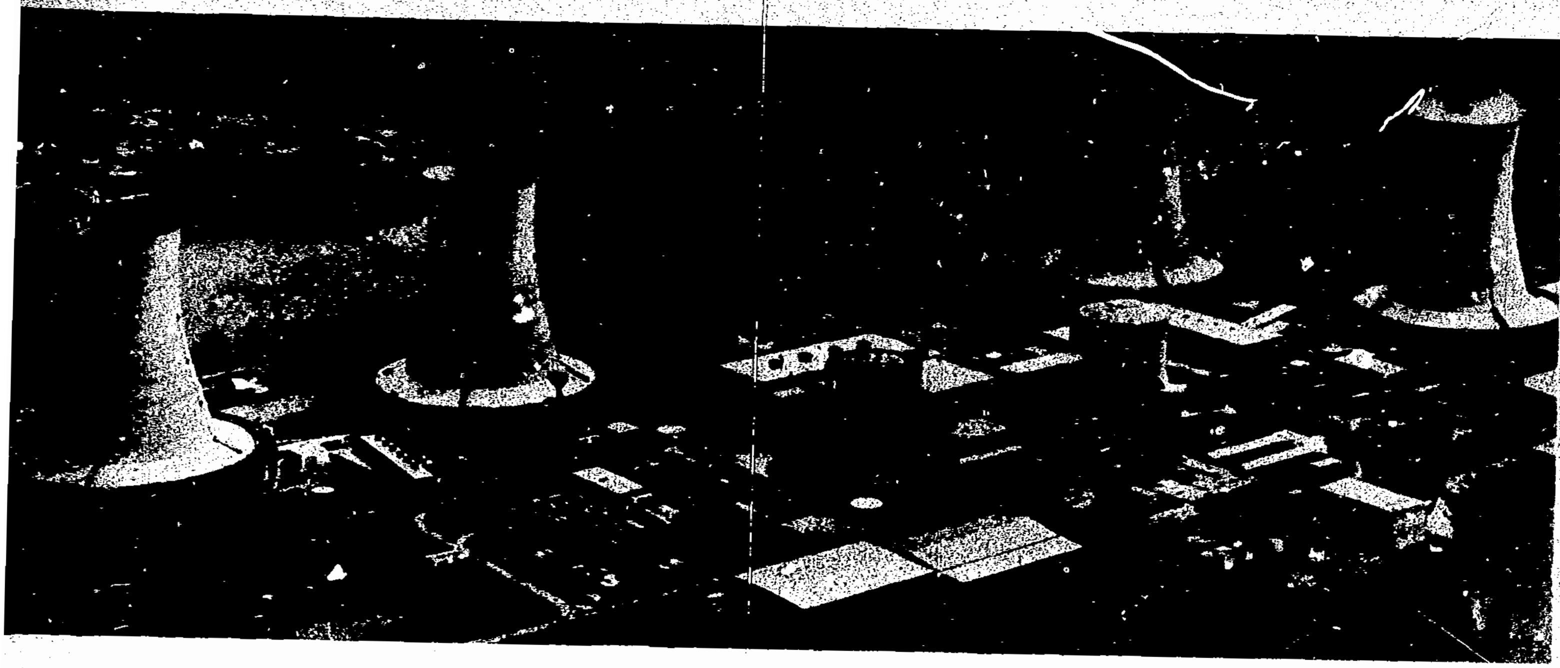
GEND
029



GEND

General Public Utilities • Electric Power Research Institute • U.S. Nuclear Regulatory Commission • U.S. Department of Energy

Preparations to Ship EPICOR Liners

Steven P. Queen

June 1983

Prepared for the
U.S. Department of Energy
Three Mile Island Operations Office
Under DOE Contract No. DE-AC07-76IDO1570

GEND 029
Distribution Category: UC-78
TMI Supplement

PREPARATIONS TO SHIP EPICOR LINERS

GEND--029
DE83 015920

Steven P. Queen

Published June 1983

General Public Utilities Nuclear Corporation
Middletown, Pennsylvania 17057

Prepared for EG&G Idaho, Inc.
and the U.S. Department of Energy
Three Mile Island Operations Office
Under DOE Contract No. DE-AC07-76IDO1570

ABSTRACT

The sampling and analysis of the hydrogen rich atmosphere of the 49 EPICOR II ion-exchange prefilter liners generated in the decontamination of radioactive water at TMI-2 will provide data to ensure safe storage and shipment of highly loaded ion-exchange media. This report discusses the prototype gas sampling tool used to breech the containment of the liners, the tool support equipment for sampling and inerting the liners, and the characterization program used for determining the radiolytic hydrogen generation rates in the liners.

ACKNOWLEDGMENTS

Thanks go to Karl Hrbac and Richard Freeman of GPU who assisted in gathering information for this report. Credit also goes to the TMI-2 Operations Department whose expertise and patience in dealing with the inherent problems associated with remotely operated equipment helped make the project a success.

CONTENTS

FIGURES

TABLES

PREPARATIONS TO SHIP EPICOR LINERS

INTRODUCTION

During the cleanup of contaminated water in the Auxiliary and Fuel Handling Building (AFHB) at Three Mile Island Unit 2 (TMI-2), the EPICOR II ion-exchange system generated 72 (predominately organic) ion-exchange resin prefilter liners. The EPICOR system consists of three resin beds in series and is designed to process contaminated water containing up to 100 μCi/mL. The first bed, called a prefilter, performs gross removal of cesium and strontium while the two remaining beds accomplish final cleaning. Curie loadings in the prefilters were generally the highests of the three beds ranging from 160 to 2200 Ci with radiation levels as high as 2800 R/h on contact. Of the 72 liners, 22 were less than 60 Ci, low enough to be disposed in a commercial burial ground in 1981, with the remaining 50 high activity liners being stored on site at TMI-2 in the Solid Waste Staging Facility (SWSF). Disposal of these 50 liners was dependent on adequate characterization for radiolytic gas generation, resin degradation, and the corrosion resistance of the liner walls.

In May 1981, Battelle Columbus Laboratories (BCL) was subcontracted by the United States Department of Energy (DOE) to characterize a selected liner, PF-16. Prior to shipment from TMI to BCL, PF-16 was manually vented in a shielded pit and a combustible gas was detected. A gas sample drawn at BCL confirmed the presence of hydrogen. Based on this information and the concern for safety, it was deemed necessary that the 49 remaining EPICOR liners be purged of hydrogen gas in a remote manner and the hydrogen generation rate quantified on various liners characteristic of the entire group before further shipments. Selection of PF-16 for characterization was based on its low pH (2.8) the most corrosive of the 50 liners, and its higher than average curie loading, 2058 Ci.

Following a memorandum of understanding between DOE and the U.S. Nuclear Regulatory Commission (NRC), DOE agreed to accept the remaining 49 prefilter liners for a limited experimental program at the Idaho National

Engineering Laboratory (INEL). EG&G Idaho, Inc., the designated subcontractor for DOE and General Public Utilities (GPU) agreed to design, construct, startup, and test inerting equipment to ensure the safe handling and shipment of the EPICOR prefilters to INEL.

Of the 50 liners, vessels PF-1 through PF-11 contain all organic ion-exchange media (anion, cation, and mixed bed) and vessels PF-12 through PF-50 contain organic ion-exchange media plus inorganic zeolites.[a] The calculated curie loadings for liners PF-1 through PF-50 are shown in Table 1.

Interim Liner Storage

After loading, the EPICOR liners were dewatered with air to less than 2% free standing water, removed from their service position in the Chemical Cleaning Building, and, using a shielded transfer cask, transferred to the SWSF.

The Unit 2 SWSF consists of two concrete storage modules (A and B) located immediately south of the Unit 2 cooling towers. Each module contains 60 cells, 7 ft in. in diameter by 13-ft deep. The cells are metal-lined and drain to a common sump. Each cell is covered by a concrete lid, 3-ft thick, weighing 50 tons. The 49 cells with EPICOR liners each contain only one liner; however, some of these cells have stackers in place to provide support for storing an additional liner.

The function of this interim storage facility is to provide shielding and secondary containment and to keep the EPICOR liners safe and dry until shipment from the island is possible. Figure 1 shows a cross-section and plan of one of the modules.

---

a. The exact resin mix in the prefilters is considered proprietary information by the EPICOR Company.

TABLE 1. EPICOR II CALCULATED PREFILTER CURIE LOADING SUMMARY

PF	Total	^{90}Sr	^{134}Cs	^{137}Cs
	Organics (Ci)			
1	1498	162	56	588
2	1052	119	39	389
3	1878	167	75	738
4	684	44	28	284
5	160	9	7	69
6	166	9	7	72
7	1402	173	50	499
8	1367	34	62	624
9	1351	24	62	627
10	227	4	10	104
11	910	18	41	416
	Zeolites and Organics (Ci)			
12	1526	34	70	690
13	1417	29	80	636
14	1458	34	67	663
15	1469	35	68	668
16	2058	30	94	945
17	178	30	80	808
18	2025	35	91	925
19	1988	34	89	908
20	1954	9	92	916
21	1954	9	92	916
22	1713	8	80	803
23	1411	99	58	580
24	1954	9	92	916
25	1954	9	92	916
26	1954	9	92	916
27	1954	9	92	916
28	917	53	40	389
29	1954	9	92	916
30	1436	16	66	661
31	1767	9	83	847
32	1767	9	83	847
33	1767	9	83	847
34	1767	9	83	847
35	1767	9	83	847
36	1767	9	83	847
37	1767	9	83	847
38	1767	9	83	847
39	1767	9	83	847

TABLE 1. (continued)

PF	Zeolites and Organics (Ci) Total	^{90}Sr	^{134}Cs	^{137}Cs
40	1767	9	83	847
41	1767	9	83	847
42	1767	9	83	847
43	1767	9	83	847
44	1845	82	78	816
45	2036	91	86	850
46	2184	97	92	965
47	1939	115	82	811
48	1939	115	82	811
49	1776	1	84	862
50	1600	3	75	782

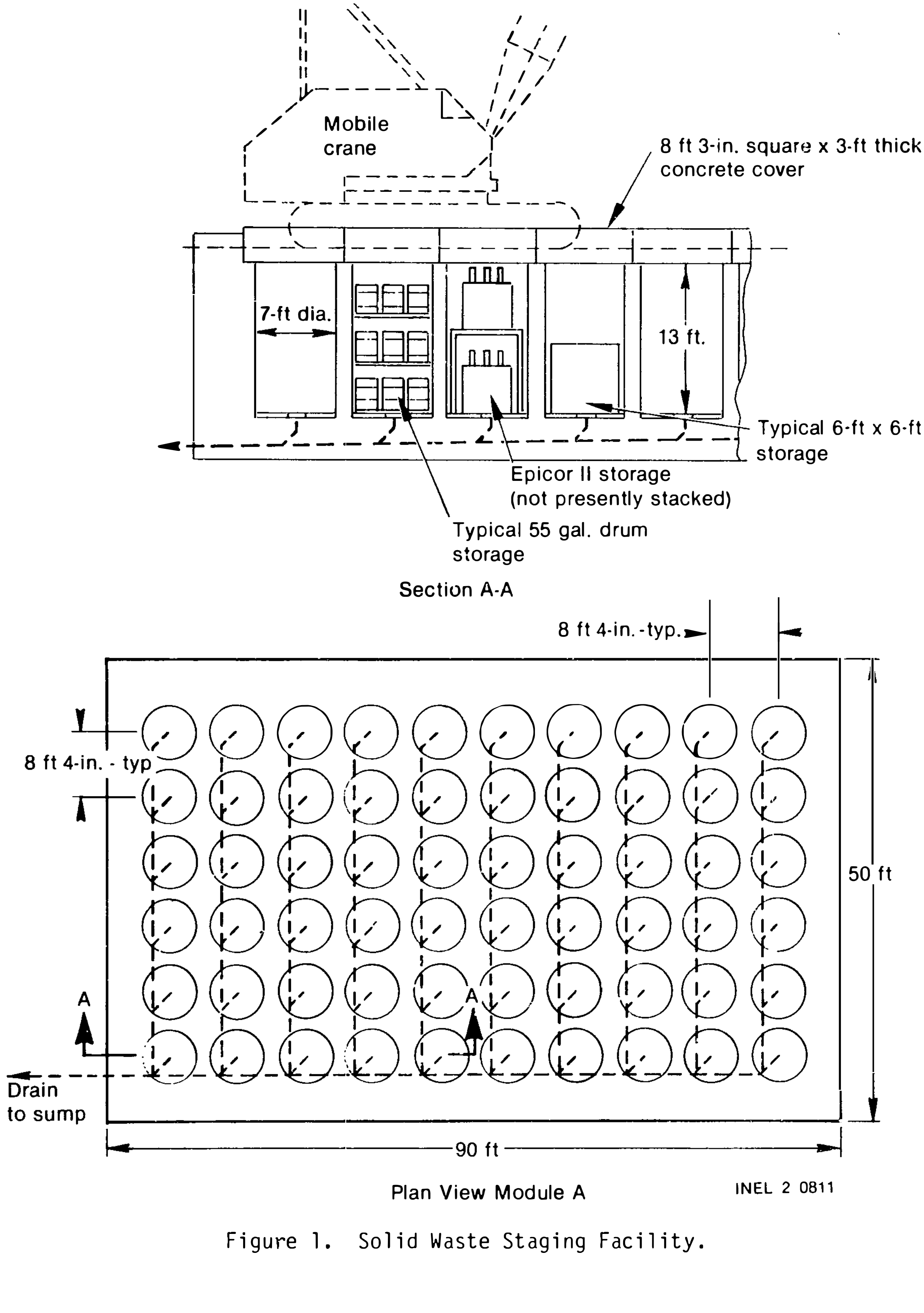


Figure 1. Solid Waste Staging Facility.

EPICOR II Prefilter Description

The typical EPICOR II ion-exchange media liner is a 5-ft high right circular cylinder, 4 ft in. in diameter and containing approximately 30 ft^3 of ion-exchange media. The walls and top are 1/4 in. thick. The bottom is 1/2 to 5/8 in. thick. The liner is fabricated of A-36 steel and is of welded construction. The interior surfaces of the liner are coated with Phenoline 368 to retard corrosion. A cross-sectional view of the typical liner is shown in Figure 2. Among the 49 remaining liners there exists three different configurations for the liner penetrations. These configurations are shown in Figure 3.

Characterization of PF-16

Due to radiolytic degradation of the EPICOR resins and radiolysis of water, a hydrogen rich gas mixture was anticipated within the liners. GPU Technical Data Report 274 evaluated the potential for hydrogen generation.[1] Based on the evaluation, EPICOR liner PF-16 was selected for a detailed experimental analysis.

PF-16 was shipped to BCL for study in May 1981 from TMI-2. This liner was selected for characterization because of its relatively high radionuclide content, approximately 2058 Ci and its low pH of 2.8. Prior to shipment, PF-16 was vented manually. Two phenomena were noticed: (a) the liner was very difficult to open manually; operators were forced to use a long "cheater bar" to attain sufficient torque to unscrew the liner's vent plug, and (b) significant amounts of hydrogen were released during the venting; a combustible gas meter in the area alarmed very soon after the plug was removed, necessitating evacuation of personnel from the area.

Subsequent analysis at BCL indicated that the liner contained 12% hydrogen by volume.[2] As a result, it was recognized that any hydrogen within the additional 49 liners must be purged, in a remote manner, to below the flammable limit of 4% by volume to ensure safe handling.

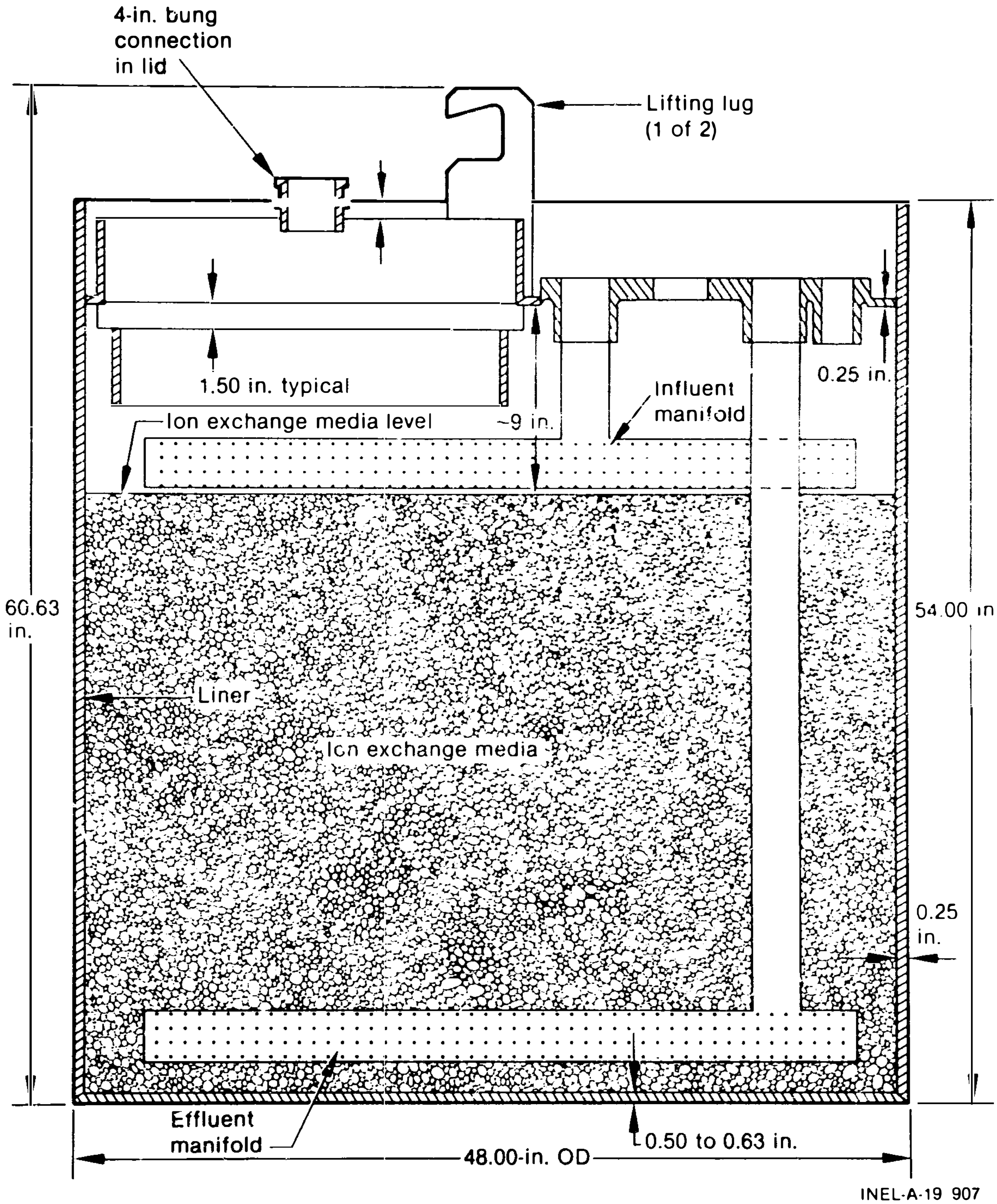


Figure 2. Cross-sectional view of a typical EPICOR II liner.

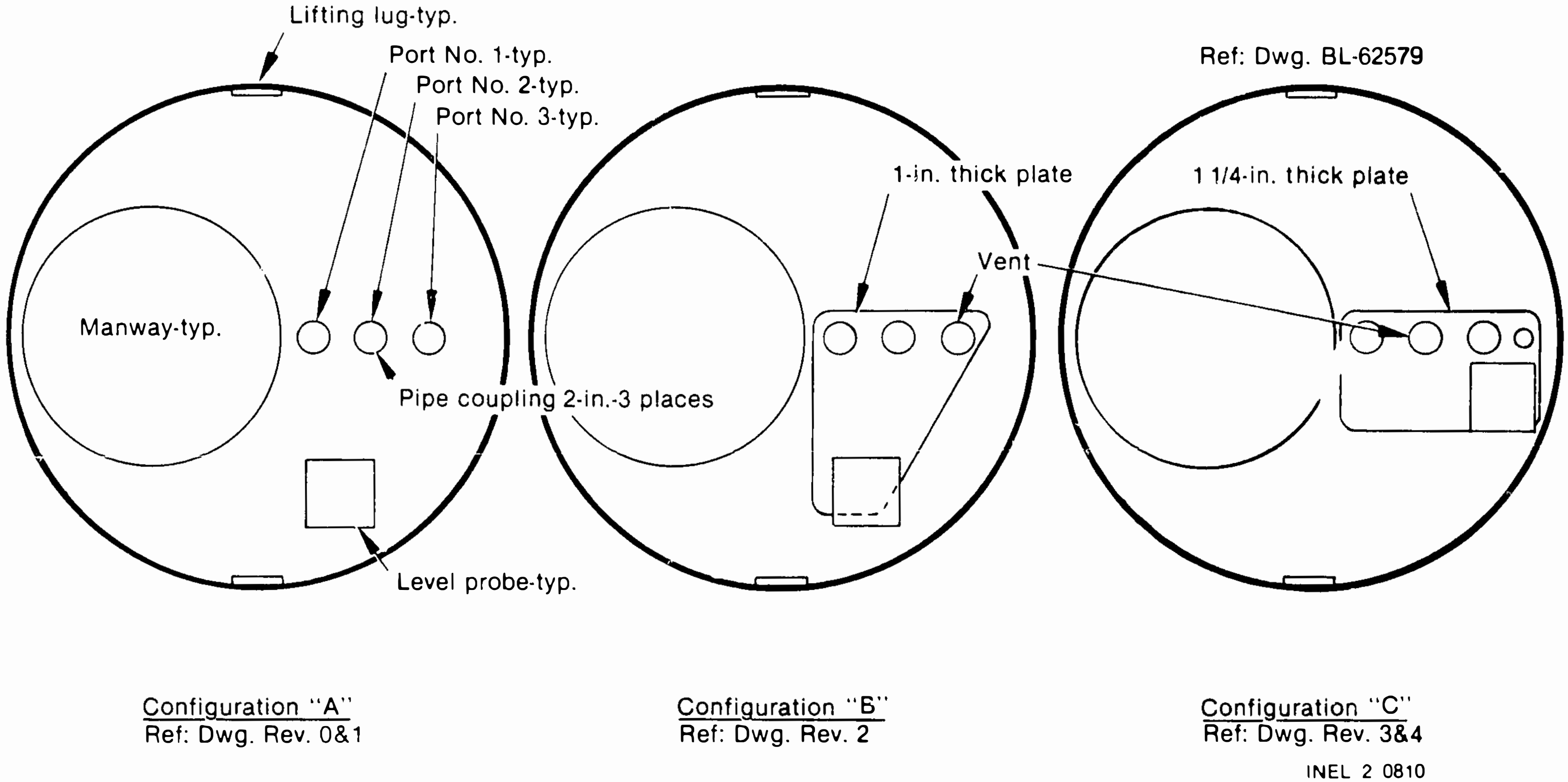


Figure 3. Various liner top configurations.

An evaluation to determine the most appropriate method to remotely breech the gas-containment boundary of the liners was undertaken by GPU and EG&G Idaho. Breech methods evaluated included (a) flexing the drum lid to break its seal, (b) puncturing the liners mechanically or with acid, (c) installing a self tapping, threaded valve, (d) removing the drum lid, and (e) unscrewing the 2-in. pipe plug. Unscrewing the 2-in. pipe plug was chosen, considering it had been successfully used on PF-16.

This report describes the development of a prototype remote gas sampling tool and the construction of inerting facilities. These facilities include a Remote Support Facility for gas analysis and a concrete enclosure used in conjunction with the gas sampling tool. In addition, the report covers operational experience, safety features, and gas generation results for the liners purged and shipped to date.

EPICOR LINER SAMPLING AND INERTING FACILITIES

EG&G Idaho developed a remotely operated tool that could remove the liner vent plug while maintaining a sealed environment around the opening. GPU developed the auxiliary equipment to work in conjunction with the tool to sample and purge the liners. The subsections below describe the equipment designed to perform these tasks.

Prototype Gas Sampler

The prototype gas sampler (PGS) is detailed in Reference 3; therefore, only a cursory description is given here.

The PGS, commonly referred to as the vent tool, is a remotely operated tool designed to loosen and remove the liner vent plug, shroud the vent hole in order to retain the liner gases, and to reinstall the plug when sampling and inerting operations are completed. All cameras, lights, and contact points of the tool with the liner are designed to preclude sparking. Figure 4 shows a cross-sectional view of the vent tool.

The vent tool is suspended from a support platform by a cable and hoist assembly. Using the hoist and support platform, the tool is lowered on to a liner such that the channel-shaped guide brackets, attached to the vent tool base, engage onto the liner's two lifting lugs as shown in Figure 5. Rotational torque from loosening the plug is transmitted to the liner lifting lugs through these guide brackets. Whereas the plug's final position is not precisely known relative to the lift lugs, final positioning of the 7/8-in. square tool tip is accomplished by air motors driving a threaded drive nut as shown in Figure 6.

Two television cameras are mounted on the tool to enable visual confirmation of tool tip alignment. During plug removal, one of the cameras provides information on drive shaft rotation and confirms plug removal. A lexan window in the tool sample housing allows the camera to view the plug. Figure 7 shows the television monitor image of the tool tip and plug through the window. Television monitors located in the Remote Support Facility receive the signal from the cameras through 100-ft long electrical cables.

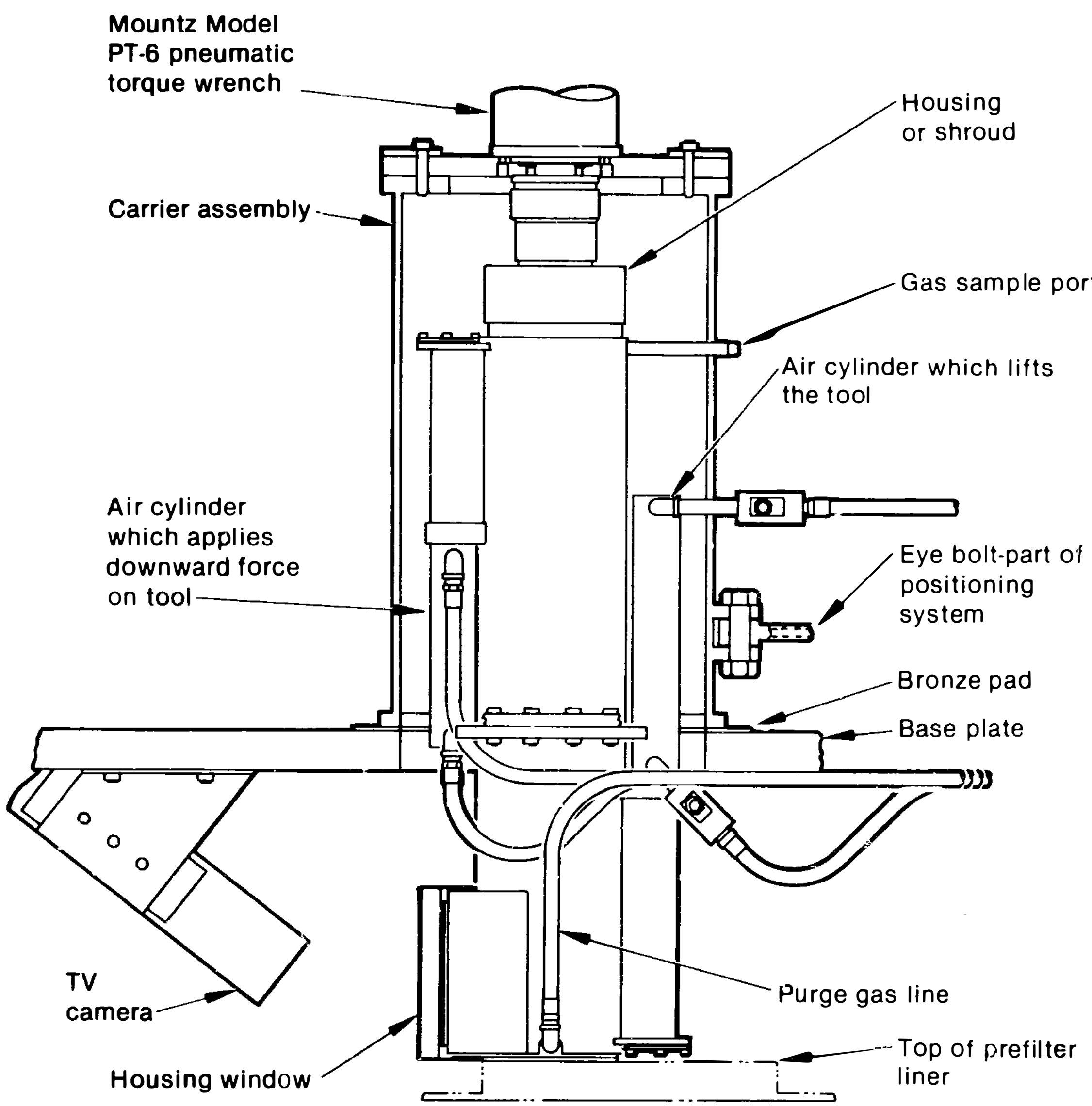


Figure 4. Cross-sectional view of vent tool.

After final tool tip positioning is accomplished, the tool tip is engaged in the plug and the tool is lowered further until the 5-in. inside diameter housing, surrounding the tool drive system and tip, is sealed against the liner. A Buna N rubber gasket glued to the bottom of the housing is used for sealing the housing to the liner. The seal is maintained up to a liner gas pressure of 20 psig by the tool weight. Two 1/4-in. ports are in the tool housing and are connected to the sampling and purging system located inside the Remote Support Facility. The ports are connected to the

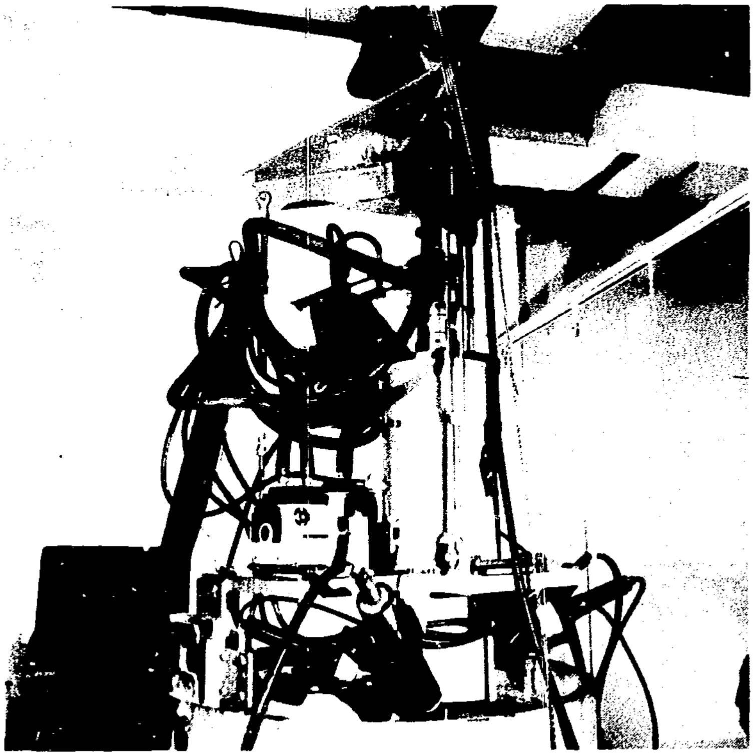


Figure 5. Vent tool engaged on liner's two lifting lugs.

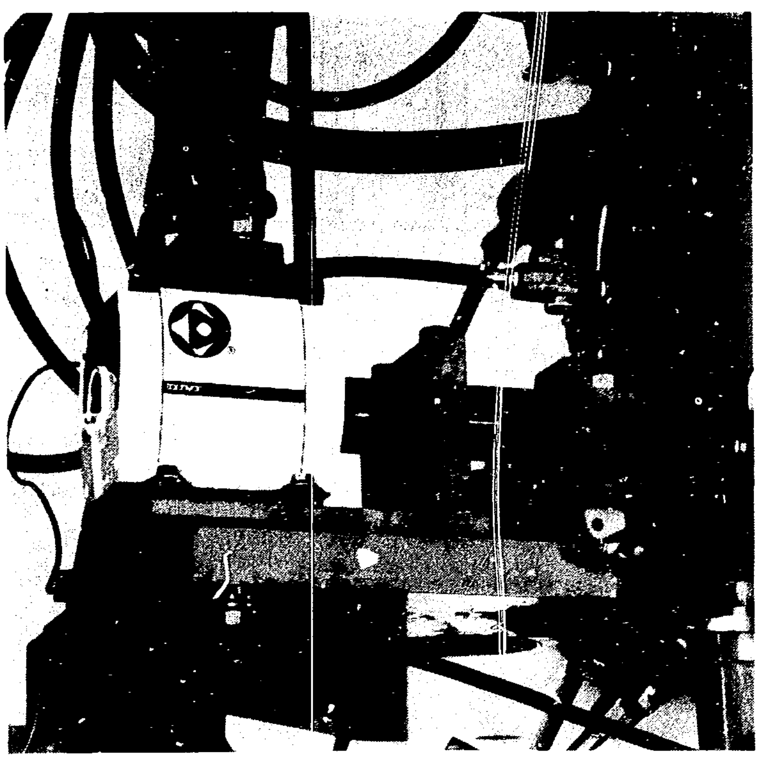


Figure 6. Vent tool positioning system.

Figure 7. TV monitor with image of plug insertion and removal.

system by flexible stainless steel lines and allow for sampling of the tool housing and the introduction of nitrogen into the housing. A cross-sectional view of the tool housing is shown in Figure 8.

The tool drive system, used to remove and reinstall the liner plug, consists of an air powered torque wrench, two air cylinders, and a ball bearing splined spindle. The wrench is capable of producing up to 2500 ft/lb of torque with a maximum unloaded speed of 1.8 rpm. It is driven by 70 psi air at a maximum flow of 40 cfm. The torque and speed of the wrench is controlled by varying the air pressure and air flow to the wrench. An air pressure regulator and a ball valve are used to control the wrench. Once the plug is loosened, removal is accomplished by air cylinders mounted vertically on the sides of the tool housing. The cylinders move the tool tip up and down along a ball bearing splined spindle. Magnets mounted on the tool tip secure the plug to the tip during vertical movements.

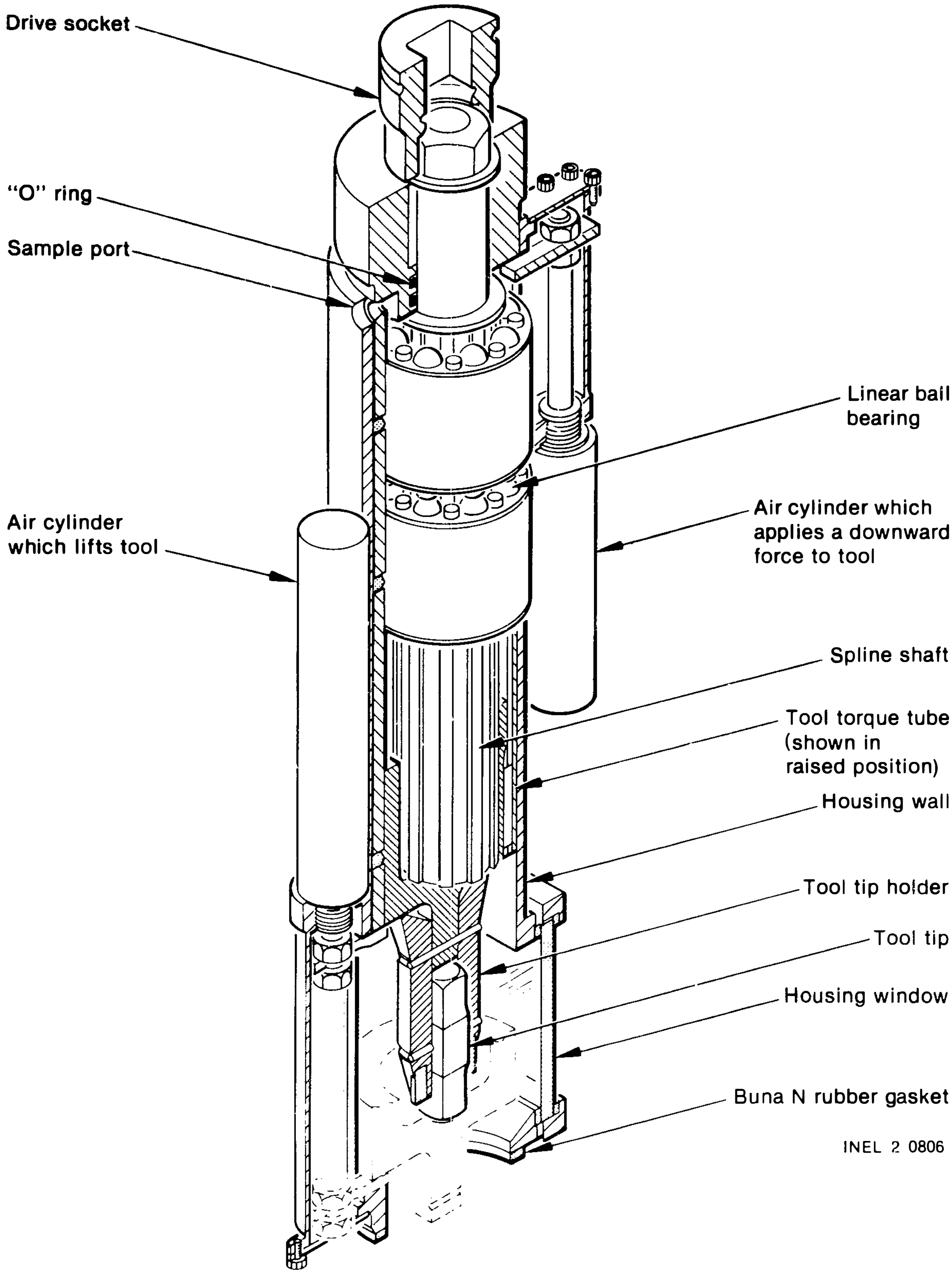


Figure 8. Cross-sectional view of vent tool housing.

The vent tool is connected to a control panel, located inside the Remote Support Facility, by a 100-ft long umbilical. The umbilical contains rubber air hoses for supplying the vent tool motors and torque wrench, stainless steel sample and purge lines, the electrical cables for the camera system, and a ground wire to electrically ground the tool to the Remote Support Facility. Figure 9 shows the control panel and Figure 10 shows an overall view of the vent tool, control panel, TV monitors, and umbilical.

Sampling and Purging System

The sampling and purging system was designed as an auxiliary system for the EPICOR liner vent tool. The purpose of the sampling and purging system is to work in conjunction with the vent tool to adequately and safely sample, analyze, and purge the 49 remaining EPICOR liners of radiolytic gases.

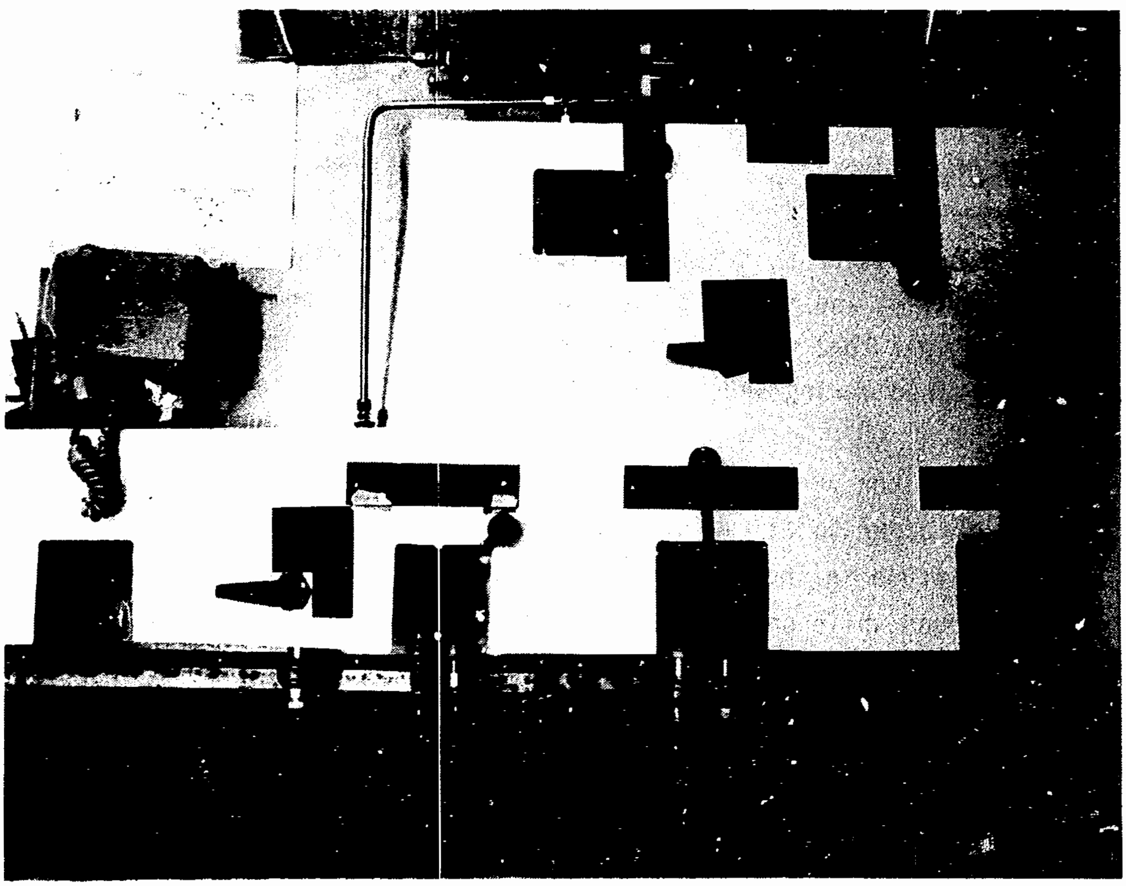


Figure 9. Vent tool control panel

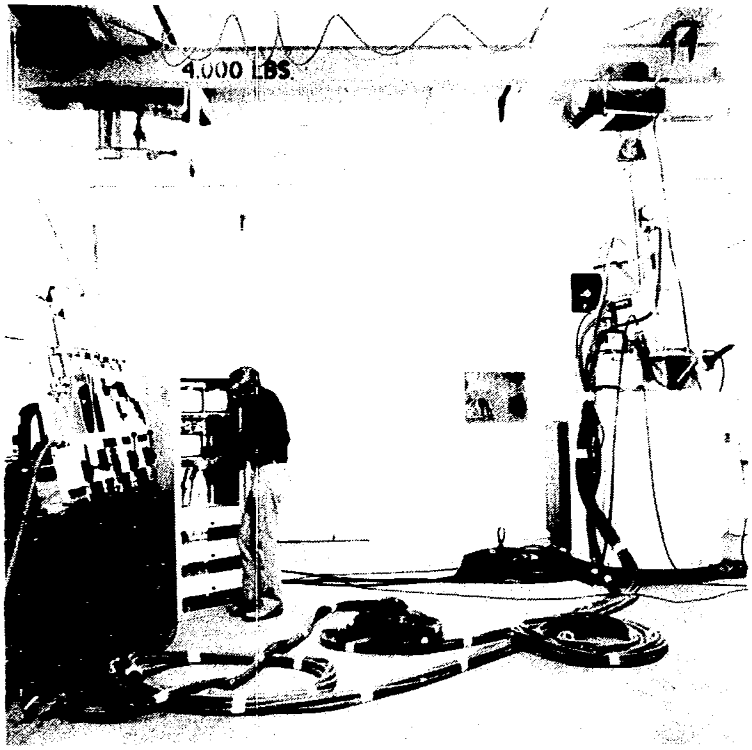


Figure 10. View of vent tool, liner, and control panel.

Design and Objectives

An evaluation to determine the most appropriate method for depressurizing, sampling, and inerting the liners in conjunction with the EG&G Idaho designed vent tool was undertaken by GPU. The evaluation was based on the data obtained during venting at TMI and characterization at BCL of PF-16.

During the venting process, PF-16 remained opened for approximately 75 min in order to allow for the hydrogen to diffuse out of the liner and air to diffuse in; however, when sampled at BCL, PF-16 was found to contain 12% hydrogen while depleted of oxygen. Two assumptions drawn from the PF-16 evidence were (a) hydrogen had been trapped in the resin bed matrix and, consequently, could not diffuse out of the liner and (b) hydrogen had been absorbed onto the resin and sufficient time had not been allowed for the hydrogen to desorb or elute from the resin and diffuse out of the liner. It was concluded that any future purging methods must force the trapped hydrogen out of the resin bed matrix and allow sufficient time for absorbed hydrogen to elute from the resin. These two conclusions were incorporated into the design and use of the sampling and purging system.

Scoping tests were performed on nonradioactive resin filled liners using the vent tool. The scoping tests examined and determined the following:

- Maximum positive pressure to breech the liner manway cover seal
- Maximum negative pressure to breech the liner manway cover seal
- Mixing and stratification of gases in the liner gas void and the vent tool sample housing
- Efficiency of purging liners with nitrogen pressurization and depressurization cycles.

Based on the scoping test results, it was concluded that the liners could be purged in a safe and efficient manner using a series of nitrogen pressurization and depressurization cycles with a maximum allowable pressure of 5 psig.

The objectives of the sampling and purging system are to work in conjunction with the vent tool to obtain representative samples from the liners, to analyze these samples and record pressure data, and to adequately purge the liners of hydrogen in preparation for shipment. In order to safely meet these objectives, the following basic design requirements were developed for the sampling and purging system:

- Must not be an ignition source for hydrogen
- Must provide overpressurization protection for liners during purging operations
- Must be capable of obtaining representative samples of liner gases through 100-ft long sampling lines

- Must be capable of sampling points in the blockhouse atmosphere
- Must interface with a gas chromatograph such that online sample analyses is possible
- Must contain sample bomb connections for obtaining radionuclide gas samples
- Must interface with appropriate filtration system for gases purged from the liners
- Must contain minimal amounts of void volume in the sampling system to prevent sampling error.

Data on the liners will include identification and quantification of the major constituent gases, pressure within the liners, and gaseous radionuclides. During the purging operation all gases will be vented to a high efficiency particulate air (HEPA) system.

Description

The sampling and purging system, located inside the Remote Support Facility obtains samples, purges, and monitors a liner through two 100-ft x 1/4-in. diameter stainless steel flexible hoses. The hoses are attached to the vent tool purge gas port located in the bottom section of the vent tool housing and to the sample port in the upper section of the housing. The system is constructed of 1/4-in. OD stainless steel tubing, nonsparking brass ball valves, a sample pump, and a gas chromatograph.

The sampling pump is a Gast Model Number 1531-107B-G288X rotary vane pump with a 42 L/min capacity. A glass chamber is installed on the pump inlet and outlet to visually confirm that water is not inadvertently being pumped from a liner. Based on availability, a pump constructed of nonsparking materials was not used in the sampling and purging system; however, two 60 micron, sintered metal filters are placed on the sample pump suction and discharge to prevent possible flame propagation should a combustible gas be present in the system. Depending on the valve lineup, the sampling pump can draw a gas sample from the vent tool sample housing or one of two points in the blockhouse atmosphere for analysis by the gas chromatograph. In addition, the pump purges a 300 cc sample bomb connected to the sampling and purging system. The sample bomb is disconnected and transported to the TMI-2 chemistry laboratory for analysis of gaseous radionuclides.

A Perkin-Elmer model Sigma 1B gas chromatograph analyzes the liner gases for H_2, O_2, N_2, CO_2, CH_4, and CO. The chromatograph contains Chromosorb 102 and Molecular Sieve 5A columns for separation of the sample into its constituent gases. A thermal conductivity type detector in conjunction with a helium or argon carrier gas and an electronic integrator quantify the constituent gases. Samples are injected into the gas chromatograph by an automatic gas sampling valve located on the chromatograph. The sample pump discharge purges the sampling valve with gas from one of the selected sampling locations. Once purged, the sampling valve is turned by the chromatograph computer using a pneumatic solenoid. This places the 0.5 cc contents of the valve into the chromatograph carrier gas stream for analysis. Once setup and calibrated, the gas chromatograph is programmed to operate automatically. Figure 11 shows the gas chromatograph.

In order to preclude the possibility of overpressurizing a liner, an electric solenoid valve is installed on the nitrogen inlet to the sampling and purging system. If the static liner pressure exceeds 5 psig, a pressure actuated switch closes the valve, stopping the flow of nitrogen to the liner during purging operations. The valve fails close in the event of a power loss.[a]

---

a. Pressure tests performed on a nonradioactive EPICOR liner indicated that the manway cover is the weakest point on a liner. The manway cover began to bulge when the liner was pressurized to 2 psig. The rubber gasket seal between the manway cover and the liner began to leak around 8 psig. The liner was pressurized to as high as 20 psig and although the seal leak increased, the manway cover remained structurally intact. This information in conjunction with the results of purging tests using pressures less than 8 psig resulted in the selection of 5 psig as the maximum allowable pressure during purging operations.

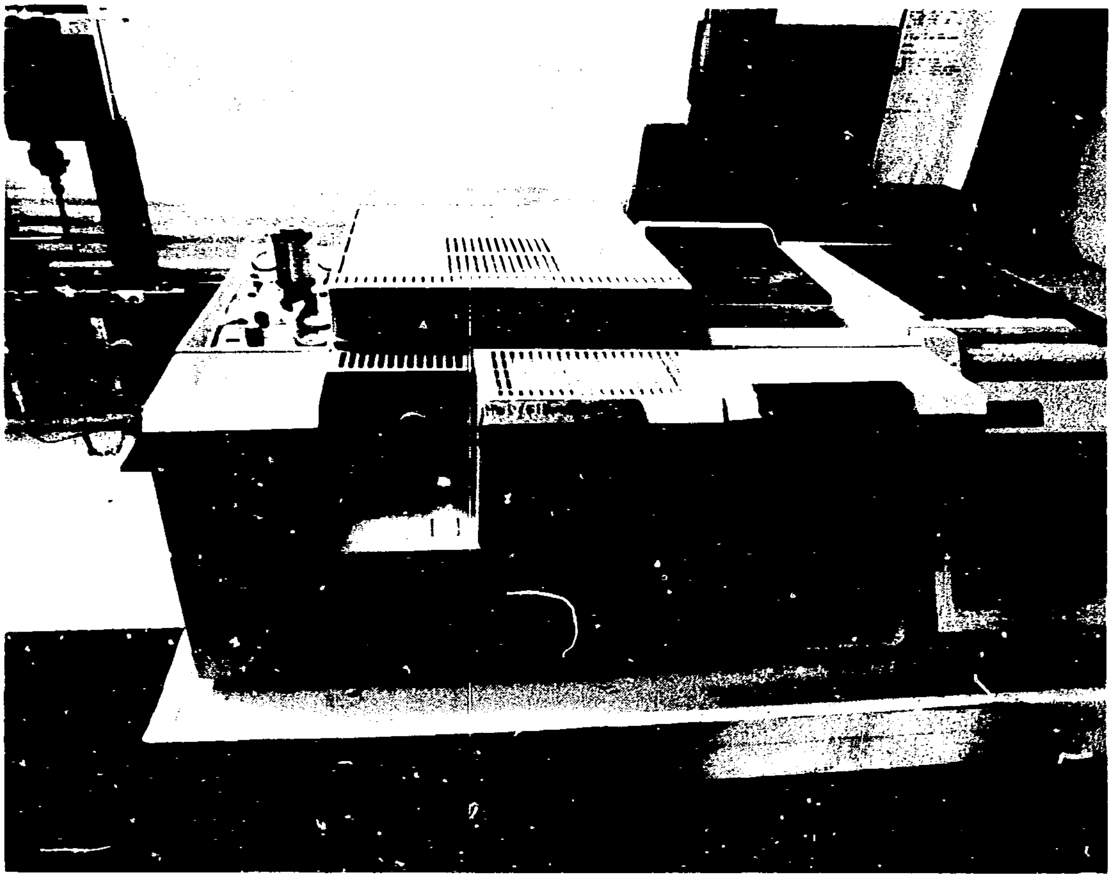


Figure 11. Gas chromatograph.

In the unlikely event of opening a liner pressurized to greater than the 20 psig designed sealing pressure of the vent tool, an ASME Section VIII relief valve is installed on the system and set at 20 psig. The relief valve discharges through the HEPA filter system. Figure 12 shows the sampling and purging system. The system has two modes of operation, (a) sampling and (b) purging and inerting.

In the sampling mode, samples are pumped from either the blockhouse atmosphere or the vent tool sample housing. When sampling from the vent tool housing, the sampling pump circulates the liner gases that are collected in the tool sample housing through the sampling and purging system, via the stainless steel flexible vent line connected to the sample port

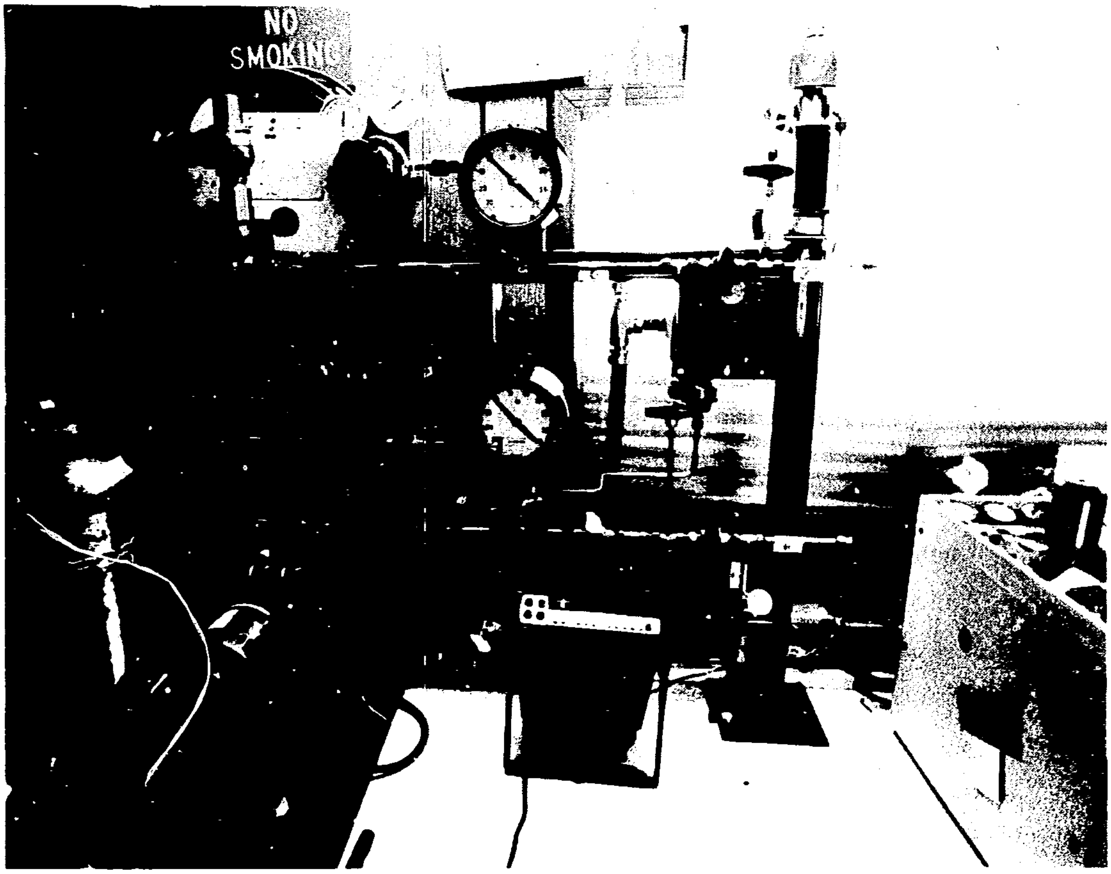


Figure 12. Sampling and purging system.

on the tool housing, and then back into the housing via the flexible stainless steel line connected to the purge port on the sample housing. Recirculation ensures a representative sample of the liner gases collected in the vent tool housing. After approximately 2 min has been allowed for recirculation, an online, 0.5 cc gas sample is injected into the gas chromatograph by the automatic gas sampling valve. The chromatograph analyzes the sample for H_2, O_2, N_2, CO_2, CH_4, and CO.

Sampling of the blockhouse atmosphere is provided by two additional sample ports located on the sampling system. The sampling and purging system is connected to the blockhouse by two 100-ft lengths of tygon tubing. One of the tubes allows the sampling pump to take suction from the top of the blockhouse atmosphere. The other tube allows sampling from the middle of the blockhouse atmosphere.

In a purging and inerting mode, the sampling and purging system is used to purge the liner of radiolytic gases and to inert the liner with nitrogen by a series of pressurization and depressurization steps. Nitrogen is supplied to the system at 50 psig from a 48,000-ft^3 capacity nitrogen tube trailer. This trailer also supplies nitrogen at 150 psig for inerting the blockhouse atmosphere. Two separate regulators on the trailer allow for the two different delivery pressures.

To accomplish liner purging and inerting, the sampling and purging system valves are aligned to allow nitrogen to flow into a liner through the flexible stainless steel line connected to the tool housing purge port. When the liner pressure has reached 5 psig, the nitrogen flow is stopped and the liner is depressurized by aligning the system valves to allow the gas in the liner to vent to a HEPA system through the flexible stainless steel line connected to the tool housing sample port. The liner is purged and inerted in cycles until the hydrogen concentration is reduced below 1% by volume. A cycle consists of pressurizing the liner to 5 psig, depressurizing to 3 psig, sampling, and then depressurizing to 1 psig. A full cycle takes approximately 20 min. Total inerting time is on the order of 2 to 5 h, depending on the liner's initial hydrogen concentration. After completion of liner purging and inerting, the liner is depressurized to atmospheric pressure.

During the initial pressurization, the liner pressure is held for up to 10 min at 1, 2.5, and 5 psig and pressure decay data is recorded. The static liner pressure is measured and recorded during each of these hold points by a pressure transducer located in the flexible stainless steel line attached to the sample port of the vent tool housing. Using ideal gas laws, the pressure decay data is analyzed to estimate the volumetric leak rate of gases from the liner.

CELL INERTING AND SHIELDING EQUIPMENT

The purpose of the cell inerting and shielding equipment is to eliminate the possibility of combustion in the storage cell if there should be a release of hydrogen into the storage cell during operation and to shield the personnel in the work area from excessive radiation fields. The subsections below describe this equipment.

Concrete Tool Enclosure

The tool enclosure, commonly referred to as the blockhouse, is a concrete cubicle, designed to replace the cell lid and enclose the vent tool, liner, and cell. It is open ended and has octagonal walls which are 114-in. high x 13-in. thick and weighs 36 tons. The enclosure contains four shielded windows for viewing the tool during positioning and two 6-in. pipe penetrations for purging the cell with inert gas. These penetrations also connect to a monitored HEPA filter which exhausts the interior of the enclosure in the event of a radiological release. The existing gasket around the top of the cell provides a seal between the cell and the enclosure. With the enclosure in place, the tool support assembly on, and cell drains flooded with water, an inert cell atmosphere surrounding the liner and tool can be achieved, and radiation in the work area is reduced to less than 10 mrem/h. The enclosure is moved from cell to cell for processing each liner using a 75-ton capacity crane.

Support Assembly

The support assembly is a 2-in. thick steel cover for the tool enclosure. Its purpose is to provide support for positioning the liner venting tool and to serve as a top for the blockhouse. The tool is suspended directly beneath the assembly by a cable attached to a 1500-lb capacity hoist. The support assembly positions the tool onto the liner using four rachet turnbuckles for horizontal and rotational movement and the hoist for vertical motion. The platform also contains four mirrors to view the vent tool through the blockhouse shield windows during orientation on the liner.

A rubber gasket on the support assembly provides an adequate seal between the platform and the blockhouse. The platform is bolted down after the tool is positioned on the liner. These bolts are sized to prevent support assembly lift for all credible events.[4] The inside surface of the support assembly is coated with a 1/2-in. sponge rubber sheet for shock wave attenuation in the event of a hydrogen detonation.

Cell Drain Seal

The drain seal consists of a water trap added to the SWSF sump system. This will permit inerting the SWSF cells without loss of inerting gas through the drain.

Ventilation System

The ventilation system for the blockhouse consists of a HEPA filter and a 5-hp blower. Capacity is 1000 cfm with the 8-in. diameter duct work. The filtered exhaust is monitored. The system intakes from a flow distributor in the concrete cell enclosure and from the exhaust of the sampling and purging system. The ventilation system is located in the Remote Support Facility.

Remote Support Facility

The Remote Support Facility is the operations center for the vent tool and the venting operation. The facility is a 21 x 8-ft mobile home type trailer. The trailer is reinforced with steel beams and is attached to a lifting sling for movement by the crane. The trailer contains: the HEPA filter and duct work for cell ventilation, an air compressor unit, and a control panel and TV monitors for the vent tool operation, the sampling and purging system, a gas chromatograph, and a room air-conditioner. The vent tool is connected to the support facility by a 100-ft long umbilical. Figure 13 shows the Remote Support Facility.

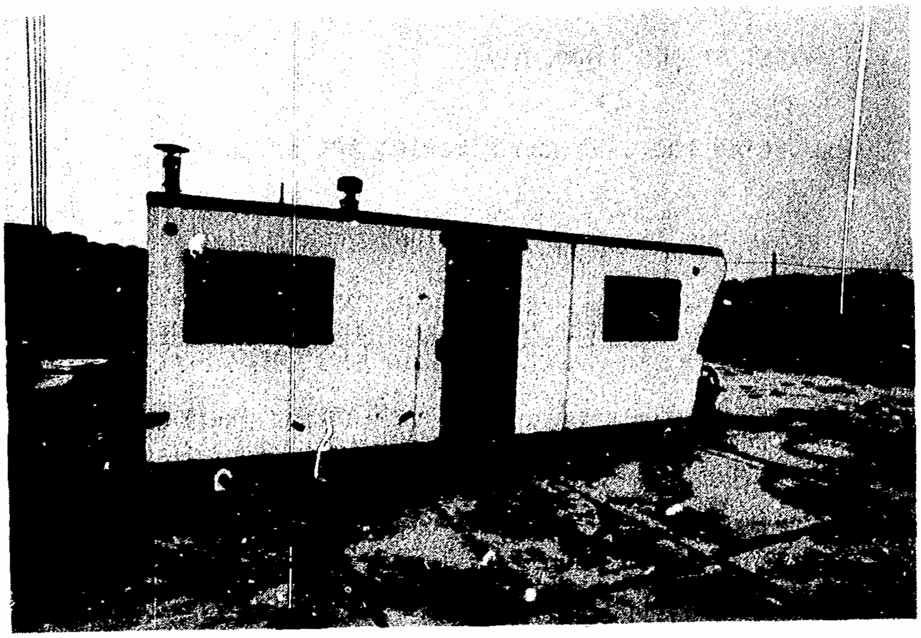


Figure 13. The Remote Support Facility.

OPERATION OF THE LINER AND CELL INERTING EQUIPMENT

This section describes the procedures used to sample and inert the liners and is divided into four subsections:

- Placement of the sampling and inerting equipment
- Removal of the liner plug
- Replacing the plug and removing the equipment
- Placing the liner in the shipping cask.

Placement of the Sampling and Inerting Equipment

After a liner is selected, the sampling and inerting equipment is staged so that all lifts can be accomplished without further crane movements. Following equipment staging, the 3-ft thick shield block is removed from the cell and the liner is visually inspected within the module cell. Mirrors are used for inspection to minimize radiation exposure to operating personnel. The liner ports, level controllers, and lifting gear orientation are noted. The shield block is then replaced.

After the liner port orientation (see Figure 3) has been determined, the appropriate spacers and guide brackets on the vent tool are adjusted. The cell lid is again removed and placed to the side. The blockhouse is rigged, lifted into position, and lowered onto the neoprene rubber gasket on top of the cell as shown in Figures 14, 15, and 16. The edges are surveyed for radiation streaming. If streaming is evident the blockhouse is slightly repositioned and lead blankets are used to minimize the streaming.

The support assembly is rigged and positioned as shown in Figure 17, 18, and 19, lowered onto the blockhouse, and bolted down leaving the tool suspended approximately 13 ft above the liner. Figure 20 shows the support assembly being bolted down and Figure 21 shows a schematic of the blockhouse and support assembly as a single unit.

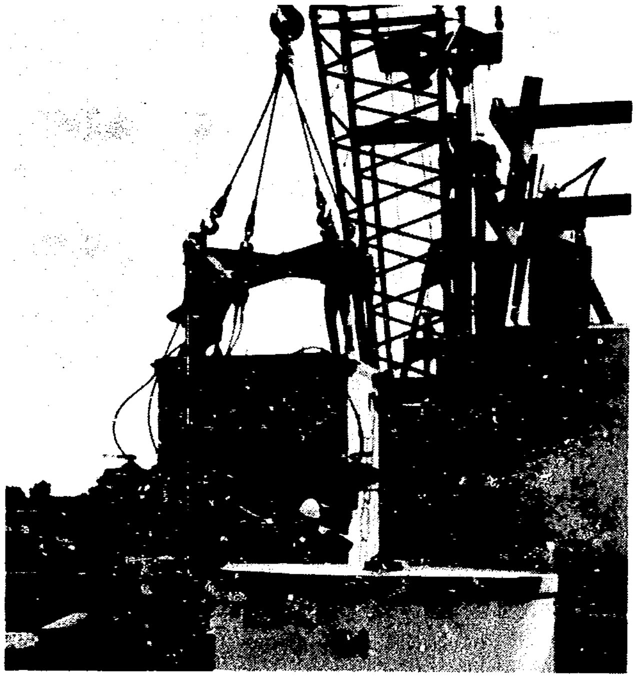


Figure 14. Rigging the concrete tool enclosure.

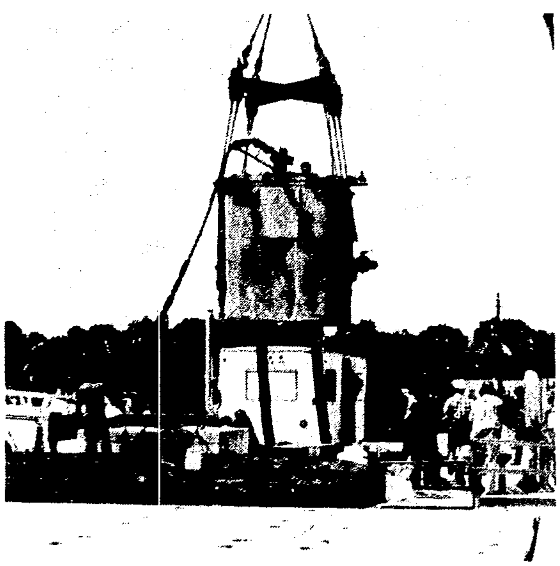


Figure 15. Positioning the concrete tool enclosure over an open cell.

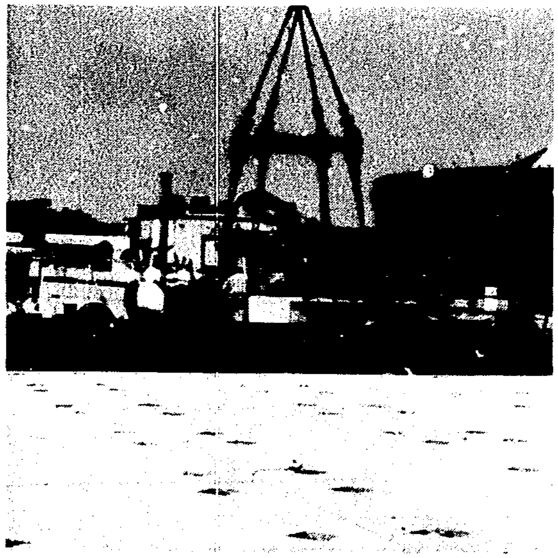


Figure 16. Lowering the concrete tool enclosure onto the cell neoprene gasket.

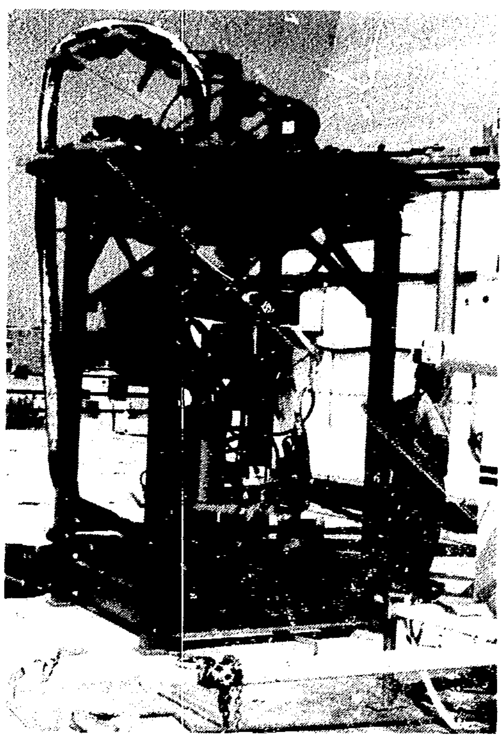


Figure 17. The support assembly and vent tool on the service structure.

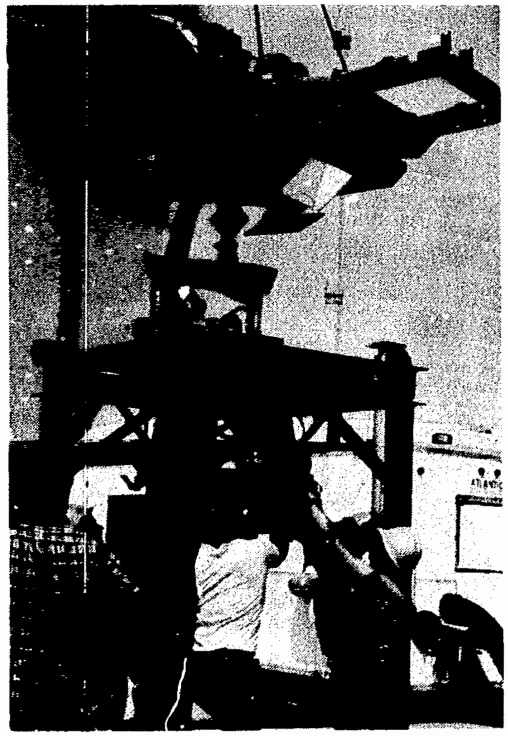


Figure 18. Removing the support assembly from the service structure.

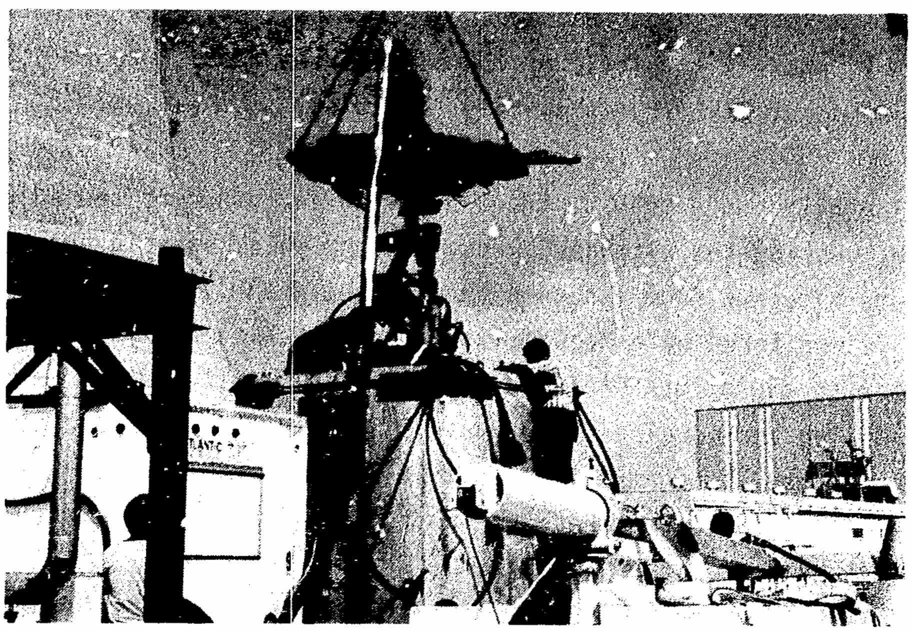


Figure 19. Placing the vent tool in the blockhouse.

Figure 20. Bolting the support assembly to the blockhouse.

Once the blockhouse and tool and support assembly are in place, the area radiation levels are reduced to below 10 mR/h. This allows for the tool umbilical, the blockhouse tygon sample lines, and the 8-in. ventilation lines to be attached to the Remote Support Facility with minimal exposure. Figure 22 shows a schematic of the blockhouse, tool, support assembly and Remote Support Facility completely assembled.

The nitrogen supply to the blockhouse is turned on and adjusted to 25 cfm. During the nitrogen purge, a 1-in. water seal in the module drain prevents nitrogen from escaping through the drain. Pressure in the blockhouse is monitored by a Magnahelic instrumentation and is kept below 1-in. of water to avoid loss of the drain loop seal. After 45 min of purging, the sampling and purging system valves are aligned to pump a sample from the blockhouse atmosphere. The sample is analyzed for O_2, N_2, and H_2 to ensure the cell atmosphere is inerted to less than 4% oxygen and less than 1% hydrogen.

The vent tool is lowered to within a foot of the liner using the hoist located on the support assembly. The tool guide brackets are centered over the liner lifting lugs using the positioning and rotation mechanisms on the

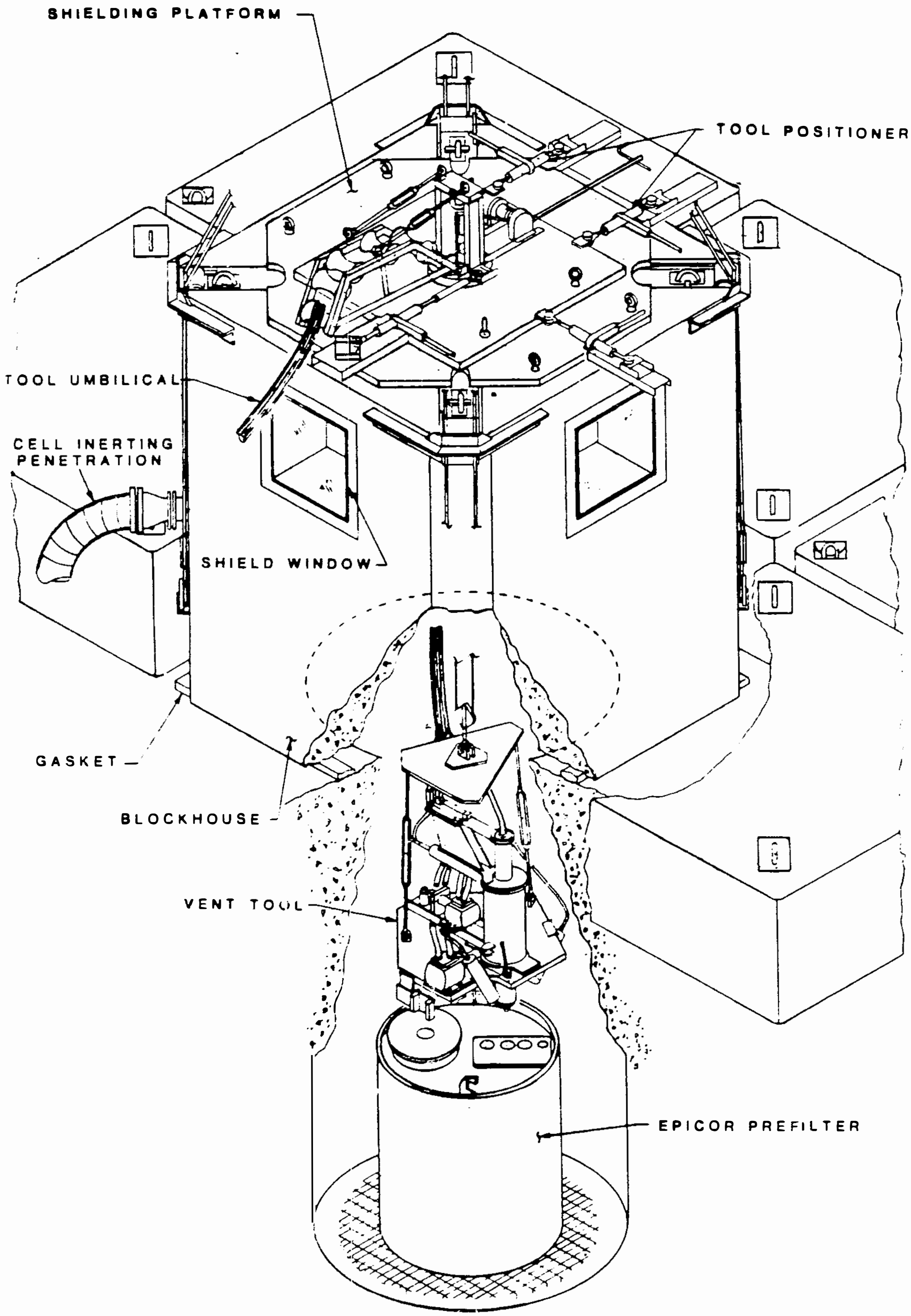


Figure 21. Isometric of the blockhouse, support assembly, and vent tool.

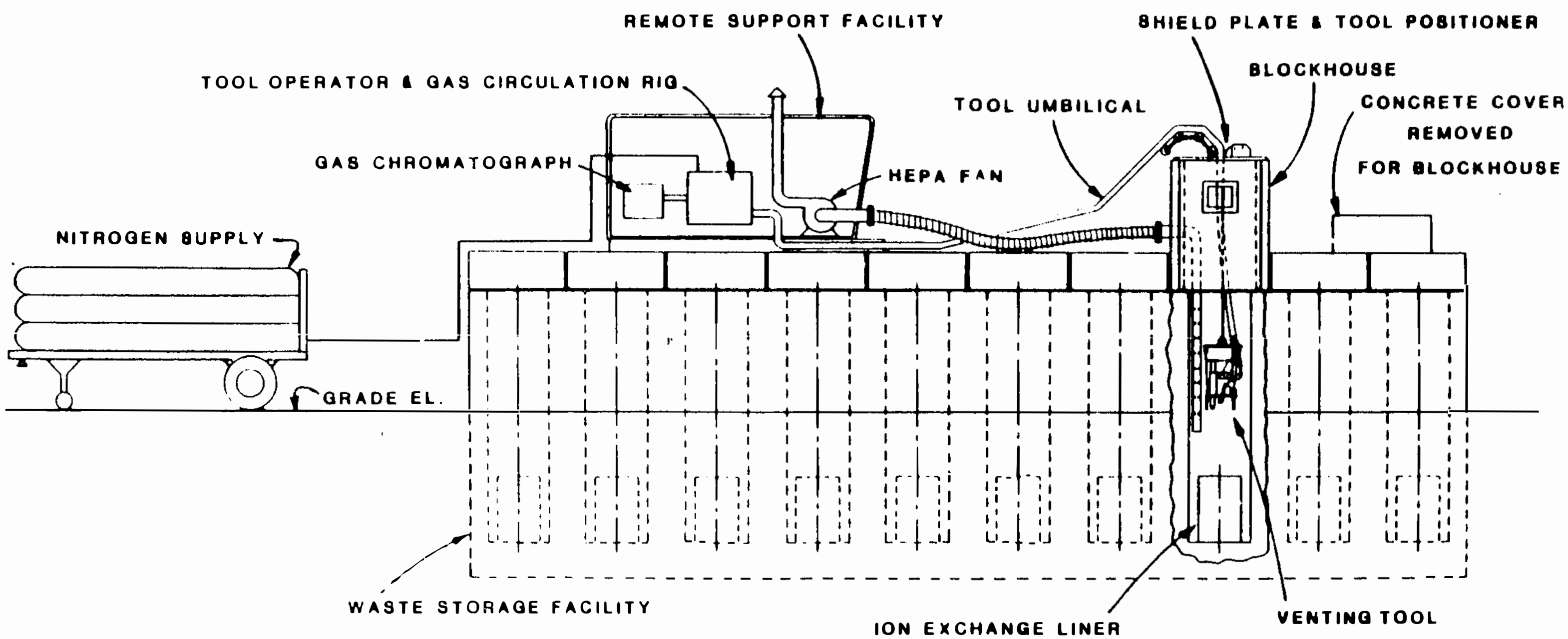


Figure 22. Schematic of the assembled inerting equipment.

support assembly. Lowering and centering the vent tool is monitored using mirrors that can be viewed through the shielded windows of the blockhouse and a TV camera positioned over one of the tool guide brackets. Figure 23 shows the TV image of the tool guide bracket over the liner lifting lug. The tool is lowered onto the liner lifting lugs about 5 in. from the liner where final positioning of the tool tip is accomplished using air-driven motors located on the vent tool. The tool tip is engaged in the plug and the tool is lowered further until the bottom of the housing is seated on the liner. Figure 24 shows the TV monitor image of the tool tip engaged into the plug.

Removal of the Liner Plug

In preparation for plug removal, the tool sample housing is inerted and sampled to confirm at least 98% N_2 inside the housing. The seal leak rate between the sampler and the liner is checked by pressurizing the tool sample housing to 5 psig with N_2 and measuring the pressure decay.

Provided an adequate seal exists, the liner plug is unthreaded and lifted out of the liner port. After allowing 20 min for gas diffusion between the tool housing and liner, the sample pump is turned on. The pump circulates the gas through the sampling lines and vent tool sample housing to ensure a representative sample. The gas sampling valve is then purged and a sample is injected into the gas chromatograph and analyzed for H_2, O_2, N_2, CH_4, CO, and CO_2. In addition, a gas sample is purged through a 300 cc gas sample bomb, isolated, and transported to the TMI-2 chemistry laboratory for radionuclide gas analysis.

After completion of the initial liner samples, a leak check is performed on the liner by pressurizing the liner with nitrogen to 5 psig and measuring pressure decay. The liner is purged with nitrogen to less than 1% H_2 by using a series of pressurization and depressurization steps. Once the H_2 is below 4% in the liner, the N_2 purge of the blockhouse is terminated. If a gas generation rate study is applicable, the tool will remain on the liner and the gases recirculated and sampled periodically until enough points are obtained to adequately define a gas generation curve.

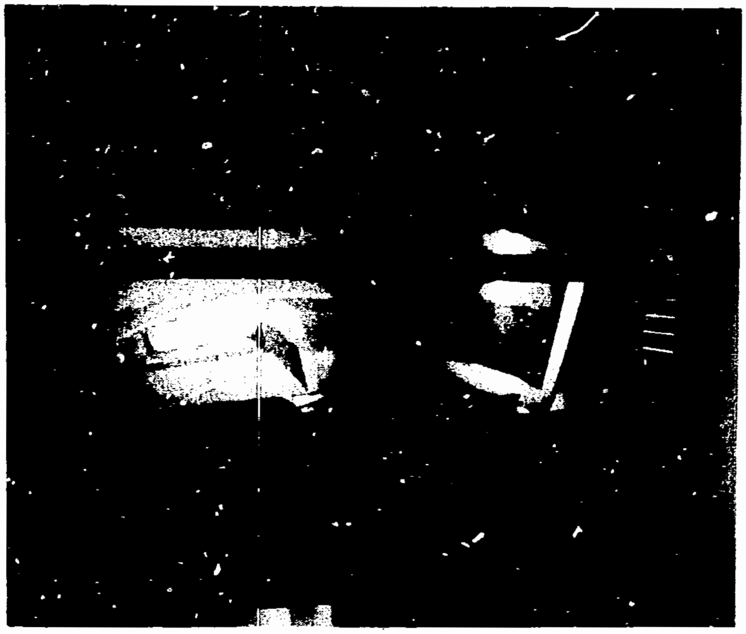


Figure 23. TV monitor image of the tool guide bracket engaging a liner lift lug.

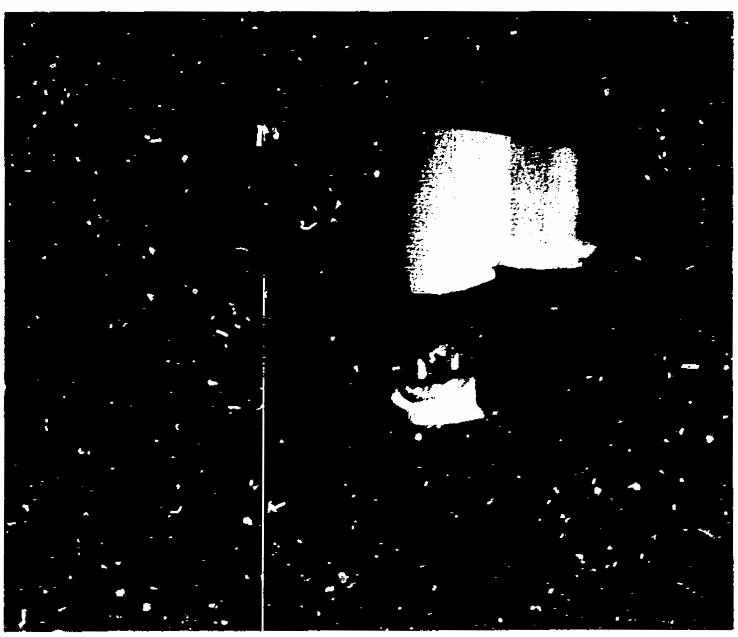


Figure 24. TV monitor image of tool tip engaging into the liner vent plug.

Replacing the Plug and Removing the Equipment

Upon completion of inerting and applicable gas generation rate studies, the liner is reinerted to less than 1% H_2, depressurized, and the plug is reinstalled and tightened. The tool is disengaged from the plug and, using the hoist, raised 13 ft off the liner. The blockhouse atmosphere is then exhausted through the HEPA system. The holddown bolts are removed from the support assembly, all umbilical and sampling connections are broken, and the tool and support assembly are lifted off of the blockhouse and placed on the tool service structure for routine maintenance. The blockhouse is lifted off the cell, staged for the next liner, and the cell lid is replaced. Applicable gas generation data is analyzed, and a preshipment storage window is determined. The method for determining this window is described in Appendix A.

Continuous airborne contamination levels are monitored for the blockhouse atmosphere and the HEPA exhaust during all previous operations by AMS 3 units. These units are set to alarm at 650 cpm above background. This provides an alarm at 50% of the 10 CFR 50 allowable release rate limit.

Placing the Liner in the Shipping Cask

Once the liner is prepared for shipment and a shipping cask is available, the liner will begin shipment by the end of the preshipment storage window in the following manner.

The shield block lid is removed from the cell and the cell adapter plate is placed over the cell, the transfer bell lowered into place and, the liner is raised into the bell. The liner and bell are moved over to the shipping cask and loading platform as shown in Figure 25. The transfer bell is then aligned with the cask adaptor plate and the liner is lowered into the cask. The bell and adapter plate are removed and the cask lid is positioned and torqued down. If the liner is expected to reach 4% hydrogen during the shipping period, the cask is inerted with nitrogen by feed and bleed or flow through depending upon the cask design. Shipments ultimately go to the INEL. The maximum estimated shipping window is 16 days. Once in Idaho, the plug is removed and the liners are stored in shielded silos for future research.[5]

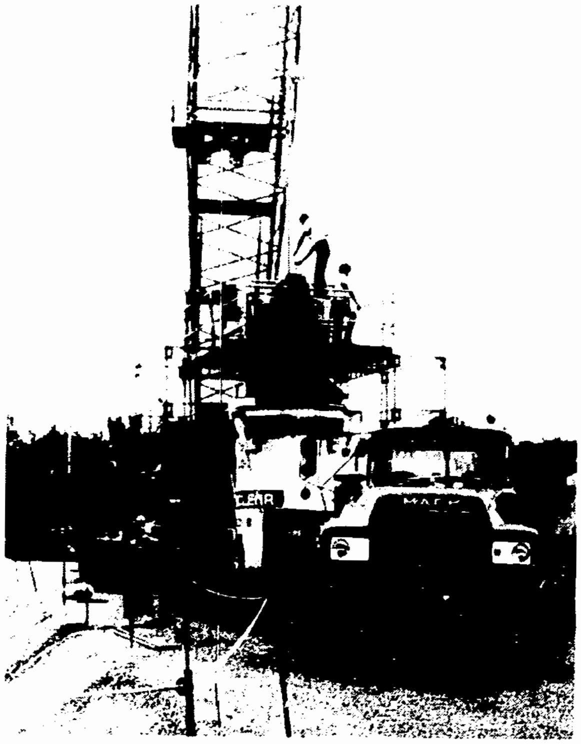


Figure 25. Lowering liner and transfer bell onto shipping cask.

FUNCTIONAL TESTING

Tests were performed on nonradioactive liners to demonstrate the safety and operability of the complete inerting system at the Solid Waste Staging Facility. Preliminary testing was conducted on an air filled liner and the functional test was performed on a hydrogen filled liner.

Preliminary testing demonstrated that the blockhouse and liner could be inerted successfully. This testing also provided additional training for operators and assisted in making the operating procedure more efficient prior to use on a radioactive liner.

Functional testing of the entire system was performed using a dewatered, nonradioactive liner placed in an empty cell and loaded to approximately 40% hydrogen and 60% nitrogen. The liner was treated as radioactive. Consequently all operations were performed in the same manner as they would be for an actual radioactive liner. The successful completion of this test indicated that the inerting system could safely and efficiently purge a liner of hydrogen. The functional testing also demonstrated the integrity of the system and the capabilities of the operators to work with the remote equipment.

GAS GENERATION STUDIES

This section describes the logic by which the liners are grouped for gas generation studies, data is collected, and the resultant gas generation rates. The need for gas generation studies was identified in the EG&G Idaho Safety Analysis Document (SAD) and GPU Technical Data Report (TDR) No. 274 (See References 1 and 6). TDR 274 concluded that quantities of radiolytically generated hydrogen inside the EPICOR prefilters could be in excess of the lower limit of flamability. In addition, the report cautioned that hydrogen generation rates could be high enough to cause the hydrogen concentration within the liners to reach flammable limits during shipment even if they were inerted prior to shipment. The basis for those conclusions was partly theoretical and partly dependant on extrapolated data from experiments performed on similar ion-exchange media. The EG&G Idaho SAD pointed out the need to address safety concerns in dealing with critical quantities of hydrogen.

Grouping the Liners for Study

The purpose of placing the liners in groups is to provide an efficient means for collecting experimental data to ensure safe handling and shipping of the liners. Based on transportation regulations forbidding the transport of combustible mixtures of gases, it is desirable to prove that once inerted to below 1% hydrogen, the EPICOR liners can meet a safe shipment criteria of less than the lower flammability limit for hydrogen or less than the lower flammability limit for oxygen (4% and 5.1% by volume, respectively) for the entire shipping window. The maximum estimated time required for shipping EPICOR liners from TMI to INEL is 8 days; however, in order to incorporate a safety factor, 16 days was chosen as the shipping window.

Prefilter Resin Categorization Plan

After examination of the prefilter resin loadings it was determined that for the purpose of gas generation studies, all 49 liners stored in the SWSF could be placed into six categories, three categories from the organic resin filled liners and three categories from the organic and zeolite filled liners. The selection of these categories was based on resin mix and ^{90}Sr loading.[a]

The highest curie loaded liner in each category will generate the most hydrogen for that category; therefore, in order to avoid performing gas generation studies on all 49 liners, only the highest curie loaded liner in each category was selected for study. Provided that these worse case liners could be proven to meet the safe shipment criteria, all liners in the same category would also meet the safe shipment criteria. The six liners selected for study are PF-3, -6, -7, -20, -37 and -46.[b]

Data Collection

In order to determine the hydrogen generation rate for a selected liner, the liner is purged of hydrogen to below 1%. Increases in the hydrogen concentration are then monitored at varying time intervals until an adequate hydrogen versus time curve can be plotted. In collecting data for this curve, two things need to be realized:

1. Immediately after the liner is purged the resins will begin to elute hydrogen to achieve the new equilibrium state. The elution portion of the curve will be steep and should not be mistaken for hydrogen production. Consequently, data points must be close enough to define the curve in this region.

---

a. More specific information on categorization by resin mix is considered proprietary information by the EPICOR Company.

b. In retrospect, seals adequate for hydrogen generation studies could not be achieved on several of the selected liners. To compensate, alternate liners from the same category were studied. After purging, studying, and inerting 18 liners, the data shows a good correlation between curie loading and hydrogen generation rate while no apparent correlation exists between the six categories of resin mix and generation rate. Ultimately hydrogen generation rates in the liners not studied were estimated by ratioing the total curies to the average hydrogen generation rate of the liners studied and not by the prefilter resin catagorization plan.

2. Once the new equilibrium is reached any increase in hydrogen will be due mainly to generation.

In preparation for gas generation studies on the 49 liners, scoping tests were performed on a radiologically clean liner. The approximate time for the elution portion of the curve to level out at an equilibrium was determined. The results indicated that sampling every 2 h for approximately 12 h would adequately define the elution region of the curve. Once the resins have reached the new equilibrium, the generation portion of the curve will be either linear or logrithmic, depending on whether the liner is air tight. In any case, the curve will be approximately straight at low concentrations and sampling at intervals longer than 2 h becomes feasible (6, 12, and 24 h intervals were chosen). Appendix A describes the use of the hydrogen versus time curve to calculate the hydrogen generation rate.

In addition to the generation data, liner pressure changes are monitored by a transducer and recorded on stripcharts; however, due to low hydrogen production rates, non air tight liners, and barometric pressure fluctuations the data contributes little to determining generation rates. The primary intent of this data is for a recorded pressure history of the studied liner. In addition to providing evidence that a liner has been purged a satisfactory number of times with nitrogen, the pressure history also shows any unusual pressure transients which may have occurred during study.

Results

As of December 31, 1982, 18 EPICOR liners have been opened, characterized, and inerted using the prototype gas sampler and the associated aux- iliary equipment. Ten of the 18 liners had hydrogen generation studies performed, three from the original characterization list (PF-3, -7, -20) and seven additional liners (PF-1, -2, -11, -18, -27, -45 and -47). Generation rates on the other eight liners were determined by interpolating a plot of hydrogen generation rate versus curie loading for the 10 studied liners. Table 2 presents the data, generation rates, and storage windows for the 18 liners.[a]

TABLE 2. HYDROGEN GENERATION RATES AND DATA FROM EPICOR PREFILTERS

Liner	Curie Loading	H_2 Generation Rate (L/h x 10^3)	Opening Gas Composition (%)[a] H_2	O_2	N_2	Opening Pressure (psig)[b]	Calculated Storage Windows (days)
1	1498	8.44	3.60	--	90.00	--	45
2	1052	8.32	4.50	0.5	92.80	--	46
3	1878	9.90	9.90	--	87.50	--	37
6	166	N/D	<0.01	--	97.00	-1.30	475
7	1402	7.02	3.70	--	91.40	--	50
8	1367	8.28	8.00	--	89.40	--	50
9	1351	7.69	12.90	--	85.30	--	50
11	910	6.63	11.50	--	91.00	--	50
18	2025	9.42	26.00	--	66.80	0.93	31
20	1954	8.44	22.40	--	72.70	2.30	45
27	1954	11.20	7.30	1.5	88.40	--	32
44	1845	10.70	10.40	--	86.70	--	34
45	2036	12.00	0.70	0.7	99.00	-1.00	29
46	2184	11.90	0.10	--	98.00	--	30
47	1939	14.80	12.80	--	82.00	--	22
48	1939	11.20	0.10	1.2	94.80	--	32
49	1776	10.30	2.70	--	89.00	--	35
50	1600	9.49	13.40	--	81.70	--	39

a. All oxygen percentages not listed are less than 0.2 %.

b. All pressures not listed are within 0.2 psig of atmosphere pressure.

a. The period of time a liner can remain in the SWSF after being inerted and still be safe for shipment is called the liners storage window. Appendix A presents the method for calculating the storage window.

After successfully inerting and shipping 18 of the EPICOR prefilters, the following observations have been made:

- The majority of the liners are not airtight, consequently very few liners were found to contain any pressure.

- In addition to H_2, O_2, and N_2, all liners contained CO_2 and trace amounts of CO and CH_4.

- Upon opening, Liners PF-6 and -45 were at a negative pressure. It is postulated that this negative pressure was due to insufficient generation of hydrogen and carbon dioxide to replenish the volume of oxygen depleted.

- All liners showed significant oxygen deficiency, generally less then 0.2% oxygen upon opening.

- The average hydrogen production rate for the EPICOR prefilters is 5.94×10^{-6} L/Ci-h. With this rate and assuming the liner does not leak, a 2000-Ci EPICOR liner will generate a 4% mixture of H_2 in a N_2 and CO_2 atmosphere, in approximately 100 days.

- The hydrogen generation rate versus curie loading is approximately linear for the range of liners studies. (See Figure 26).

- There was no apparent correlation between the six different categories of liners and hydrogen generation rates.

- Liners PF-18 and -20 were found at a significant positive pressure indicating a tightly sealed vessel. The volume of hydrogen in these vessels compared to within 24% of that predicted by the experimentally determined generation rate (5.94×10^{-6} L/Ci-h).

- During shipment all inerted liners remained well below 4% by volume hydrogen and below 5% by volume oxygen.

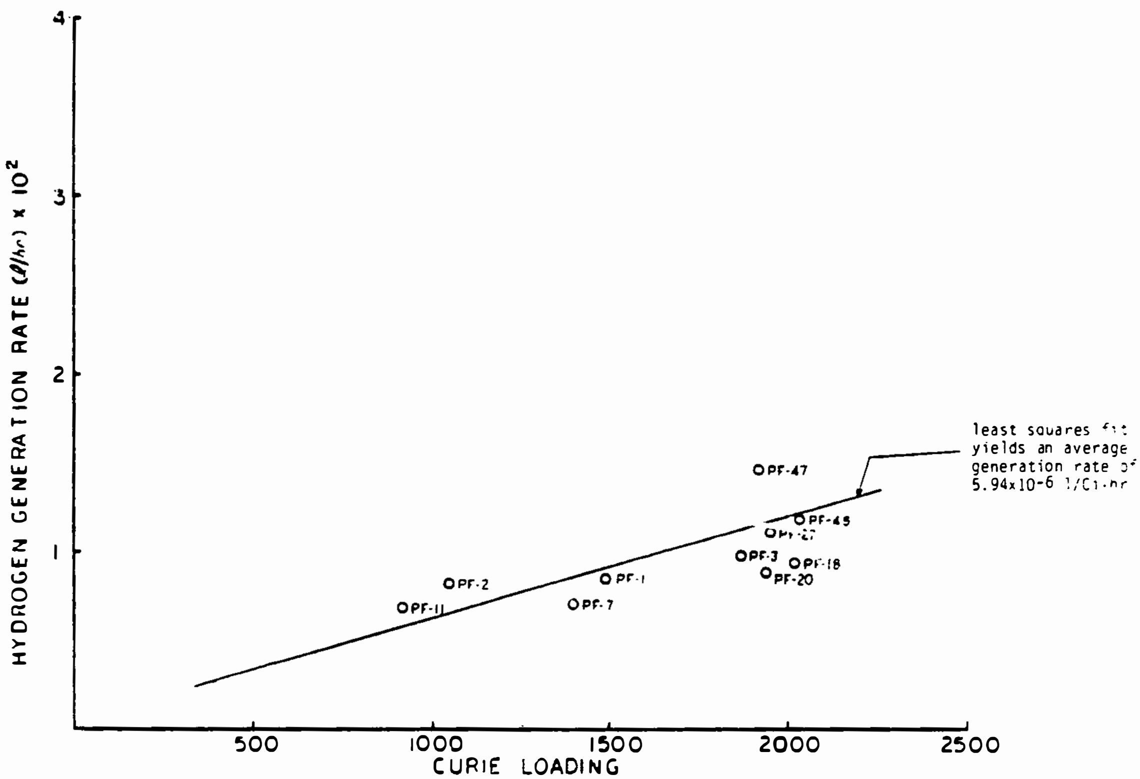


Figure 26. Hydrogen generation rate versus curies for EPICOR liners.

CONCLUSION

As of December 31, 1982, 18 of the 49 EPICOR II prefilters have been successfully inerted and shipped from TMI to the INEL. The data collected from the gas generation studies provided the information to ensure safe handling and shipping of the prefilters with respect to hydrogen generation. The remaining 31 liners will continue to be inerted and shipped at approximately four liners per month until completion.

Ten of the 18 liners shipped were studied for hydrogen generation. The average hydrogen generation rate is 5.94×10^{-6} L/Ci-h. The magnitude of this generation rate predicts safe shipping windows well in excess of the necessary 16 day shipping window required by DOE. Further, it is not expected that the 31 remaining prefilters will vary significantly from the first 10 studied, with respect to hydrogen generation. Consequently, all remaining liners are predicted to meet the safe shipping criteria of less than 4% hydrogen during transport.

The prototype gas sampler and its auxiliary facilities have provided a safe, remote method of sampling, purging, and inerting the EPICOR II prefilters. The remote manner in which this equipment is used has saved significant man rem exposure, avoided the personnel hazards associated with critical quantities of hydrogen gas, and provided data to aid in the processing of highly loaded ion-exchange media.

REFERENCES

1. J. R. Sheff, Evalution of Data, Literature, and Experiments Related to Hydrogen Generation in PF Vessels, GPU/TDR 274, December 24, 1981.

2. Battelle Columbus Laboratories, Preliminary Characterization of EPICOR II Prefilter 16 Liner, GEND-INF-015, November 1981.

3. John M. Bower, Development of A Prototype Gas Sampler for EPICOR II Prefilter Liners, GEND-INF-025, September 1982.

4. J. Greenborg, P. Babel, S. Queen, Preparation of EPICOR II Liners for Shipment, General Public Utilities, Safety Evaluation-008, March 29, 1982.

5. R. C. Schmitt and K. C. Sumpter, Research and Disposition of Highly Loaded Organic Resins, Published by EG&G Idaho, Inc., 1982.

6. R. C. Green, A Conceptual Safety Assessment of the EG&G Designed EPICOR II 4 x 4 Liner Sampling Tool, December 11, 1981.

APPENDIX A

DETERMINING HYDROGEN GENERATION RATES AND STORAGE WINDOWS IN EPICOR LINERS

APPENDIX A

DETERMINING HYDROGEN GENERATION RATES
AND STORAGE WINDOWS IN EPICOR LINERS

Assumptions

1. Hydrogen generation rate is constant in EPICOR liners

2. EPICOR liners are not airtight, consequently they do not build up pressure

3. Two years is long enough for hydrogen concentrations to reach an equilibrium with the liner leak rate and generation rate.

Theory

Calculating Hydrogen Generation Rates in Non Airtight Liners

In order to model the hydrogen concentration inside a nonairtight EPICOR liner a standard component balance for hydrogen will be set up and solved for the generation rate. The leak rate term for air or gas, F_{out}, will then be eliminated using the fact that a logrithmic curve can be defined by three points on that curve (two points from a two week generation study and the equilibrium value of hydrogen in the liner after two years of storage).

Hydrogen component balance . . .

$$\frac{d(VC_H)}{dt} = F_{in} C_H^{outside} - F_{out} C_H + K_H \text{ .}$$

Since the concentration of hydrogen outside the liner at any time is zero the equation simplifies to

$$V \frac{dc_H}{dt} = -F_{out} C_H + K_H$$

where

K_H	=	hydrogen generation rate, L/h
V	=	gas void volume of liner, L
C_H	=	hydrogen concentration in the liner
$C_H^{outside}$	=	hydrogen concentration outside the liner
F_{out}	=	leak rate of gas out of liner, L/h
t	=	time, hours (h).

Solving the differential equation for the hydrogen generation rate . . .

$$K_H = \frac{F_{out}\left[C_H^f - C_H^o \exp\left(-F_{out}\,\Delta\, t/V\right)\right]}{1 - \exp\left(-F_{out}\,\Delta\, t/V\right)} \qquad (1)$$

where

C_h^f = concentration of hydrogen at $t = t_f$ during generation study

C_H^o = concentration of hydrogen at $t = t_o$ during generation study.

Looking at Equation (1), suppose that t is such a large period of time that C_H^f has reached an equilibrium with the generation and leak rates (i.e., $C_H^f = C_H^\infty$ and Δt is equivalent to ∞). This is essentially taking the limit as t approaches infinity i.e.,

$$K_H = \frac{F_{out}\left[C_H^f - C_H^o \exp^0\left(-F_{out}\,\Delta\, \overset{\infty}{t}/V\right)\right]}{1 - \exp^0\left(-F_{out}\,\Delta\, \overset{\infty}{t}/V\right)} \;.$$

The exponential terms drop out and the equation reduces to

$$K_H = F_{out}\, C_H^f$$

or

$$K_H = F_{out}\ C_H^{\infty} \qquad (2)$$

where

C_H^{∞} = the concentration of hydrogen in the liner at equilibrium.

Since K_H is a constant, Equation (2) can be substituted into Equation (1)

$$K_H\ F_{out}\ C_H^{\infty} = \frac{F_{out}\left[C_H^f - C_H^0 \exp\left(-F_{out}\ \Delta\ t/V\right)\right]}{1 - \exp\ -F_{out}\ \Delta\ t/V} .$$

Solving for the gas leak rate, F_{out}

$$F_{out} = \frac{V}{\Delta t} \ln \frac{C_H^{\infty} - C_H^f}{C_H^{\infty} - C_H^0} . \qquad (3)$$

And finally, in order to eliminate the gas leak rate from the computation, substitute Equation (3) into Equation (2) yielding:

$$K_H = \frac{-V}{\Delta t}\ C_H^{\infty} \ln \frac{C_H^{\infty} - C_H^f}{C_H^{\infty} - C_H^0} . \qquad (4)$$

Equation (4) indicates that the determination of the hydrogen generation rate in a leaking (nonpressurized) liner is dependent on three points from the generation curve and the liner volume.

Modeling the Hydrogen Concentration in a Leaking Liner

Solving Equation (1) for C_H^f yields the hydrogen concentration in the liner at any time, t, based on the calculated K_H and F_{out} values and the initial starting point, C_H^0.

$$C_H^f = \frac{K_H}{F_{out}} + C_H^0 - \frac{K_H}{F_{out}} \exp\ (F_{out}\ \Delta\ t/V) . \qquad (5)$$

Equation (5) models the H_2 concentration provided the liner remains in a leaking mode (nonairtight); however, in order to be conservative, for storage and shipping purposes, we will assume the liner stops leaking after inerting is completed.

If the liner does not leak gas the equation modeling the concentration is

$$C_H^f = C_H^o + \frac{K_H \Delta t}{V} \quad . \tag{6}$$

A plot of Equation (6) using the calculated generation rate for PF-3 is shown in comparison to the actual data for this liner in Figure A-1.

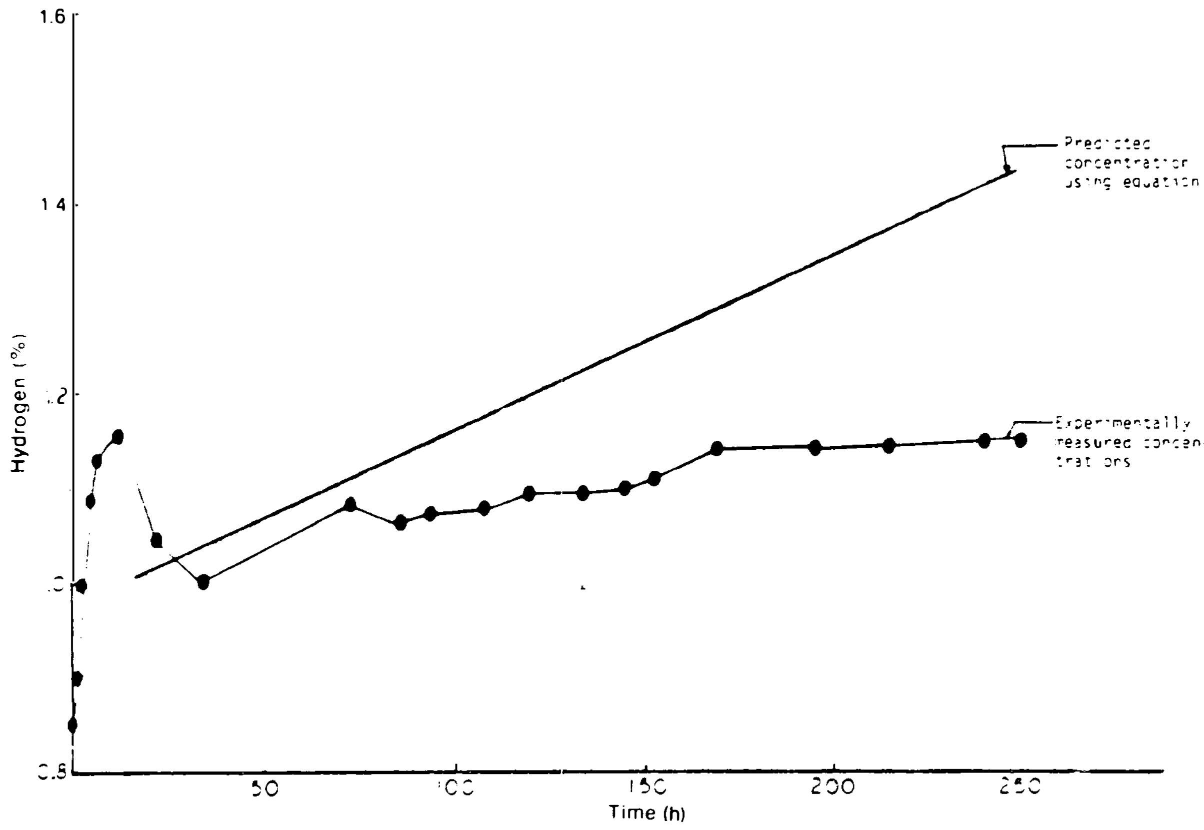


Figure A-1. Predicted and experimental hydrogen concentration versus time for EPICOR prefilters during a two week generation study.

Determining Storage and Shipping Windows

Once the generation rate is solved the storage window can be calculated in a conservative manner by assuming the liner stops leaking and all hydrogen produced remains in the liner. Since the worse case shipment is 16 days or 384 h and the hydrogen concentration at the beginning of storage is less than $C_H^o = 0.01$ and the hydrogen concentration at the end of shipment must be less than $C_H^f = 0.04$

$$t \text{ storage} = \frac{(0.04 - 0.01)}{K_H} - 384 \text{ (h)} \qquad (7)$$

where t storage equals the time a liner can be stored on the island prior to shipment without being reinerted.

Example Calculation on PF-3

Data:

Liner H_2 concentration upon opening: $C_H^\infty = 0.099$

H_2 generation data point taken from Figure A-1:

$C_H^o = 0.00992$

$t_o = 36$ h

H_2 generation data point taken from Figure A-1:

$C_H^f = 0.0114$

$t_f = 156$ h.

Calculation

1. Plug data points into Equation (4) to calculate the generation rate, K_H.

$$K_H = \frac{7141}{126\ h} (0.009) \ln \frac{(0.099 - 0.0114)}{0.099 - 0.00992}$$

$$K_H = 0.00989\ L/h \quad .$$

2. To be conservative, assume the liner stops leaking and calculate the storage window with Equation (7).

$$t\ storage = \frac{(0.03)\ (7141)}{(0.00989\ L/h)} - 384\ h = 1782\ h = 74.2\ days \quad .$$

3. To further enhance the conservatism by a safety factor of 2, divide the calculated storage window by 2 and set this value equal to the storage window.

$$t\ storage = \frac{74.2}{2} = 37.1\ days \quad .$$

Conclusion

PF-3, after being inerted to less than 1% H_2, can be stored at TMI for 37.1 days, shipped for 16 days and arrive, at its destination at less than 4% H_2.