DESIGN & CONSTRUCTION INNOVATIONS OF THE DEFENSE WASTE PROCESSING FACILITY

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ABSTRACT

Construction of the Defense Waste Processing Facility (DWPF) at the Savannah River Site (SRS) is essentially complete. The facility is designed to convert high-level radioactive waste, now contained in large steel tanks as aqueous salts and sludge, into solid borosilicate glass in stainless steel canisters. All processing of the radioactive material and operations in a radioactive environment will be done remotely. The stringent requirements dictated by remote operation and new approaches to the glassification process led to the development of a number of first-of-a-kind pieces of equipment, new construction fabrication and erection techniques, and new applications of old techniques.

The design features and construction methods used in the vitrification building and its equipment were to accomplish the objective of providing a state-of-the-art vitrification facility.

PROCESS AND FACILITY OVERVIEW

High level radioactive waste, generated at the SRS is stored in large underground tanks in insoluble sludge and aqueous salt solutions. This waste will be converted to and immobilized in a solid glass form in stainless steel canisters in the vitrification building of the DWPF shown in Fig. 1. The canisters ultimately are to be shipped to a federal repository after temporary storage on-site. All radioactive operations are performed remotely, and process control is by a distributed control system.

The sludge portion of the high-level waste is washed in existing waste tanks and transferred to the vitrification facility. A simplified flowsheet is given in Fig. 2. The soluble salt portion of the waste contains radioactive elements which must be removed before the decontaminated salt solution can be converted to saltstone. Radionuclides are removed from the salt solution in the in-tank precipitation process and, after an organic removal step (precipitate processing), blended with the sludge. Each batch of waste is acidified with formic acid. Elemental mercury is removed and recovered, frit is added, and the mixture is concentrated by evaporation. The resulting slurry containing waste and glass-forming frit is fed continuously to a Joule-heated melter. Water is flashed off and the remaining waste solids form a molten glass which flows through a pour spout into stainless steel canisters. (1) The canisters are decontaminated on the outside, welded closed and then stored on-site in an interim storage building until they can be shipped to a federal repository. Benzene will be disposed of by incineration, recovered mercury will be reused in the reprocessing plants and the decontaminated salt will be solidified with concrete (to form "saltstone") and permanently stored in underground concrete vaults.

All of the radioactive operations are performed remotely in the Remote Process Cell (RPC), in the vitrification building. The cell is subdivided into separate Chemical Processing, Melting, Decontamination and Welding Cells. Primary process control is from a central control room using a Distributed Control System (DCS). The cells and general process flow are shown in Fig. 3. Some of the mechanical handling is done locally using programmable logic controllers (PLC's) or manual control stations with direct observation through lead glass windows and in-cell closed circuit television (CCTV). Melter and other process off gases are decontaminated and filtered in the building and then through an underground sand filter before being discharged to the atmosphere through a stack.

DESIGN PHILOSOPHY

Design of the DWPF is based on totally remote operation and maintenance of all chemical and mechanical processes that are handling any radioactive materials or are being conducted in a radioactive environment.

The validity of this design philosophy is based on 35 years of successful operation of the two remote chemical separations facilities at SRS which have shown this approach to give high attainment, low personnel radiation exposure, and excellent safety and efficiency.

Fundamental to this philosophy is the need to quickly replace any failed equipment, then repair it without holding up process operation. This "replace-and-repair" concept, as opposed to "repair-in-place" or "direct maintenance," minimizes downtime and personnel radiation exposure. For repair and replace maintenance, operating spares are provided for every remotable piece of cell equipment. In the event of failure, the piece is remotely removed to decontamination and repair facilities inside the remote area. An operating spare is immediately installed (remotely) and plant operations are resumed. Decontamination and repair of the failed equipment then can be made while normal operations continue. Repaired equipment items become spares for future failures. The facility is expected to achieve an "on-line" time or attainment of at least 75%. The practice

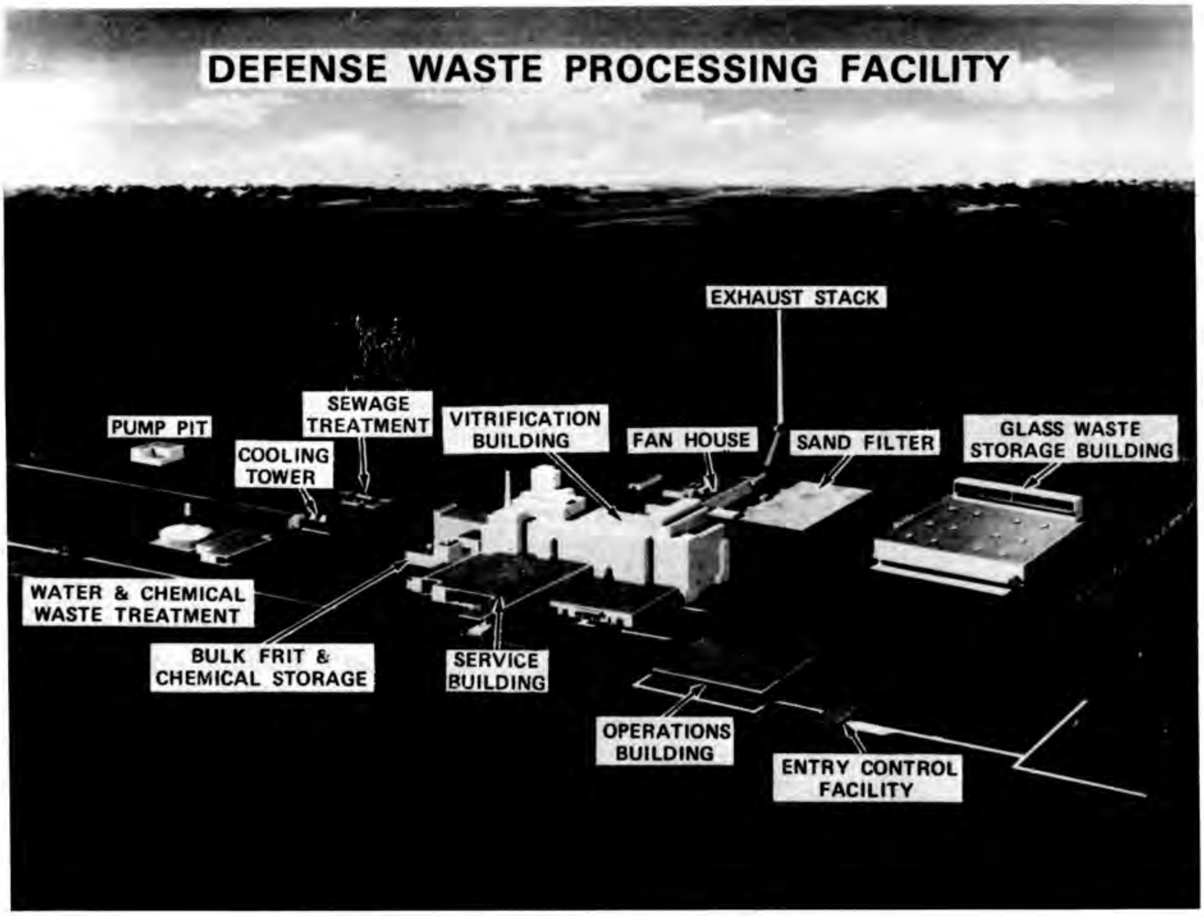

Fig. 1. Defense Waste Processing Facility.

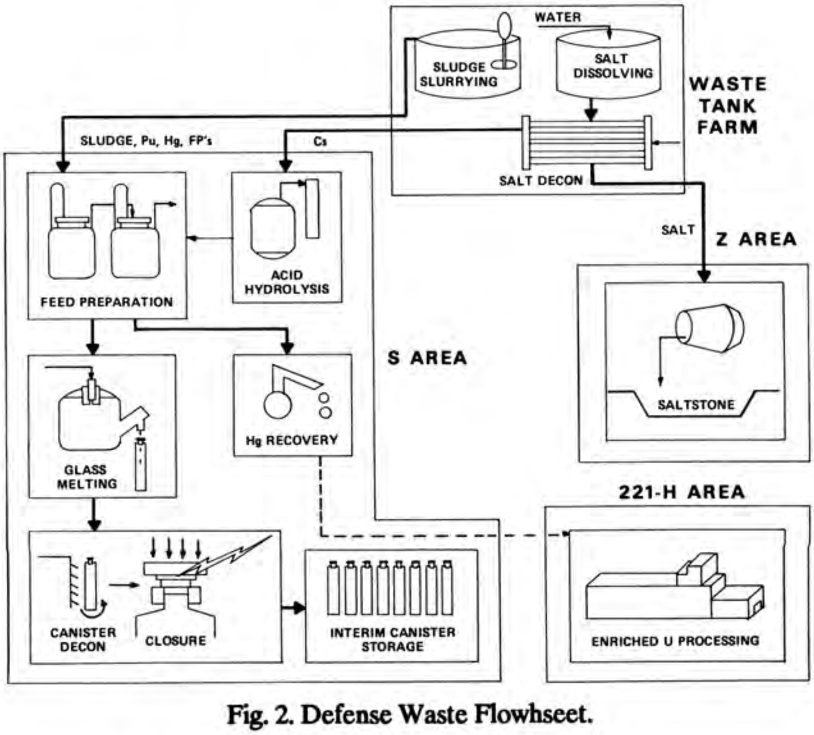

Fig. 2. Defense Waste Flowhseet.

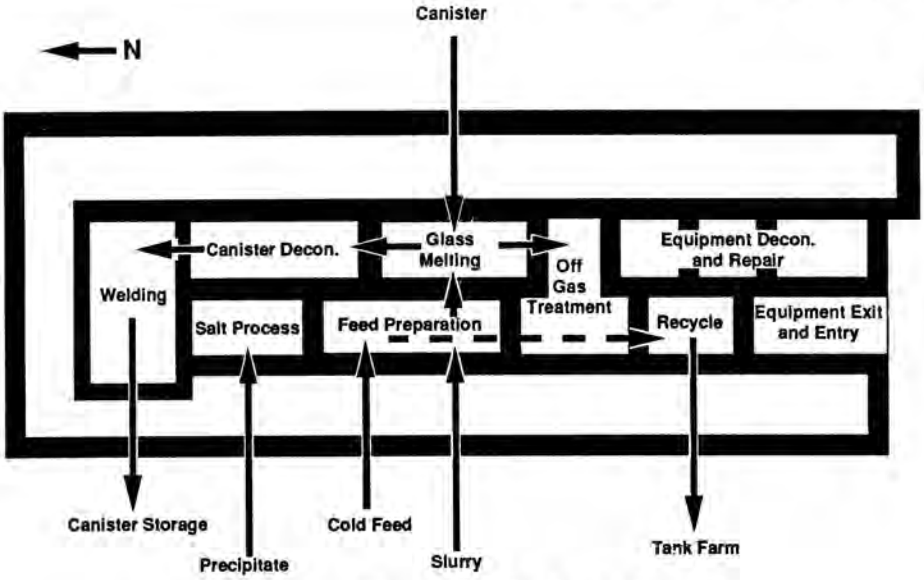

Fig. 3. Process Flow in the Vitrification Building.

of replace and repair maintenance is the main reason that this high percentage of operating or "up time" can be attained.

Many of the proven design features used in existing SRS remote facilities were retained for the DWPF, either as is or modified for operations or conditions that are similar. In those areas where entirely different operations needed to be performed, the same generic principles were applied but new specific designs had to be developed. Nevertheless, many of the pioneer features, as well as modifications suggested by the experience gained during the 35 years of remote operation, were utilized.

Equipment design continued to emphasize ease of remote disassembly so that the components which are most likely to fail (such as motors, bearings, seals, etc.) can be removed separately and quickly. But the success of this type of remotely operated facility requires fabrication of the cells and their equipment to very close tolerances especially in the design and construction of the interface points between the cells themselves and the equipment in them. The structural portion of the cells and equipment were fabricated to the same close tolerances used in earlier remote cells to achieve maximum remotability, interchangeability of identical parts and equipment, and simplified replacement of those parts most subject to failure.

Typically, the critical parts of the cell are the termination flanges of embedded piping, support pads and positioning trunnions all of which appear in Fig. 4. The tolerance range is from 1/64" for positioning trunnions and equipment support pads to ±1/16" for embedded flanges. Similarly, equipment and "jumpers" connecting the equipment to embedded pipe (and conduit) must be designed and fabricated to ±1/16" for the positions of all connecting points relative to the equipment supports and positioning trunnions. Some

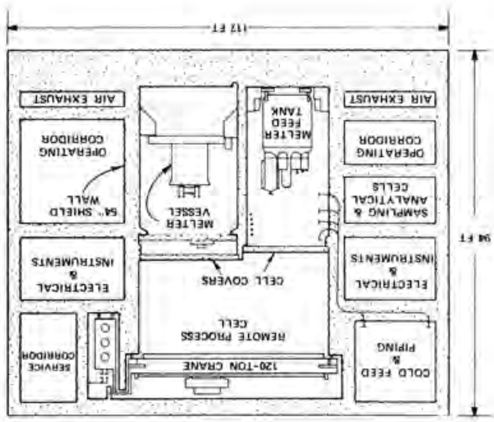

Fig. 4 - Cross-Section - Vitrification Building

equipment with multi levels of stack-ups must use even closer tolerances to meet the required final fit-up requirements.

A full scale mock-up shop capable of duplicating all dimensional features and tolerances of all remote cells in but about one quarter of the space was constructed so that present and future remote equipment can be "mocked up" and ensured a proper fit with no interferences prior to installation in the remote cells.

DESIGN INNOVATIONS

An array of new, one-of-a-kind (and first-of-a-kind) equipment was required for DWPF, such as the glass melter, canister decontamination chamber, smear test station, welder, shielded canister transporter, and associated handling and transfer facilities. New remotability concepts

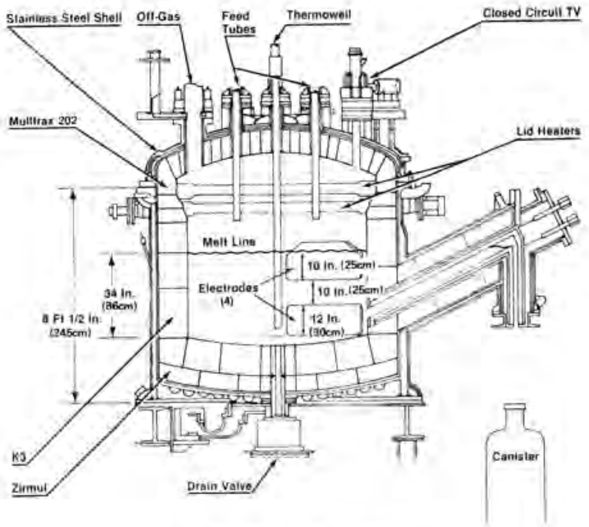

Fig. 5 - DWPF Melter

as well as extended and refined old concepts have been applied to the new equipment.

The glass melter is the heart of the vitrification process. Fig. 5 is a cross-sectional view. It is a cylindrical, jacketed, stainless steel vessel with fitted, internal refractory. The vessel is mounted integrally in a frame. The frame also includes a vent seal pot and provides a place for all the necessary service connections for which there is not enough room on the melter head itself. The specific internal design features are the result of an on-going R & D program starting in the mid 70's and still continuing. The melter, frame and close tolerance interface points were fabricated and assembled off-site. The electrodes, various supplemental heaters and wiring were installed on-site prior to installation as a complete unit in the vitrification building.

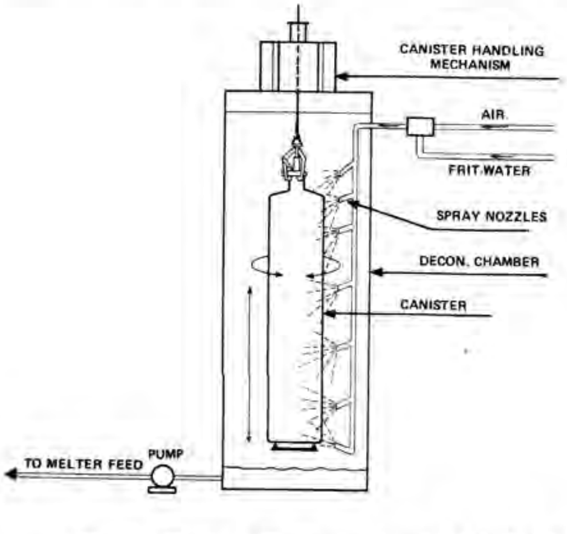

Fig. 6 - Canister Decontamination Method

The canister decontamination chamber, shown schematically in Fig. 6 is designed to provide a programmed sequence for remote "frit blasting" and rinsing to decontaminate the outside of the filled canister. A temporary closure to exclude water from the canister was fitted immediately after filling with molten glass. The canister is rotated inside the chamber past fixed nozzles which direct the frit slurry to cover the entire surface of each canister. The first chamber fabricated was tested extensively and demonstrated successfully at the site.

A similar mechanism was incorporated into a Smear Test Station (STS) which does a remote "smear" of the decontaminated canister to verify that the canister is free of loose ("smearable") contamination and is ready for storage.

After decontamination and smearing, a permanent plug is resistance welded into the fill nozzle at the top of the canister. Figure 7 depicts the canister sealing process. The welder is also an entirely new piece of equipment. It is remotely operated and welds a 5" diameter plug into the canister fill nozzle using 75,000 lbs. of force and 250,000 amperes of electrical current at about 15 volts for 1.5 seconds. The integrity of the weld is determined by analyzing the electrical and mechanical parameters during the weld period. A data acquisition system collects the data and compares it with acceptance criteria based on tests done earlier on full-scale test welds. Data was accumulated over a long test period and over a wide range of conditions. Based on this data, the integrity of any weld can be inferred from the specific parametric data collected as the weld was made.

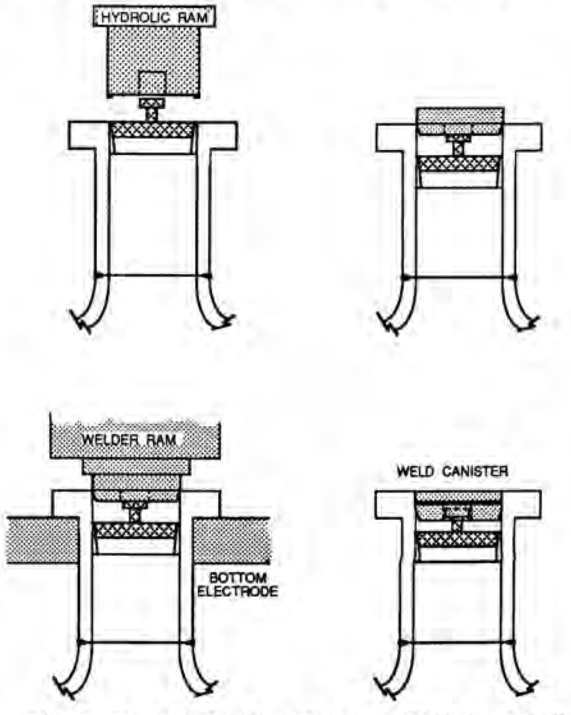

Fig. 7 - Canister Sealing Process - Welt Test Cell

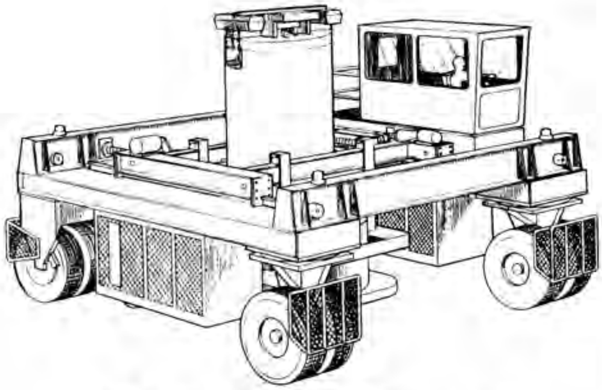

Fig. 8 - Shielded Canister Transporter

The Shielded Canister Transporter (SCT) in Fig. 8 is designed to transport canisters filled with glass waste from the vitrification building to the interim storage building. It is basically patterned after a straddle carrier but with considerable specialized features. The transporter in operation lifts a concrete plug from a load out hatch at the vitrification building and then with a hoist and grapple arrangement lifts a pre-positioned canister out of the underground load-out tunnel into the shielded cask mounted on the SCT. The plug is then replaced in the load-out hatch and the SCT is driven to the storage building. There, the placement of the canister into a storage location is essentially the reverse of the removal of the canister from the load-out hatch just described. The whole operation is carried out by an operator riding in a shielded cab on the SCT. The operator is assisted by a CCTV system and PLC to verify the proper positioning of the SCT and correct sequence of operations. Approximate overall dimensions of the SCT are 25 feet long, 20 feet wide and 18 1/2 feet high. It weighs about 130 tons.

Transfers of canisters between operating cells is done through tunnels equipped with motorized, remotely operated carts designed to hold one can at a time. The canisters are loaded remotely into and out of the carts by in-cell cranes in each of the cells. The in-cell cranes also operate remotely. In the event of an in-cell crane failure, the failed trolley, bridge or both can be removed and replaced remotely by the Main Process Cell (MPC) Crane which can access all equipment in the remote process cell.

Designs for remote removal of "embedded" through-wall piping and bus bars were developed to overcome the potential for premature failure of in-wall piping carrying abrasive slurries and large electrical currents. Several new fixtures were designed and techniques developed to allow remote removal of several sizes(up to 10" in diameter) of through-wall piping used in services where severe corrosion or line plugging might be expected to occur. The through-wall portion of bus bars carrying power to the melter is also designed to be remotely replaceable.

An entirely new concept for electrical wiring to service the remote cell was developed to allow several different wiring configurations for power, instruments, and TV signals (coax). Any of these configurations can be remotely replaced in any given embedded conduit in the event of failure or future changes in process requirements. The wiring complement in embedded conduit in the existing facilities on-site is limited to six wires suitable for power transmission only; replacement of the wires is impossible unless cell access can be made. Continuity of process operation is dependent on utilization of existing spares.

A fully remotable, rigid piping system for in-cell transfers was developed. All horizontal piping runs were designed to have no low points to accumulate solids. The pipe runs are stacked in a vertical array, and piping at the bottom of the vertical array can be removed and replaced without disturbing the piping above it. In-cell transfer systems in existing plant facilities, although fully remotable, are "stacked" in a horizontal array and have expansion joints with low points.

An in-cell tank sampling system in Fig. 9 has a centrally located, shielded cell to which sample piping from all in-cell vessels is routed. Some sample runs approach 150 feet in length horizontally and with total lifts of up to 20 feet. Sampled streams range from essentially water to slurries containing 40% solids. The system also is capable of taking samples of gaseous process streams (e.g. vents, off-gasses, etc.) and in-cell air. The significant feature is the almost total absence of personnel exposure associated with routine process sampling operations.

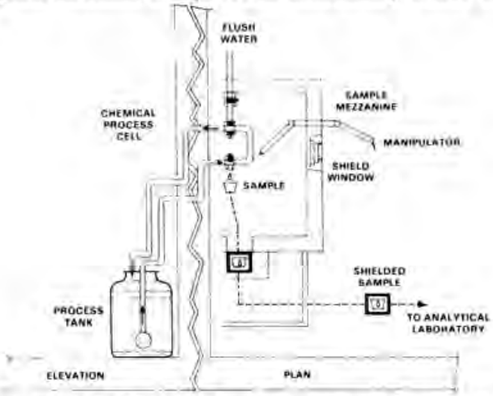

Fig. 9 - Vitrification Process Tank Sampling

A new design for a remotely removable pump motor was developed to permit removal and replacement of the motor, bearings, and seals from the radioactive environment without requiring removal of the pump itself or its piping. This avoids extensive and unnecessary decontamination work and exposure of personnel. In another development, hydraulically installed couplings are used on agitator shafts to dramatically reduce shaft fit-up time and shaft run-out. The lower shaft run-out extends shaft and bearing operating life and reduced the fit-up time lowers personnel exposure when changes are necessary.

The MainProcess Cell (MPC) Crane will do all of the remote removal and replacement of equipment using radio control and CCTV from a central control room. There is no operator on the crane. There are eight TV cameras on the crane itself. Each camera has its own monitor at the operator's console. The operator may also monitor the output from any of the various fixed, in-cell TV cameras.

A Distributed Control System has been designed as the primary control for the process. (2) The system utilizes direct digital control technology to monitor and control the major feed preparation steps, the melter and its off-gas system and most of the plant utility systems. The host computer down loads control software to process and display control modules and also collects historical trend data on process parameters. Various redundant features and isolation methods are used to ensure safe shutdown capability under any emergency.

CONSTRUCTION INNOVATIONS

The complex nature of the Vitrification Building led Construction to develop a number of innovative techniques to avoid congestion among the various crafts and to expedite the construction schedule.

The construction techniques that had the most impact on the schedule were modular fabrication and setting of embedded and corridor pipe, off-site fabrication of piping and equipment, pre-fabrication of stainless steel cell liners and using a roof truss form system for placing the vitrification building roof concrete.

The shear number of embedded items required, added to the congestion inside the building, made the fabrication of embedded items in modular sections almost a necessity. All the to-be-embedded items such as pipe, conduit, steel plates, etc. for a given section of wall were placed and anchored in a structural steel frame which then became the "pipe module" for that section. The modules ranged from 4 to 36 feet long and were about 40 feet high and 2 1/2 feet wide. Over 30 modules were fabricated and placed. Most of the piping in the modules was pre-fabricated by an off-site vendor so that a minimum number of field welds were required. It is estimated that well over 1000 additional field welds would have been required if modules had not be used.

The modular concept was extended to the operating corridors which contain about 40,000 feet of pipe. Since corridor space was limited, standard methods of erection would have been costly and time consuming. Pipe modules were built in about 60 foot lengths. All the header piping was placed on the steel framework for each module, and whenever possible, branch connections were added, lines were insulated, and testing done--all under shop rather than field conditions. After placement of the module, connections to adjacent modules were completed, pipes were anchored, final testing done and insulation finished.

Previously, all close tolerance work on equipment for remote cells was performed entirely on-site. Normally, vendors built the basic equipment pieces and shipped them to the site where special craftsmen added the critical, close tolerance components which interfaced with other remote equipment. On this project it was decided to have almost all of the close tolerance remote equipment fabricated off-site because the site no longer maintained sufficient craftsmen or facilities to handle a project this size and meet schedules. Most of the vendors, however, had never fabricated their equipment to such tolerances nor were they equipped with the necessary temperature controlled facilities. Nevertheless, with close follow-up by site design and project personnel, the work was completed satisfactorily, and this approach will be used in the future.

Certain of the remote cells required stainless steel liners. In keeping with the construction techniques applied elsewhere on this project, the liners were pre-fabricated in units as large as could be handled for placement. The pre-fabricated panels, about 8 by 22 feet, were assembled into sections up to 24 feet long. The sections were then erected and aligned against a rigid interior support system where they were brought to the required rectangular configuration. Assembly of the liners on the work slab eliminated the majority of the welding which would have had to be done in confined spaces. Each liner portion weighed about 50 tons and was lifted into place using two cranes in tandem. Only the welds necessary to join the liner sections together were then made. The liners also served as the forms for the walls of the cells in which the liners were installed.

Perhaps the most effective schedule - reducing and cost-saving technique employed was the innovative truss forming system used to place the 4 foot thick roof spanning 71 feet of the remote cells and adjacent operating corridors of the Vitrification Building. (3) See the building cross section in Fig. 10.

The "truss and pan" system of shoring for the concrete pour of the roof consisted of a series of trusses spanning the remote cell and adjacent service corridors. The trusses were spaced 6 feet apart with stiffened plates or pans spanning between the trusses. The corridor roof trusses were 3 feet deep while the trusses over the remote cell were 11 feet deep. Pairs of trusses with a pan welded in between were fabricated in a laydown yard. The assemblies were trucked to the building and hoisted into place with a crawler crane and pans and stiffening between assemblies was added. Each assembly weighed about 18 tons. After placing of reinforcing bars, conduit for wiring and anchor bolts, con-

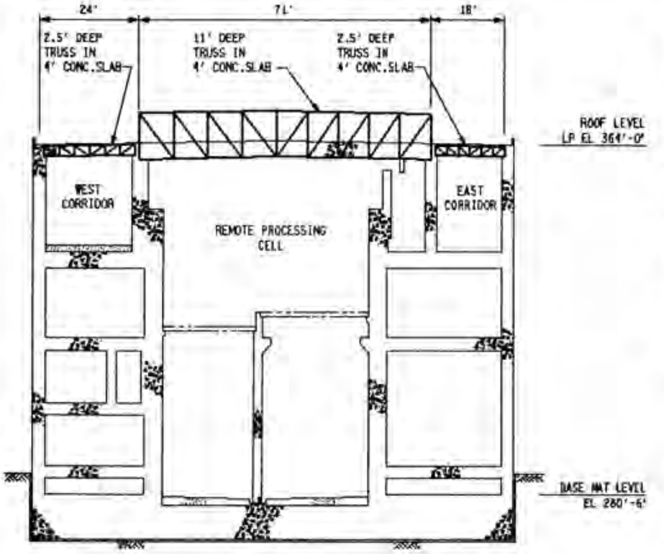

Fig. 10 - Vitrification Building - Roof Truss

crete was pumped to the roof in 18 separate "pours" each about 60 by 40 feet and 4 feet thick. The 3 foot corridor trusses were completely embedded but the upper portions (7 feet) of the 11 foot remote cell trusses were removed later by flame cutting. The truss and pan technique shortened the project construction schedule by at least 6 months, allowed the preplacing of service corridor piping modules (described earlier) from overhead by the large construction cranes, permitted work to proceed everywhere under the roof in an unobstructed manner while the roof slab was being placed, allowed all the roof construction work to be done more safely from above, and allowed all cranes operating in the cell areas to continue without interruption.

Another strategy used to expedite project completion was sequential turnover of completed facility segments to Operations while other segments were still under construction. (A facility segment is defined as a logical, definable unit of process, building, or auxiliary equipment; about 740 such segments were identified.)

This permitted operations personnel to begin check-out and run-in of completed portions of facilities while work was still proceeding on others. This accelerated the schedule and expedited resolution of design and construction problems which surfaced during check-out because the full staff of design and construction personnel were still available.

The translation of R&D and process and equipment development to Design and Construction was also done on a "fast track." Progressive developments went to Design and Construction as soon as sufficient scope could be defined for building and service requirements, but before all final details were ready. In fact, when construction was started, final design was only about 35% complete. Time between process and equipment development and construction was held to a minimum.

Successful use of the "fast track" approach, sequential turnover of facility segments, and simultaneous activities by construction and operations in close proximity required closer cooperation between the groups than usual. A Project Guidance Committee was formed to provide the necessary degree of cooperation. The committee was formed to address problems or conflicts which arose among the various project organizations and to provide rapid and timely resolution to any such problems or conflicts. The committee was and is made up of responsible and decision making representatives of Design, Construction and Operations at the working level. The committee has been largely responsible for the smooth progress and spirit of cooperation which has characterized the project.

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