determined by the contingency allowance guidelines can be altered to reflect the type of construction and conditions that may impact the total estimated cost.*

The overall contingency for this project, 24% for the building and 27% for the equipment, is reflective of the minimal amount of information about the facility and process. As better design information is presented, the contingency level will be lower.

V. **OTHER COMMENTS/CONCERNS SPECIFIC TO THE ESTIMATE**

1. This project will be a FY02 new start; Design will commence in October of 2002, with construction and procurement activities anticipated to start in January 2004.
2. This project has been estimated for LMITCO design and typical subcontracted construction.
3. The two parts of this project, building and equipment, may be combined into one project. The costs associated with administrative areas including Project Management, Quality Assurance, Construction Management, and field supervision will decrease, due to some economies of scale. It is anticipated that design or the costs associated with the construction and the fabrication and installation of equipment will not decrease.

DETAILED COST ESTIMATE SHEET

PAGE # 1

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477-1

PROJECT NO.: 341-1
PREPARED BY: S. M. Bradford

PREPARED BY: **S. M. Bradford**

DATE 15-Dec-1998

TIME: 08:02:41

REPORT NAME: Detail Cost Estimate Sheet

[illegible]

DETAILED COST ESTIMATE SHEET

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477-1

PREPARED BY: S. M. Bradford

DATE 15-Dec-1998

TIME: 08:02:41

REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
<u>1.2.1</u>	<u>PROJECT MANAGEMENT</u>											
	Project Management and Support - .5 FTE	45	mnth		Z-6310	80.000	3,600	266,292				266,292
	Miscellaneous Project Support - Allowance	1	lot		Z-6310	200.000	200	14,794				14,794
	Cost Estimating - CID Support	18	mnth		Z-6330	8.000	144	8,844				8,844
	Environmental Compliance Support - .05 FTE	33	mnth		Z-7332	8.000	264	14,792				14,792
	Management Support @ 20%	1	lot		Z-6310	790.000	790	58,436				58,436
	<u>PROJECT MANAGEMENT S/T</u>						4,998	\$363,159				\$363,159
<u>1.2.2</u>	<u>CONSTRUCTION MANAGEMENT</u>											
	CC/CE Activities during bld/Award, Closeout - .25 FTE	3	mnth		Z-6340	40.000	120	8,876				8,876
	CC/CE Activities during Construction - 1 FTE	18	mnth		Z-6340	160.000	2,880	213,034				213,034
	CC Activities during FPT	9	mnth		Z-6340	40.000	360	26,629				26,629
	Constructability Reviews and Special Conditions	1	lot		Z-6340	120.000	120	8,876				8,876
	Safety Engineering	18	mnth		Z-7120	27.000	486	29,981				29,981
	Pool Account	1	lot		Z-OTH	3480.00	3,480	83,520				83,520
	<u>CONSTRUCTION MANAGEMENT S/T</u>						7,446	\$370,917				\$370,917

Lockheed Martin Idaho Technologies Co.

Rev 6-96

PROJECT NAME: Extreme Ecosystems Test Fac
Equipment

LOCATION 1: INEEL

REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477-1

PREPARED BY: S. M. Bradford

DETAILED COST ESTIMATE SHEET

PAGE # 3

DATE 15-Dec-1998

TIME: 08:02:41

REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
<u>1.3.1</u>	<u>GENERAL CONDITIONS</u>											
	Full Time Non-Working Supervisor	18	mnth		ZT-IW GEN	160.000	2,880	88,733				88,733
	Training	1	lot		ZT-SM GEN	120.000	120	2,351				2,351
	Mob/Demob	1	lot	1,500.00	ZT-IW GEN	40.000	40	1,232		1,500		2,732
	Vendor Data, As-Builts, Misc. Submittals	1	lot		ZT-IW GEN	340.000	340	10,475				10,475
	Punchlist, Project Closeout	1	lot		ZT-IW GEN	80.000	80	2,465				2,465
	<u>GENERAL CONDITIONS S/T</u>						3,460	\$105,256		\$1,500		\$106,756
<u>1.3.2</u>	<u>SITEWORK</u>											
	<u>SITEWORK S/T</u>						0					
<u>1.3.3</u>	<u>CONCRETE</u>											
	Equipment Pads	150	cy	450.00	GEN	0.000				67,500		67,500
	<u>CONCRETE S/T</u>						0			\$67,500		\$67,500
<u>1.3.4</u>	<u>MASONRY</u>											
	<u>MASONRY S/T</u>						0					

DETAILED COST ESTIMATE SHEET

[illegible]

DETAILED COST ESTIMATE SHEET

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
1.3.11 P-101	<u>EQUIPMENT</u> Recycle Water Pump - 50 gpm, 4600 ft head, sst, 75 hp	1	ea	20,000.00	ZT-PF PIPE	80.000	80	2,157		20,000		22,157
P-105	Brine Pump - 8 gpm, 230 ft head, sst, 1 hp	1	ea	20,000.00	ZT-PF PIPE	30.000	30	809		20,000		20,809
T-101	DI Water Tank - 2600 gal, plastic	1	ea	4,000.00	ZT-PF PIPE	12.000	12	324		4,000		4,324
P-103	DI Water Pump - 8 gpm, 4800 ft head, sst, 15 hp	1	ea	20,000.00	ZT-PF PIPE	50.000	50	1,348		20,000		21,348
E-104A,B	Water Chiller - 160,000 BTU/hr, 260 sf	2	ea	15,200.00	ZT-PF PIPE	40.000	80	2,157		30,400		32,557
E-108	Ice Maker - 220,000 BTU/hr	1	ea	152,000.00	ZT-PF PIPE	24.000	24	647		152,000		152,647
B-103	Ice Storage Bin - sst	1	ea	7,000.00	ZT-PF PIPE	12.000	12	324		7,000		7,324
E-109	Ice Storage Bin Cooling Coil	1	ea	8,265.00	ZT-PF PIPE	12.000	12	324		8,265		8,589
CR-101	Ice Crusher/Shaver - 5800 lb/hr	1	ea	5,000.00	ZT-PF PIPE	24.000	24	647		5,000		5,647
MX-101	Solids Mixer - 150 cft/hr	1	ea	32,600.00	ZT-PF PIPE	40.000	40	1,078		32,600		33,678
F-101A,B	Solids Filter	2	ea	4,700.00	ZT-PF PIPE	2.000	4	108		9,400		9,508
E-102A,B	Gas Cooler - 1000 BTU/hr, 2 sf	2	ea	1,500.00	ZT-PF PIPE	8.000	16	431		3,000		3,431
V-102	Liquid Knock Out Drum - 800 gal, sst	1	ea	8,000.00	ZT-PF PIPE	20.000	20	539		8,000		8,539
C-101	Methane Recycle Compressor - 10 ACFM	1	ea	50,000.00	ZT-PF PIPE	20.000	20	539		50,000		50,539
P-108A,B	CO2 Recycle Pump - 50 gpm, 250 ft head, 3 hp	2	ea	26,240.00	ZT-PF PIPE	36.000	72	1,941		52,480		54,421
E-103A,B	Gas Chiller - 325,000 BTU/hr, 120 sf	2	ea	17,900.00	ZT-PF PIPE	110.000	220	5,931		35,800		41,731
BL-102	DH Test Vessel Air Blower - 1200 cfm	1	ea	4,700.00	ZT-SM PIPE	20.000	20	392		4,700		5,092
E-106A,B	Methane Vaporizer - 800,000 BTU/hr, 140 cf	2	ea	86,000.00	ZT-PF PIPE	80.000	160	4,314		172,000		176,314

Lockheed Martin Idaho Technologies Co.

Rev 6-96

PROJECT NAME: Extreme Ecosystems Test Fac

EQUIPMENT

LOCATION 1: INEEL

REQUESTOR: J. M. Beller

DETAILED COST ESTIMATE SHEET

PAGE # 7

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477-1

PREPARED BY: S. M. Bradford

DATE 15-Dec-1998

TIME: 08:02:41

REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
1.3.11 T-103	<u>EQUIPMENT</u> Methane Tank - 1000 gal	1	ea	3,500.00	ZT-PF PIPE	12.000	12	324		3,500		3,824
T-104	Natural Gas Tank - 1000 gal	1	ea	3,500.00	ZT-PF PIPE	12.000	12	324		3,500		3,824
T-105	CO2 Tank - 3400 gal	1	ea	43,000.00	ZT-PF PIPE	20.000	20	539		43,000		43,539
P-102	CO2 Pump - 10 gpm, 3200 ft head, 10 hp	1	ea	44,719.00	ZT-PF PIPE	36.000	36	971		44,719		45,690
P-106	Methane Pump - 15 gpm, 11,000 ft head, 30 hp	1	ea	26,684.00	ZT-PF PIPE	50.000	50	1,348		26,684		28,032
E-101	CO2 Cooler - 24,000 BTU/hr, 24 sf	1	ea	3,475.00	ZT-PF PIPE	12.000	12	324		3,475		3,799
EH-102	DH Test Vessel Air Heater - 16 kw	1	ea	800.00	ZT-SM PIPE	1.600	2	31		800		831
E-105	DHTV Heating/Cooling Coil	1	ea	12,225.00	ZT-PF PIPE	12.000	12	324		12,225		12,549
	DWG 507620											
BL-201	Sediment Drying Air Blower - 100 cfm	1	ea	120.00	ZT-SM PIPE	16.000	16	313		120		433
EH-201	Sediment Drying Air Heater - 1.5 KW	1	ea	500.00	ZT-SM PIPE	1.200	1	24		500		524
B-201	Sediment Bin #3 - 12 cf, cs	1	ea	1,150.00	ZT-PF PIPE	6.000	6	162		1,150		1,312
MX-201	Sediment Bin #3 Mixer	1	ea	11,100.00	ZT-PF PIPE	32.000	32	863		11,100		11,963
E-210	Sediment Bin #3 Cooling Coil - 12,000 BTU/hr, 3 cf	1	ea	8,265.00	ZT-PF PIPE	12.000	12	324		8,265		8,589
B-202	Sediment Bin #4 - 12 cf, cs	1	ea	1,150.00	ZT-PF PIPE	6.000	6	162		1,150		1,312
MX-202	Sediment Bin #4 Mixer	1	ea	11,100.00	ZT-PF PIPE	32.000	32	863		11,100		11,963
E-211	Sediment Bin #4 Cooling Coil - 12,000 BTU/hr, 3 cf	1	ea	8,265.00	ZT-PF PIPE	12.000	12	324		8,265		8,589
V-207	Sediment Water Accumulator - 30 gal, sst	1	ea	680.00	ZT-PF PIPE	2.000	2	54		680		734

PROJECT NAME: Extreme Ecosystems Test Fac
Equipment
LOCATION 1: INEEL
REQUESTOR: J. M. Beller

DETAILED COST ESTIMATE SHEET

TYPE OF ESTIMATE: Planning
PROJECT NO.: 8477-1
PREPARED BY: S. M. Bradford
DATE 15-Dec-1998
TIME: 08:02:41
REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11 V-201	EQUIPMENT Vertical Multi-Phase Test Vessel	1	lot	500,000.00	ZT-PF PIPE	24.000	24	647		500,000		500,647
T-202	Brine/Recycle Water Tank - 100 gal, plastic	1	ea	450.00	ZT-PF PIPE	2.000	2	54		450		504
P-201	Recycle Water Pump - 5 gpm, 4800 ft head, sst, 7.5 hp	1	ea	20,000.00	ZT-PF PIPE	36.000	36	971		20,000		20,971
P-205	Brine Pump - 1 gpm, 230 ft head, sst, .1 hp	1	ea	20,000.00	ZT-PF PIPE	30.000	30	809		20,000		20,809
T-201	DI Water Tank - 100 gal, plastic	1	ea	450.00	ZT-PF PIPE	2.000	2	54		450		504
P-203	DI Water Pump - 1 gpm, 4800 ft head, sst, 1 hp	1	ea	20,000.00	ZT-PF PIPE	30.000	30	809		20,000		20,809
E-204A,B	Water Chiller - 160,000 BTU/hr, 260 sf	2	ea	15,200.00	ZT-PF PIPE	40.000	80	2,157		30,400		32,557
E-208	Ice Maker - 32,000 BTU/hr	1	ea	50,000.00	ZT-PF PIPE	16.000	16	431		50,000		50,431
B-203	Ice Storage Bin - sst	1	ea	1,350.00	ZT-PF PIPE	5.000	5	135		1,350		1,485
E-209	Ice Storage Bin Cooling Coil	1	ea	8,265.00	ZT-PF PIPE	12.000	12	324		8,265		8,589
CR-201	Ice Crusher/Shaver - 1000 lb/hr	1	ea	3,000.00	ZT-PF PIPE	16.000	16	431		3,000		3,431
MX-203	Solids Mixer - 15 cft/hr	1	ea	11,100.00	ZT-PF PIPE	32.000	32	863		11,100		11,963
BL-202	VMPTV Air Blower - 100 cfm	1	ea	120.00	ZT-SM PIPE	16.000	16	313		120		433
F-201A,B	Solids Filter	2	ea	3,300.00	ZT-PF PIPE	1.200	2	65		6,600		6,665
E-202A,B	Gas Cooler - 1000 BTU/hr, 2 sf	2	ea	1,500.00	ZT-PF PIPE	8.000	16	431		3,000		3,431
V-202	Liquid Knock Out Drum - 90 gal, sst	1	ea	1,220.00	ZT-PF PIPE	5.000	5	135		1,220		1,355
P-208A,B	CO2 Recycle Pump - 50 gpm, 250 ft head, 3 hp	2	ea	75,000.00	ZT-PF PIPE	36.000	72	1,941		150,000		151,941
C-201	Methane Recycle Compressor - 10 acfm	1	ea	50,000.00	ZT-PF PIPE	18.000	18	485		50,000		50,485

DETAILED COST ESTIMATE SHEET

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
<u>1.3.11</u>	<u>EQUIPMENT</u>											
	Sample Storage Vessels	100	ea	3,800.00	ZT-PF PIPE	40.000	4,000	107,840		380,000		487,840
	N2 Gas Bottles	10	ea	50.00		0.000				500		500
	<u>EQUIPMENT S/T</u>						7,273	\$345,516		\$4,650,513		\$4,996,029
<u>1.3.12</u>	<u>FURNISHINGS</u>											
							0					
	<u>FURNISHINGS S/T</u>											
<u>1.3.13</u>	<u>SPECIAL CONSTRUCTION</u>											
	Refrigerated Room	1,500	sf	102.00	ZT-SM HVAC	0.146	219	4,290		153,000		157,290
	- Doors	1	set	6,175.00	ZT-SM HVAC	20.000	20	392		6,175		6,567
	- Refrigeration Unit	1	lot	61,000.00	HVAC	0.000		15,000		61,000		76,000
	Vault Compartments	100	ea	1,500.00	HVAC	0.000				150,000		150,000
	<u>SPECIAL CONSTRUCTION S/T</u>						239	\$19,682		\$370,175		\$389,857
<u>1.3.14</u>	<u>CONVEYING SYSTEMS</u>											
	Refrigeration Room Crane - 2.5 Ton, 30' Span, Floor Op	1	ea	45,980.00	ZT-IW STEEL	80.000	80	2,465		45,980		48,445
	<u>CONVEYING SYSTEMS S/T</u>						80	\$2,465		\$45,980		\$48,445

DETAILED COST ESTIMATE SHEET

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
<u>1.3.15</u>	<u>MECHANICAL</u>											
	HEATING AND COOLING UNITS											
	- Air Handling Unit w/ Heat Recovery and Evap Coolers - 50,000 cfm	1	lot	214,000.00	ZT-SM HVAC	200.000	200	3,918		214,000		217,918
	PIPING											
	- Process Piping and Fittings - assume sst, 2"	2,000	ft	100.00	ZT-PF PIPE	0.250	500	13,480		200,000		213,480
	- Process Valves	30	ea	2,000.00	ZT-PF PIPE	8.000	240	6,470		60,000		66,470
	DI Water Treatment System	1	lot	25,000.00	ZT-PF PIPE	40.000	40	1,078		25,000		26,078
	<u>MECHANICAL SIT</u>						980	\$24,947		\$499,000		\$523,947
<u>1.3.16</u>	<u>ELECTRICAL</u>											
	EQUIPMENT											
	- MCC	1	lot	60,000.00	ZT-EL ELEC	200.000	200	6,182		60,000		66,182
	- Standby Power Panel	1	lot	7,500.00	ZT-EL ELEC	24.000	24	742		7,500		8,242
	- Standby Generator	1	lot	40,000.00	ZT-EL ELEC	80.000	80	2,473		40,000		42,473
	- - Factory Representative	1	lot		ELEC	0.000					2,500	2,500
	- Automatic Transfer Switch	1	ea	14,168.00	ZT-EL ELEC	24.000	24	742		14,168		14,910
	- Manual Transfer Switch	1	ea	586.00	ZT-EL ELEC	6.000	6	185		586		771
	- UPS - 223 kVA	1	lot	225,000.00	ELEC	0.000				225,000		225,000

PROJECT NAME: Extreme Ecosystems Test Fac
Equipment

LOCATION 1: INEEL

REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning

PROJECT NO.: 8477-1

PREPARED BY: S. M. Bradford

DETAILED COST ESTIMATE SHEET

PAGE # 12

DATE 15-Dec-1998

TIME: 08:02:41

REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MAT'L UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	SIC (OTHER 1)	TOTAL COST
1.3.16	ELECTRICAL - Mini-Power Zone - 480V, 15 KVA	1	ea	4,800.00	ZT-EL ELEC	15.000	15	464		4,800		5,264
	Equipment Feeders	1	lot	5,500.00	ZT-EL ELEC	380.000	380	11,746		5,500		17,246
	INSTRUMENTATION											
	- Instruments and Feeds	1	lot	750,000.00	ZT-EL ELEC	2000.00	2,000	61,820		750,000		811,820
	- Down Hole Test Vessel Instrument Pack	1	lot	250,000.00	ELEC	0.000				250,000		250,000
	- Data Acquisition System	1	lot	200,000.00	ZT-EL ELEC	1000.00	1,000	30,910		200,000		230,910
	ELECTRICAL S/T						3,729	\$115,263		\$1,557,554	\$2,500	\$1,675,317
1.5.1	G&A/PIF ADDER											
	G&A on Construction, Procurement Fee	1	lot			0.000					356,491	356,491
	PIF on Construction, Procurement Fee	1	lot			0.000					510,965	510,965
	G&A/PIF ADDER S/T						0				\$867,456	\$867,456
	PROJECT SUBTOTAL						42,505	\$2,263,316	\$0	\$7,282,222	\$869,956	\$10,415,494

CONTINGENCY ANALYSIS

PROJECT NAME: Extreme Ecosystems Test Fac
Equipment
LOCATION 1: INEEL
REQUESTOR: J. M. Beller

TYPE OF ESTIMATE: Planning
PROJECT NO: 8477-1
PREPARED BY: S. M. Bradford

DATE: 15-Dec-1998
TIME: 08:02:58

REPORT NAME: Contingency Analysis

PROBABLE % VARIATION									PROJECT CONTINGENCY		SUMMARY
WBS Element	Cost Estimate Element	Total Cost w/o Contingency	% Total Cost	Prob. % Var. From Est.		Wt. % of Prob.		Contingency	%	Cost	Total Cost by Element
				-	+	-	+				
1.1.1	DESIGN ENGINEERING TITLE I & II	781,020	4.97	5	20	0.25	0.99	0.870%	3.21%	138,152	919,172
1.1.2	QUALITY ASSURANCE	177,091	1.13	5	20	0.06	0.23	0.197%	0.73%	31,325	208,416
1.2.1	PROJECT MANAGEMENT	363,159	2.31	5	20	0.12	0.46	0.405%	1.49%	64,238	427,397
1.2.2	CONSTRUCTION MANAGEMENT	370,917	2.36	5	20	0.12	0.47	0.413%	1.53%	65,610	436,527
1.3.1	GENERAL CONDITIONS	123,390	0.79	5	25	0.04	0.20	0.173%	0.64%	27,438	150,828
1.3.2	SITWORK	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.3	CONCRETE	81,861	0.52	5	25	0.03	0.13	0.115%	0.42%	18,204	100,065
1.3.4	MASONRY	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.5	METALS	60,638	0.39	5	25	0.02	0.10	0.085%	0.31%	13,484	74,122
1.3.6	WOOD & PLASTICS	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.7	THERMAL & MOISTURE PROTECTION	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.8	DOORS & WINDOWS	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.9	FINISHES	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.10	SPECIALTIES	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.11	EQUIPMENT	6,901,524	43.95	5	35	2.20	15.38	13.625%	50.32%	2,162,533	9,064,057
1.3.12	FURNISHINGS	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
1.3.13	SPECIAL CONSTRUCTION	516,583	3.29	5	30	0.16	0.99	0.872%	3.22%	138,370	654,953
1.3.14	CONVEYING SYSTEMS	64,191	0.41	5	20	0.02	0.08	0.072%	0.26%	11,355	75,546
1.3.15	MECHANICAL	711,970	4.53	5	30	0.23	1.36	1.202%	4.44%	190,706	902,676
1.3.16	ELECTRICAL	2,217,792	14.12	5	35	0.71	4.94	4.378%	16.17%	694,926	2,912,718
1.5.1	G&A/PIF ADDER	867,456	5.52	5	25	0.28	1.38	1.215%	4.49%	192,897	1,060,353
1.5.2	PROCUREMENT FEES	320,338	2.04	5	25	0.10	0.51	0.449%	1.66%	71,234	391,572
	ESCALATION	2,144,745	13.66	5	25	0.68	3.41	3.005%	11.10%	476,853	2,621,598
	SUBTOTAL	15,702,675	100.00					27.075%			
	CALCULATED CONTINGENCY	4,251,575									
	RESULTANT TEC	19,954,250									
	ROUNDED TEC	20,000,000									
	PROJECT CONTINGENCY	4,297,325						27.37%			
	MANAGEMENT RESERVE	0									
	CONTINGENCY	4,297,325									
	TOTAL ESTIMATED COST	20,000,000								4,297,325	20,000,000

CONFIDENCE LEVEL AND ASSUMED RISKS:

The Lockheed Martin Idaho Technologies Co. Cost Estimate Contingency Analysis Model is based on the applied contingency and the assumptions upon which the estimate was predicated. The model is applied with a suggested risk level of 18% and a level of confidence of 90% the estimate will fall within the bid range. The Contingency Analysis is based on a weighted average to provide a 90 % probability of underrun and a 10% probability of overrun.

CONTINGENCY ANALYSIS GUIDE BY TYPE OF ESTIMATE

Guidelines established by DOE/FM 50, Cost Estimating Guide, Vol. 6, Cost Guide, and as presented in the INEL Cost Estimating Guide.

PLANNING 20% - 30%
Experimental/Special Conditions.....Up to 50%
Conceptual 15% - 25%
Experimental/Special Conditions.....Up to 40%
TITLE I 10% - 20%
TITLE II 5% - 15%
TITLE III/AFC Market Conditions

FY-99 G&A/PIF ADDER CALCULATION SHEET

PROJECT: Extreme Ecosystems Test Facility - Equipment

DATE: 12/15/98

PROCUREMENT FEE:

CONSTRUCTION =	\$10,677,947	
GFE =	\$0	
Subtotal	\$10,677,947	
FEE @ 3.0% =	\$10,677,947 * 0.03 =	\$320,338

G&A @ 27% (with a ceiling of \$500,000 imposed per year)

CONSTRUCTION \$ OR CEILING * # OF YEARS

YEARS OF CONST. = 2	\$1,000,000	
GFE =	\$0	
PROCUREMENT FEE =	\$320,338	
Subtotal	\$1,320,338	
FEE @ 27% =	\$1,320,338 * 0.27 =	\$356,491

PIF @ 4.5%

CONSTRUCTION =	\$10,677,947	
GFE =	\$0	
PROCUREMENT FEE =	\$320,338	
G&A =	\$356,491	
Subtotal	\$11,354,777	
FEE @ 4.5% =	\$11,354,777 * 0.045 =	\$510,965

TOTAL PROCUREMENT FEE: \$320,338

TOTAL G&A FEE: \$356,491

TOTAL PIF: \$510,965