5. Review of cost estimate

Section 5 contains a review of SAI's cost estimate that was provided as an informal supplement to the design report. It was reviewed for reliability of the equipment cost breakdown, the areas of cost uncertainty, and the areas for potential cost savings.

Section No. 1 - Utilities and Chemicals

This section cannot be evaluated without a layout of the facility and knowledge of the utility source locations and conditions. Several items are listed, such as R/O water pump, N_2 and CO_2 compressors, which are not on the flow sheet.

Section No. 2 - Heat Exchangers

The estimate lists two heat exchangers each (both a high and low pressure unit) for H-101, H-501, and H-602 but only one is shown on the flow sheet.

Section No. 3 - Pumps

There are two P-702 Dowtherm pumps in the estimate, but only one is shown on the flowsheet.

Section No. 4 - Compressors

This section should be deleted since neither of the two compressors are shown on the flow sheet.

Section No. 5 - Instruments and Control Valves

In general, unit pricing looks reasonable, but the total list should not be used since a major revision is being made on the instrument flow sheets.

Section No. 6 - Process Vessels

Vessels V-101, 102, and 103 are costed in the estimate but do not show on the flow sheet. Two each of vessels V-202, 503, 504, 505, 606, and 707 are in the estimate, but only one each is shown on the flow sheet. The estimate of $1700 equipment cost on the coal hopper/feeder, V-202, does not agree with the quote of $12,000 from PEMCO in the final report document.

Section No. 7 - Burners and Fired Heaters

Two each of heaters B-102 and B-704 are costed, but only one is shown on the flow sheet.

Section No. 9 - Miscellaneous

Two each of items X-101, M-301, M-401, F-502, X-604, and F-603 are listed in the estimate, but only one is shown on the flow sheet. A reverse osmosis permeator unit, X-104, is in the estimate but is not shown on the flow sheet. Since the heater/reactor is still not well established, no additional investigation into their costs was made. It seems strange that such major items of costs are listed under miscellaneous.

Sections X2 and X3 - Valves, Fitting, Tubing, and Miscellaneous Building Support

No comments could be made on these sections since a major revision is under way on the flow sheet, and no information on the building is available to MRC.

Contingency

A contingency of 15% on the overall project seems very low with such key uncertainties as the gas heater design, the reactor design, and other incomplete designs. In addition, no allowance was made to coordinate costs to a construction schedule and include an escalation factor to account for inflation.

6. MRC safety analysis

The purpose of this safety assessment is to provide a third party review to assist in maximizing the safety and property protection features. This analysis identifies the highly probable and highly serious potential safety hazards and includes appropriate recommendations.

This safety review is concerned with the process concept and generic safety features of the conceptual facility design. Specific design features are considered when identified in the Operation and Safety Manual, indicated on process flow sheets, or verbally communicated to MRC personnel; however, a comprehensive safety analysis of the design was not possible because of a lack of a definitive design. We have attempted to identify potential hazards in the process, facility, monitoring systems, and procedures from information available and to suggest corrective or mitigating changes.

The general method of analysis used was based upon the ERDA developed "Occupancy-Use Readiness Manual - Safety Considerations" ERDA-76-45-1. This method provides an overall review of the safety concerns of the project but does not provide a systems analysis on the component and component interaction level as does fault-tree analysis. This technique involves the DOE's management oversight and risk tree (MORT) concepts.

The major areas considered in the analysis were: the structures, services, process and hardware design, management control systems, monitoring systems, and personnel readiness. Each of these areas is discussed in greater detail and suggestions to improve or ensure safety and property protection in each area are offered.

6.1. Building and Grounds

It is important to be assured that no one is in the cell, or endangered by the relief mechanisms, while the process equipment is energized. This involves:

- Assurance by the operator that the cell is unoccupied prior to system activation.
- Methods of preventing entry into the cell - possibly system interlocks.
- Methods of locking and assuring that the perimeter fence around the test cells is secured. The fenced area should allow for safe "blow-out" of the cell without endangering personnel.

If the blow-out design of the roof is considered, the effect of snow loading on the degree of blow-out protection needs to be evaluated. A preferred cell relief mechanism may be to blow the rear walls into bunkers. The blown-out panels should be designed not to shear any utilities.

Employe evacuation routes into the proposed fenced enclosure or near any endangering utilities (high pressure lines, etc.) must be avoided. Thus, to meet Life Safety Codes, two or more exits in the direction opposite the cell are recommended.

The layout of the total system (control room, cells, gas supplies, etc.) should consider all energy sources with the potential for causing accidents. Ground space permitting, all such energy sources should be separated so that they will not impinge on each other. This will probably exclude all gas storage, etc. from the proposed fenced area. Also, supply lines should not be endangered by the cell relief mechanism, see Figure 6-1.

It is recommended that the Control Room and test cells be physically isolated from each other as far as practical. This is recommended because:

- Design analysis of the cells cannot anticipate consequences of all possible system failures.
- Noise created by an explosion may be harmful to control room occupants and it will be difficult to analyze these effects as part of the cell safety analysis.
- Minimize cross-ventilation problems.

6.2. Ventilation

To enable the monitoring system to be used to detect leaks, the cell ventilation should be set at the minimum level required to prevent heat buildup. To

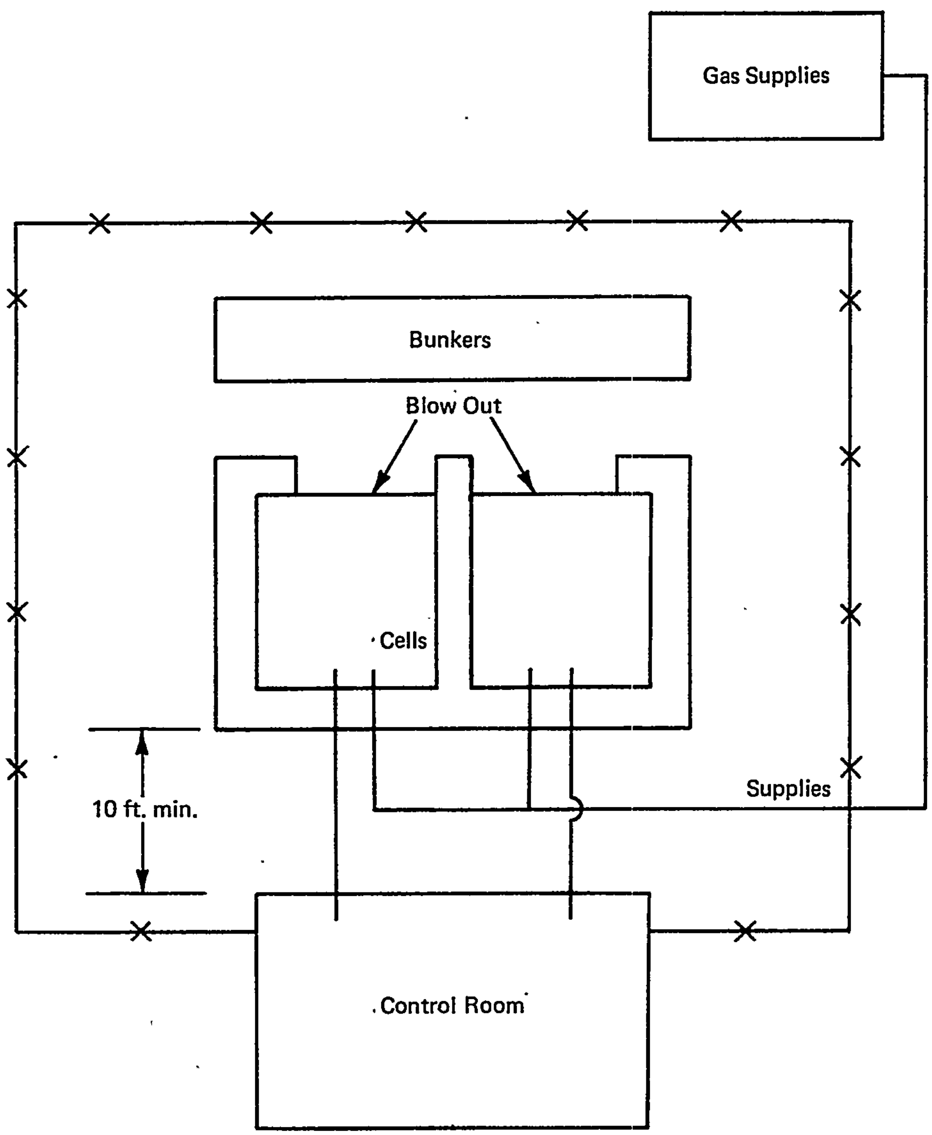

FIGURE 6-1 - Suggested facility and exclusion layout.

further reduce required ventilation, all heat generating equipment that is not an explosion hazard can be placed outside the cell. This will also reduce exposure of maintenance personnel to hazards presented by the process equipment in the cell.

Sensing monitors should be strategically located (including monitoring the exhaust ventilation duct). If toxic gases are monitored, a "leak" alarm can be activated. If gas concentrations begin approaching "Lower Explosive Limits (LEL), the cell ventilation should automatically switch to high-speed. High-speed ventilation should occur at no less than 50% LEL.

Manual switching to high-speed ventilation should be available to sweep the cell of toxic gases prior to personnel entry into the cell.

A similar two-speed ventilation system may be considered for the Control Room. Pipe lines entering the Control Room carrying flammable and toxic gases should be minimized. If some dangerous gases are required for analytical purposes, monitors should be near these pipes and in the exhaust ducts. The manned Control Room should be ventilated when levels of toxic gases reach the "action level."

6.3. Services

Emergency power should be supplied to all system components and sub-systems necessary to control or shut down the process and ensure personnel safety when commercial power is lost. Such components or sub-systems should include:

- Instrumentation - both process indicators as well as gas detectors for personnel safety.

- Lighting for the control room.

- Ventilation for the cells (if this method is to be used as a protective feature).

- Air compressor and control system for the air operated valves.

6.4. Fire Protection

In addition to standard sprinkler systems in the Control Room, special dedicated automatic fire suppression may be considered for remote and expensive systems. Dedicated "dry" or antifreeze sprinkler systems for the Dowtherm System (which is external to the cell) and other isolated process support systems may be advisable. The need of these sprinklers should be determined by a cost/benefit trade-off.

A dedicated automatic Halon system for the electronic console is recommended, based on the cost of the electronic equipment (several hundred thousand dollars, plus time lost to replace). If dedicated Halon protection for the electronics is not feasible, smoke detectors should be considered in the equipment areas. Smoke detectors will allow fire control action prior to sprinkler ignition. Water may damage the electronics. If the electronics are water sprinklered and become wet during an incident, the electronic instruments should be dried as quickly as possible to minimize losses or damage caused by water.

It is suggested that the Morgantown representative of Fenwall Explosion Suppression

Systems be contacted to evaluate the practicality of protecting the cells from explosions. The equipment contents of the cells are valuable enough to warrant a cost/benefit, feasibility analysis of this type of protection. The Fenwall explosion suppression system would serve to reduce loss of or damage to equipment, rather than serve as a personnel protection device because the cell should be unoccupied at any time the process system is in operation.

All the automatic fire suppression systems recommended above should automatically notify the Fire Department or some 24 hr/day manned, emergency response office. Hand extinguishers of the proper type (i.e. Halon in the electronics areas) are recommended.

6.5. Communications

Intercom systems are suggested for use in the cell area to enable continuous and reliable communications with the Control Room.

Emergency procedures should be revised to provide for immediate notification of the Fire Department and/or Safety Department upon occurrence of a fire, before control actions are initiated by operators. Delays in notifying fire departments too often result in catastrophic losses.

6.6. Gas Supply

Appropriate relief devices throughout the gas supply systems are always the first line of defense against overpressurization. Venting of relieved toxic and flammable gases requires attention to ensure no additional hazards are created. An overview of the design indicates relief devices were considered.

Further design evaluation, however, raises the possibility that flash-back arrestors need to be considered. Wherever burning gases may reach large energy sources, flash-back arrestors should be considered. Also, in long pipe runs that contain flammables, the possibility of detonations resulting from sonic deflagrations should be evaluated. Detonations are prevented by avoiding long straight pipe runs where deflagrations can accelerate to sonic levels. Consultations with Dr. Grelecki of Hazards Research Corp. (Ph. 201/627-4560) concerning system explosion characteristics are strongly recommended.

All piping containing high pressure gases should be heavily anchored (at frequent intervals) to prevent pipe - whip upon failure. This is particularly true of small diameter thin walled pipes. High flow check valves (inertial shut-off valves) should be considered at cell wall penetrations in lines carrying combustible gases. This would prevent flooding the cell if a major leak or rupture occurs.

6.7. Process/Hardware Design

Gages containing process fluids that are flammable or toxic should not be located in manned areas (Control Room, etc.). Transducers and digital/remote read-outs are recommended. Backup gages in the remote cells are recommended as a means of observing pressure trapping points in the systems, when cell entry is required.

The capability to remotely vent the char and liquid pots, before the cell is entered to remove them, is recommended in order to prevent personnel from sustaining injury while opening the pressurized containers.

A method of unmanned leak testing of the cell system is recommended. Elevating helium pressures in the system, with no cell ventilation, and observing strategically placed monitors, or monitoring pressure losses from the system may be acceptable techniques.

If carbon steel relief valves are used, they should be located away from the hot equipment. Also, it would be safer to have some system to alert personnel when relief valves are activated. Pressure sensing and venting devices should be incorporated at all points where pressures may be isolated.

All system components (such as the Dowtherm System and the steam generating system) that are not significantly hazardous should be located outside the cell. This will allow maintenance activities without endangering maintenance personnel.

In system designs and operations, such as this one, it is generally observed that operating personnel and system components are usually well protected. Deaths, injuries, and other catastrophies are then usually related to improper maintenance or incomplete identification of all possible unusual failure modes. Thus, special precautions should be taken so that maintenance personnel are not endangered.

6.8. Information Systems

The wide range of temperatures and pressures used necessitates the use of a system to positively indicate to the operator what temperatures and pressures exist at various locations within the process system. Use of multiple gages or readouts, however, is a common source of operator error. Also potential errors can occur if the operator has to isolate or valve out high or low pressure sensors from the system. If this potential problem cannot be designed out of the system, then operating procedures should be designed to ensure that the isolating procedures are followed correctly and that the operator obtains information from the active sensor readout.

Notification of out-of-limit parameters such as excessive temperature or pressure or the presence of gases in excess of predetermined concentrations should be made to operators in a positive, active, method rather than rely upon the operator obtaining this information from a passive readout. This is particularly important where the out-of-limit parameter may indicate some hazard to operators. It is also important that such alarms or notification devices be placed where the operator who must react will be notified immediately.

A review of SAI Safety Report Table 4.1, LIMITS FOR HAZARDOUS GAS MONITORING, indicates that some of the Control Room concentration values may be above acceptable levels. The values listed in Table 4.1 reflect single occurrence Threshold Level Values but fail to recognize possible synergistic effects. The synergistic effects of H_2S, HCN, and CO are such that the acceptable concentration levels should be lowered. For further reference, the NIOSH criteria document, Coal Gasification Plants, lists suggested concentration levels for various contaminants.

Additionally, the limits for hydrogen gas appear to be too high from an explosion prevention viewpoint. A concentration of 25% of the Lower Explosive Limit (LEL) should trigger an alarm or notification to the operators that a leak has occurred. A concentration of 50% LEL should trigger an automatic shutdown and high-speed ventilation as discussed previously. These action levels should be applied to all flammable gases unless health concerns require lower action levels.

Because gas supply and pressures are essential to the process, it is suggested that the supply of gases be verified prior to starting an operation.

Visual monitoring of the cell from the Control Room could be accomplished by a closed circuit video system. Such a system could also allow for remote damage and risk assessment before personnel enter the cell after a problem occurs.

The design of the controls and instrumentation readouts should consider human factors such as physical man-machine interfaces and visual displays/information transfers. This is particularly important when the operator must react promptly to information he receives. This system has at least 47 alarms associated with it, with several alarms possibly indicating different process deviations. The design of the controls and readouts could have a significant impact on the operator's ability to control the system.

The Automatic Data Acquisition System may be usable for controlling the process or advising operators of the proper response to take to alarm signals.

6.9. Written Procedures

Written operating and maintenance procedures should be prepared and used for all operations where risk to personnel is significant. An example of a procedural step which should be documented and followed is verification that high pressures do not exist in the char pot or liquid receiver before initiation of steps to remove these components.

In the area of emergency procedures, actions should be prioritized when they cannot be performed simultaneously. Specifically, the Fire Department should be notified immediately before other actions are taken to control a fire.

Emergency Shutdown Procedures should be prepared both for situations originating within the system/facility and for situations external to the facility (i.e., a fire in an adjacent building).

6.10. Personnel Readiness

Emergency equipment such as supplied breathing air and protective clothing and equipment should be readily available and personnel should be adequately trained in their usage.

Training of personnel in standard operating procedures will apparently be done quite well. Additional emphasis on emergency procedures and in training others such as fire/rescue and maintenance personnel may need to be considered.

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