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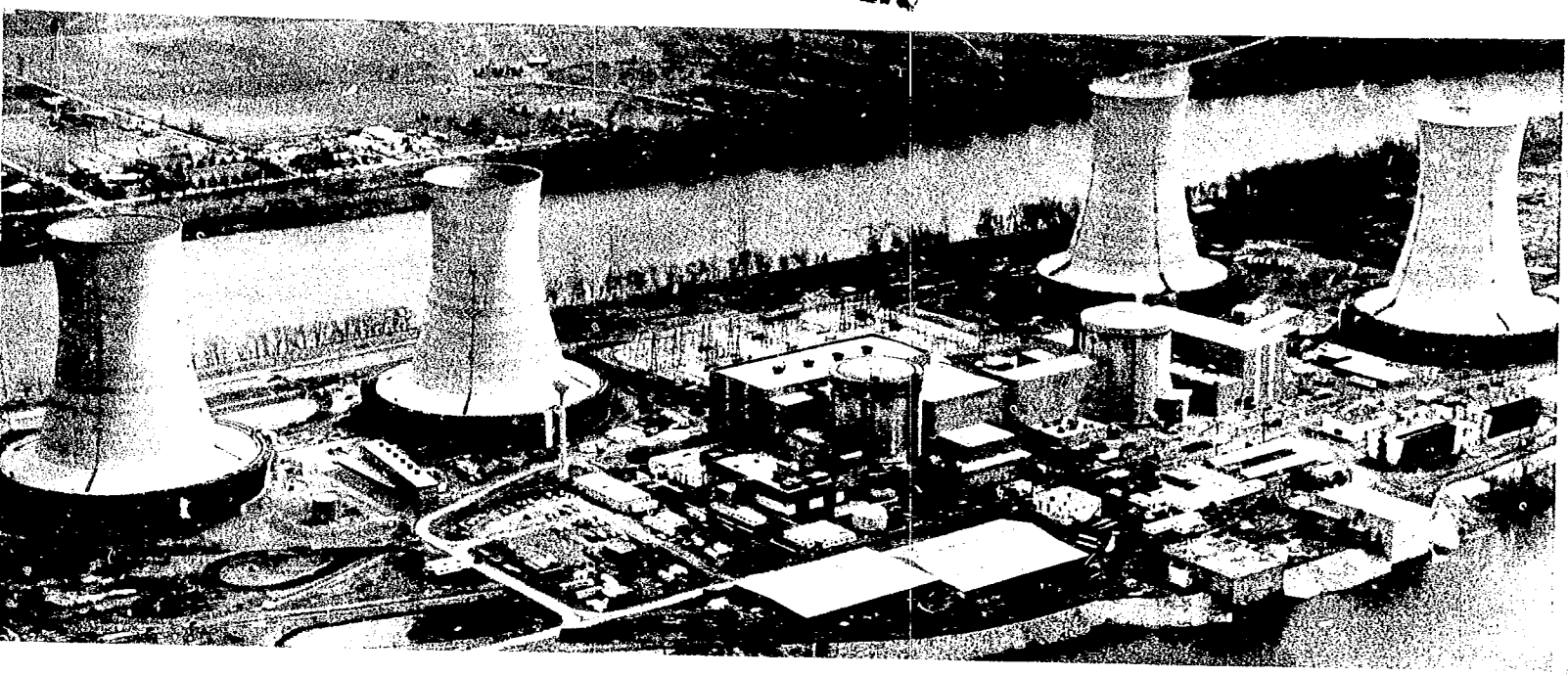

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PRELIMINARY CHARACTERIZATION OF EPICOR II PREFILTER 16 LINER

Battelle Columbus Laboratories

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

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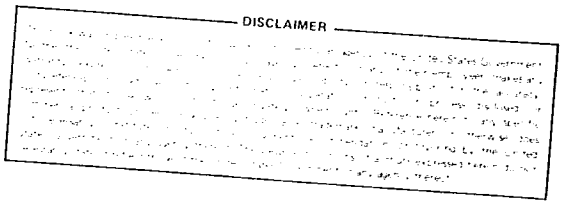

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ABSTRACT

Characterization of the EPICOR prefilter liner number 16 will provide information to aid in the development of technology for safely processing highly loaded ion exchange media that was used to decontaminate water from the TMI-2 auxiliary and fuel handling building. This report provides a historical record of (a) liner preparation for shipment, (b) liner shipment, (c) design and development of associated specialized handling and sampling equipment, (d) problems encountered, (e) corrective and/or alternative actions taken, and (f) liner transfer to the hot cell. This report summarizes the preliminary core sampling and ion exchange media observations, gas sampling analyses and results, liner visual examinations, liquid sample and preliminary results, external gamma scans, and liner temperature profile.

CONTENTS

FIGURES

TABLES

PRELIMINARY CHARACTERIZATION OF EPICOR II PREFILTER 16 LINER

INTRODUCTION

The Department of Energy is conducting a TMI-2 Information and Examination Program[a] to gain information that will be of generic benefit to the safety of all light-water reactors and to aid in the accident cleanup and decontamination of other civilian nuclear plants. As part of this program, EPICOR II Prefilter 16 liner (PF-16) is being examined at Battelle Columbus Laboratories (BCL) to aid in the development of technology for safely processing contaminated ion exchange media and to gain information on the shelf life of these media and liners. The EPICOR II system was used to decontaminate water from auxiliary and fuel handling building (AFHB) at TMI-2.

The program includes shipment and receipt of the liner, in-cell nondestructive and destructive examinations and storage/monitoring of the liner for 24 months following in-cell examinations. This report covers progress through mid July, 1981. The specific activities included in this interim report are the BCL safety analysis, liner preparation and shipment, liner receipt and transfer into hot cell, transfer device construction, in-cell gas sampling and liner visual examination, ion exchange media coring and examination, liquid sampling, external gamma scans, and liner temperature profile. A subsequent report will be issued at the completion of the in-cell activities. and a final report will be issued at the completion of the 24-month storage/monitoring period.

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a. Four organizations, the General Public Utilities Nuclear Company (GPUNC), the Electric Power Research Institute (EPRI), the Nuclear Regulatory Commission (NRC), and the Department of Energy (DOE), have agreed to establish a TMI-2 Technical Information and Examination Program and have signed a Coordination Agreement to implement this Program. The Coordination Agreement identifies the objectives to which the signatories subscribe and defines, in broad terms, methods to achieve these objectives consistent with the other obligations of the signatories. These organizations are identified by the acronym GEND.

EPICOR II LINER DESCRIPTION

The EPICOR II liner is a five feet high right circular cylinder four feet in diameter and contains approximately 30 cubic feet of ion exchange media. The walls and top are 1/4 inch thick and the bottom is 1/2 to 5/8 inch thick. The liner is fabricated of A36 carbon 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 a typical EPICOR II liner is shown in Figure 1.

The liner selected for characterization is EPICOR II prefilter liner No. 16 (PF-16). Schematic views showing the configuration of the liner penetration plugs and the liner lifting lugs are presented in Figure 2.

The liner is believed to contain inorganic zeolites and three types of organic ion exchange media (anion, cation, and mixed bed). The liner was in service March 3 and 4 1980, and processed 8,250 gallons of water from the reactor coolant bleed tank A. The liner has been exposed, since March 4, 1980, to a curie loading of 1250 curies of mixed fission products and their daughter products. The residual effluent pH of 2.79 was determined during dewatering (removal of residual water) operations by General Public Utilities Nuclear Corporation (GPUNC) personnel.

TABLE 1. CHEMISTRY AND RADIOCHEMISTRY OF PF-16 INFLUENT WATER

Chemistry	
pH	7.93
Conductivity	1200 μmho/cm
Boron	1341.7 ppm
Sodium	220 ppm
Radiochemistry	
Gross β γ	4.01E+1 μCi/ml
Cs^{137}	3.176E+1 μCi/ml
Cs^{134}	6.068E+0 μCi/ml
La^{140}	<2.016E-1 μCi/ml
Ba^{140}	<1.40E-1 μCi/ml
I^{131}	<5.908E-2 μCi/ml
Co^{58}	<8.55E-2 μCi/ml
Co^{60}	<7.27E-3 μCi/ml
Sr^{90}	∿1.43E+0 μCi/ml

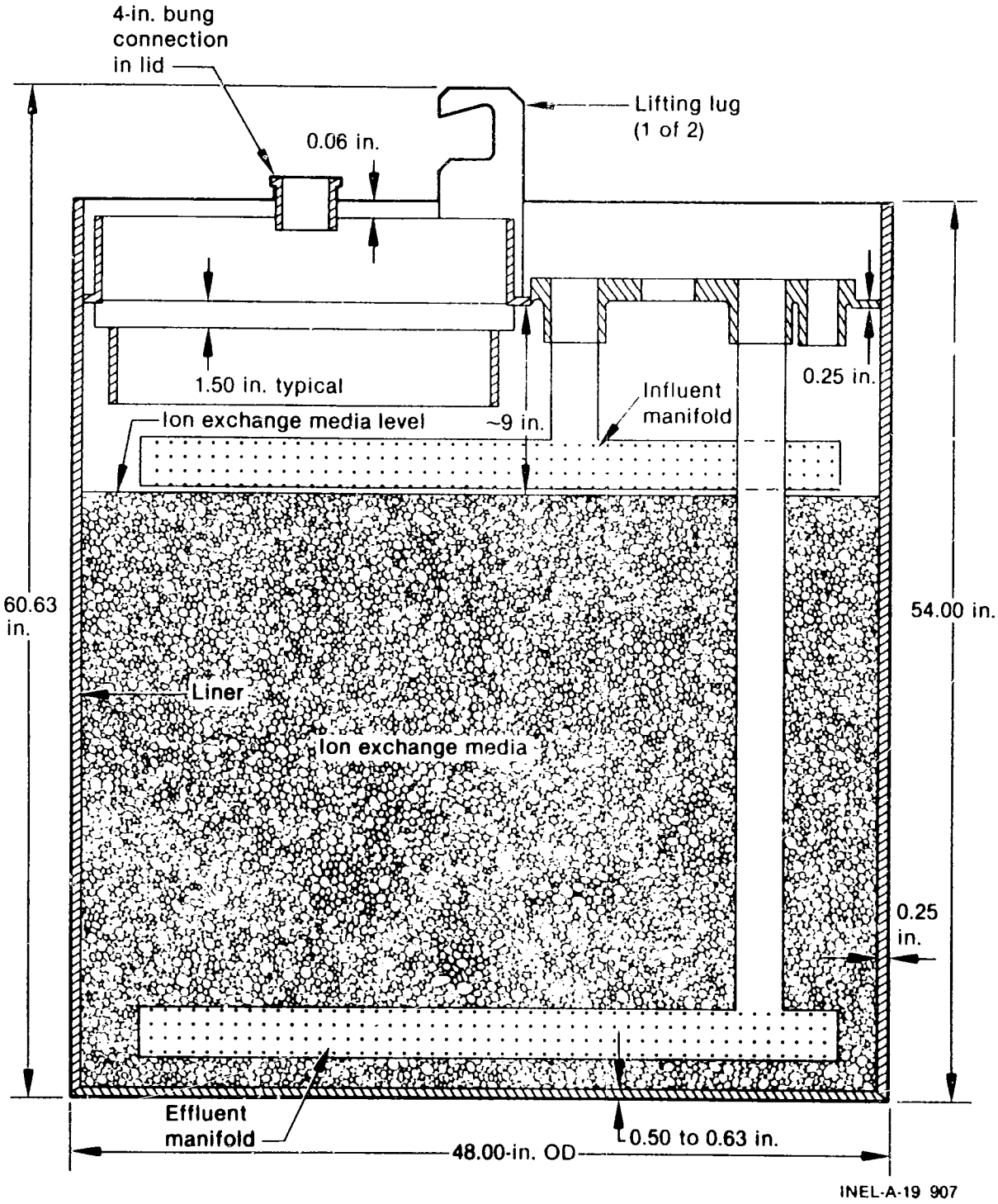
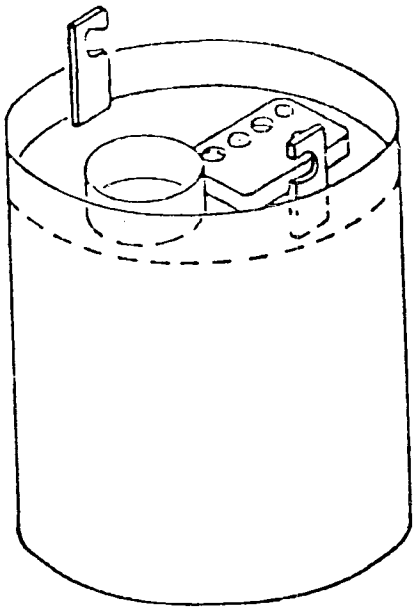


FIGURE 1. Cross-sectional view of a typical EPICOR-II liner.



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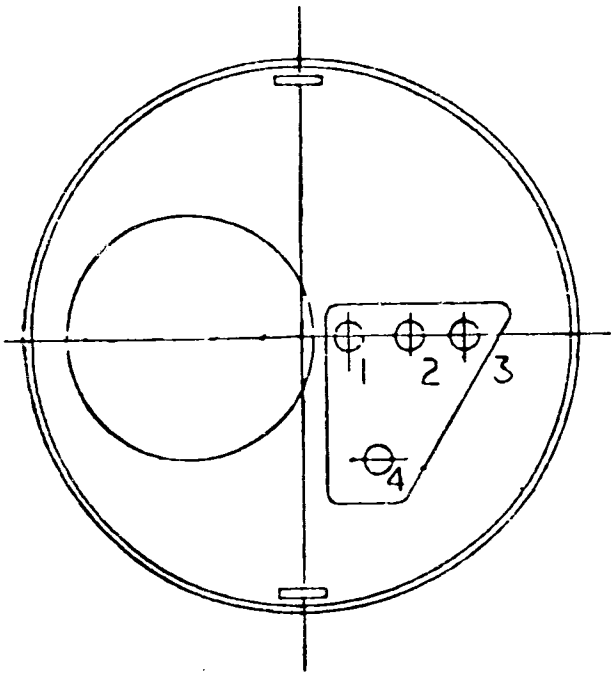

1. INLET
2. OUTLET
3. VENT
4. CONDUCTIVITY PROBE

B

FIGURE 2. Schematics showing (A) orientation of PF-16 lifting lugs and (B) configuration of PF-16 penetration.

SAFETY ANALYSIS

The BCL Operational Practice calls for review and approval of certain operations by the Radiological Safety Committee (RSC), which is an independent group of BCL staff memebers. In general, operations or experiments which are judged to be off normal or pose unique operational problems are reviewed by this committee. In accordance with this practice, a detailed description of the operations associated with the receipt, handling, and examination of the liner was submitted to the RSC for review and approval. This document addressed the potential hazards associated with each of the major operations, and procedures and administrative steps that are to be taken to minimize the probability of problems or their consequences.

It was anticipated that a combustible gas mixture might have been generated inside the liner during storage at Three Mile Island (TMI) from the radiation-induced degradation of the resins and from the radiolysis of the contaminated water. It was also assumed that this gas mixture could combust if ignited by sparks generated under appropriate conditions during gas sampling operations. However, in subsequent communications from EG&G/TIO, BCL was informed that the liner would be vented prior to shipment from TMI and, therefore, would not contain combustible gas mixtures at the time of arrival at BCL. It was further assumed that the gas sampling operations could be performed within two months of the date of liner venting and still be below the lower flammability limit. This information was presented to the RSC.

Another hazard associated with the liner handling operations was exposure of operating personnel to excessive amounts of radiation. It was pointed out that the use of a transfer device during cask unloading operations would significantly reduce personnel exposure. In addition, continuous monitoring of the radiation levels in the work area by the Health Physics staff would provide information to further reduce personnel exposure to radiation, the objective being to keep exposures to personnel as low as practicable.

Based on a review of the information presented, the RSC approved all operations involving receipt, handling, examination, and storage of the liner.

LINER PREPARATION AND SHIPMENT

A Brookhaven National Laboratory (BNL) report[1] states several generalizations concerning the effects of radiation on ion-exchange resins, some of which may be applicable to the EPICOR materials. On this basis, it was believed that resin degradation had, through radiolysis, produced combustible gases within the liner. A GPU combustible gas source term evaluation[2] indicated that the predominant combustible species present would be hydrogen, with the worst case concentration of the order of 13 volume percent. Because the lower combustible limit of hydrogen is 4.0 volume percent, it was felt that venting of the liner prior to shipment was necessary to minimize hazards. It was concluded by EG&G[2] that venting of the liner and shipment to BCL within 15 days of recapping the vent penetration would ensure the hydrogen generated during transit would not result in a combustible configuration. Based on GPU's worst case combustible source term, it was concluded that the hydrogen generation in 15 days would not lead to a level in excess of 0.54 volume percent. Because this value is well below the lower flammable limit, it was concluded that the risk of combustion during shipment would be negligible.

On May 16, 1981, the liner was vented at TMI in the Chemical Cleaning Building. At 1400 hours on May 16, 1981, the liner vent plug was partially removed (unscrewed four turns) at which time a combustible mixture of gas was detected and personnel were evacuated from the area around the liner. The detection of a combustible gas mixture continued for approximately five hours. The vent plug was completely removed at 0530 hours on May 17, 1981 and a new plug inserted at 0645 hours. Attempts made to remove the effluent plug were unsuccessful.

The liner was loaded into the lead/steel transfer device for subsequent transfer into cask CNS 8-120 (ATCOR LL-50-100) leased from Chem Nuclear Inc. The cask is a licensed type B cask meeting all applicable DOT/NRC requirements. The cask shielding consists of two layers of steel approximately one inch thick, separated by 3 1/2 inches of lead. The cask lid and gasket are designed to withstand 0.5 atmospheres of internal pressure. The actual transfer occurred on May 17, 1981 and subsequent shipment of the liner and cask to BCL took place on May 19, 1981.

LINER RECEIPT AT LABORATORY AND TRANSFER INTO CELL

Liner PF-16 was received on May 19, 1981 at the Battelle Nuclear Center at West Jefferson, Ohio, and preliminary radiation and smear survey was conducted by BCL Health Physics personnel. The maximum radiation reading at the cask surface was 7 mR/hr (βγ) and the readings fell to a maximum of 3.5 mR/hr (βγ) in the vertical plane at the trailer edge nearest the cask. The radiation reading at the truck cab was <2 mR/hr (βγ). The smear survey indicated the contamination levels were well below the 2200 dpm/100cm^2 (βγ) and 220 dpm/100cm^2 (α) limits. These preliminary readings were taken before the rain shield was removed and while the cask was on the trailer. Therefore, the readings represent primarily the radiation and contamination of the cask sides and were the basis for accepting the shipment. The low-boy trailer was backed into the Hot Laboratory building truck dock area and the tractor was uncoupled.

The cask rain shield was removed the next day, May 20, 1981 and the tie down bars detached. It was found that the rain shield binders were not tight and the rain shield was slightly off center. Also, the cask tie downs were loose and could be moved slightly by hand. After removal of the rain shield and tie downs, a more detailed radiation and smear survey was conducted by the BCL Health Physics personnel. A maximum radiation reading of 70 mR/hr (βγ) was registered at the cask lid. The smear survey yielded a contamination level of <200 dpm/100cm^2 (βγ) and <4 dpm/100cm^2 (α). After completing the surveys, the cask was removed from the trailer using a 50-ton crane.

A bubble solution (Snoop^{TM}) was applied around each of the six cask lid plugs and no leakage of gas from the cask was detected. A gas sampling chamber had been constructed using the cask drawings ATCOR INC. 1042-D-0021 Rev. C and 1042-B-0005. This chamber was designed to mate with the top of the cask. However, the cask lid plugs had raised 1-1/4 inch square male fittings rather than the drilled holes and handles shown in the reference drawings; therefore, a new chamber handle had to be fabricated.

The sampling chamber was then attached over one of the cask lid plugs, the chamber was evacuated, the cask plug was loosened, and the cask internal air was sampled. An area gas monitor was operated during the sampling operation but no release of activity was observed and no activity was detectable from within the sample bulb. Therefore, the sample chamber was removed and the cask plug was then completely removed. A radiation and contamination survey was conducted. The radiation readings were >500 R/hr inside the plug hole near the liner, 100 R/hr inside the plug hole about two feet above the liner, 50 R/hr at the top of the cask plug hole, and 2 R/hr at three feet above the cask plug hole. A smear taken from inside the plug hole exhibited contamination of <500 dpm/100cm^2. The cask drain plug was then removed and found to be dry and clean. The drain and cask lid plugs were reinserted and tightened. Because there was no detectable pressure or radioactive air in the cask, purging of the cask was not required.

Following the radiological surveys, the next operations were the removal of the cask lid and preparation of the liner for transfer into the hot cell. During these operations, the radiation from the cask was continuously monitored by the BCL Health Physics personnel. The cask lid was raised about six inches and a radiation reading of about 190 R/hr was obtained in the opening between the cask body and the raised lid near the outside edge of the cask. A radiation reading was taken to determine the radiation streaming directly from the liner through the opening between the cask body and lid. The monitor was raised and lowered at a distance of about two feet from the cask. A maximum reading of 200 R/hr was obtained at a height of about two feet above the top edge of the cask body. With the cask lid fully removed, the radiation level two feet above the top of the cask centerline was also 200 R/hr. A contact radiation reading at the side of the cask, a few inches below the cask top, was only 200 mR/hr.

A lead and steel shielded device was used for the transfer from the cask into the hot cell. It was designed so that it would also be the shielded storage chamber for the later out-of-cell storage of the liner. This device was designed at BCL and fabricated by local contractors. Using an adaptor plate to distribute the weight around the cask top opening, the

transfer/storage device was positioned on top of the cask (see Figure 4). Radiation readings were taken with the transfer/storage device on top of the cask and before the liner was raised into the device. With the device top shield in place, the maximum radiation through the shield was 100-150 mR/hr. A contact radiation reading at the mating surface of the transfer/storage device and the cask was 10-20 R/hr. The radiation reading fell to 2 R/hr at a distance of one foot from the cask in the same horizontal plane at the top of the cask. The device top shield was removed and the radiation reading at the open top of the device (about 7 feet above the unshielded liner) was 50 R/hr. The liner was then raised into the transfer of storage device, properly positioned, locked into place, and the transfer device cover shield was installed. The contact radiation readings were generally 1-1.5 R/hr with a maximum of 2 R/hr through the device top shield. The transfer device, with the liner inside, was then lifted from the cask and the bottom shield attached. The contact radiation through the side of the transfer/storage device (with the liner inside) was 35 mR/hr near the top, 150 mR/hr about half the way down the device, and 20 mR/hr near the bottom. The maximum contact radiation reading was 150 mR/hr throught the side of the device. The contact radiation reading through the bottom shield was 50 mR/hr.

After removal of the liner from the cask, the dunnage was removed, a radiation and smear survey was conducted, the cask lid was installed and the cask prepared for shipment.

The heavy element hot cell was prepared to accept the liner by cleaning and removing the cell ceiling plates. The transfer device was wrapped in polyethylene, the bottom shield was removed; and the transfer device with the liner inside was lowered into the cell using a 50-ton crane. The liner was unlatched from the transfer device and the transfer device was removed from the hot cell. The hot cell ceiling plates were then replaced. The liner was raised using the in-cell 5-ton crane and liner placed into a polyethylene bag to prevent unnecessary contamination of the liner surface.

TRANSFER/STORAGE DEVICE

A transfer and storage device (hereafter referred to as the transfer device) was designed and constructed to: (a) transfer the liner from the shipping cask into the hot cell and (b) provide a shielded storage container for the 24-month storage and monitoring of the liner outside of the hot cell.

The transfer device is essentially a cylindrical lead/steel shield with removable top and bottom shielding cover plates. The design of the transfer device was based on shielding calculations made with the objective of a maximum outer surface radiation reading of approximately 50 mR/hr. The inner and outer walls of the cylindrical body are steel. The three inch space between these two concentric steel cylinders is filled with lead. The lead provides the majority of the shielding and the steel provides the necessary structural strength. The top and bottom plates are also combination lead/steel units. The inner and side surfaces of each of the two plates are 1/4 inch thick steel and the outer surface is 1/2 inch thick steel. A two inch space between the inner and outer surfaces in each of the cover plates is filled with two inches of lead. As in the case of the main body, the lead provides the primary shielding and the steel provides the structural strength.

The transfer device is shown in Figure 3. The overall height, not including lifting lugs, is 67-1/2 inches; the inside diameter is 54 inches and the outside diameter is 62 inches.

Before the PF-16 liner arrived at BCL, the transfer device was tested using a dummy liner to ensure the device would function properly. The manner in which the transfer device was used to transfer the liner from the cask into the hot cell is described in the preceding section. Figure 4 shows the transfer device resting on top of the shipping cask containing the liner.

The future use of the device will be for removing the liner from the hot cell. Once the transfer device and enclosed liner are out of the cell, they will be moved to a location for storage within the Hot Laboratory building.

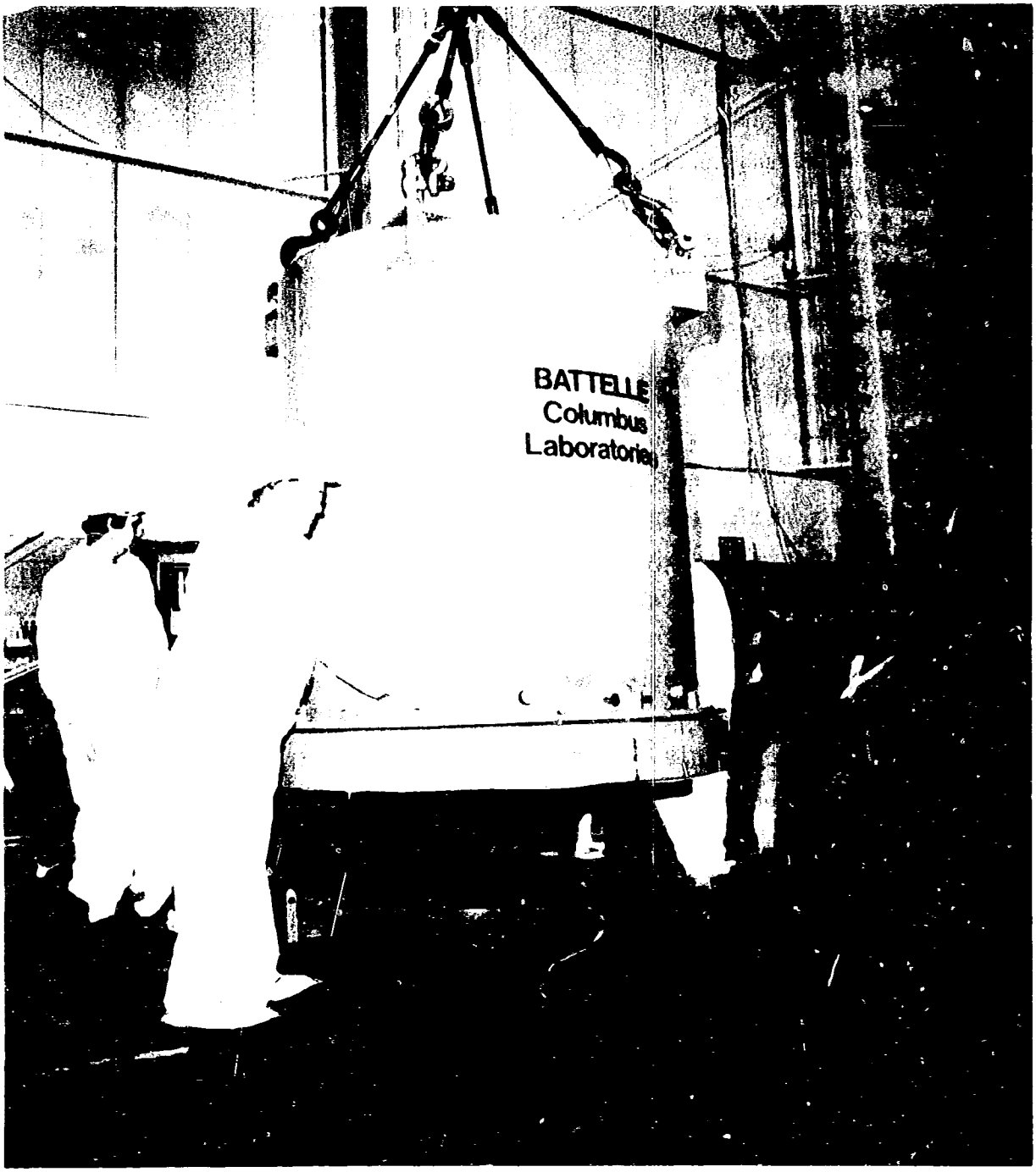

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FIGURE 3. Transfer device.

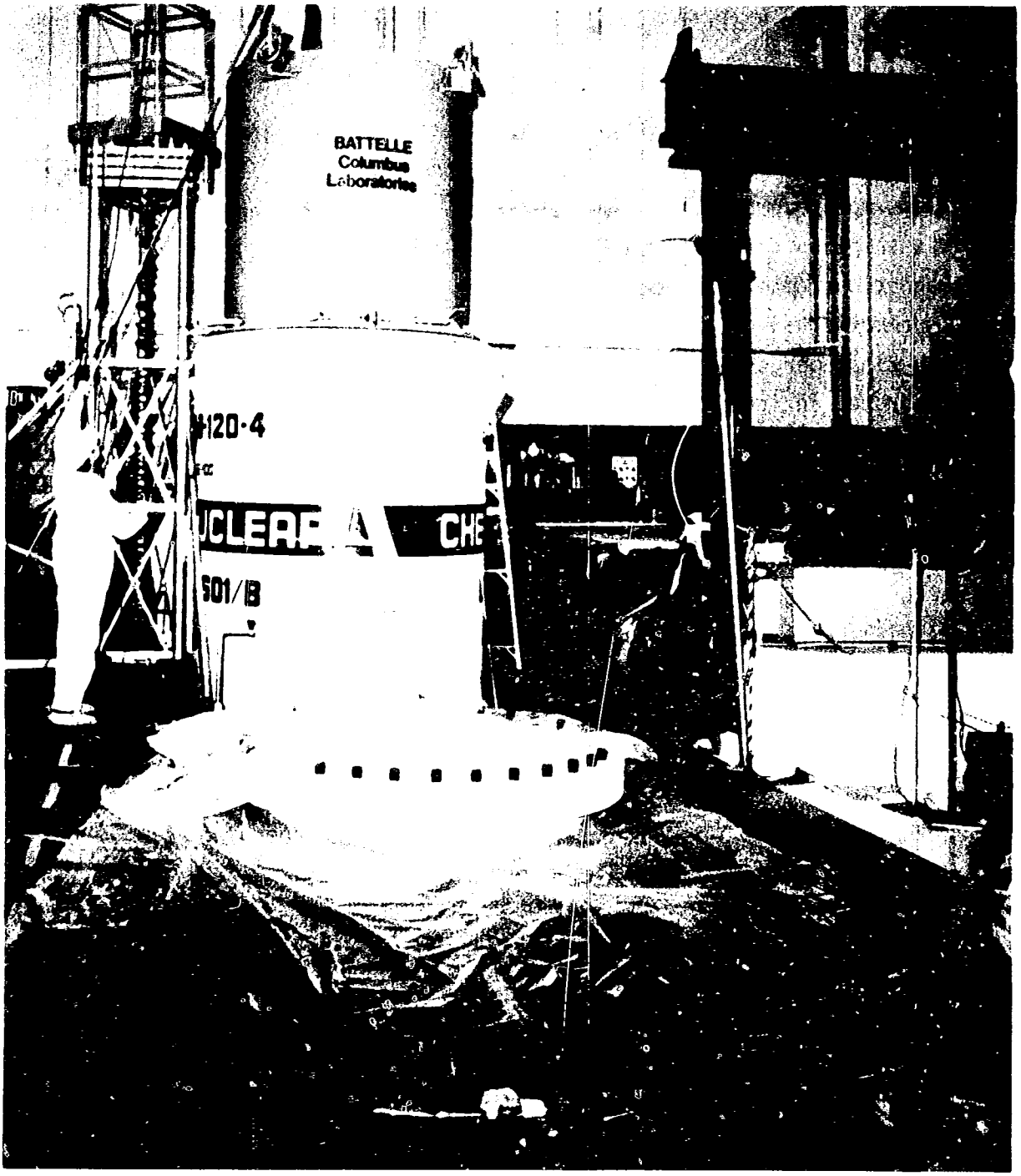

FIGURE 4. Transfer device resting on top of shipping cask.

GAS SAMPLING AND ANALYSIS

One of the early tasks following the transfer of the liner into the hot cell was to obtain a sample of gas from the free space above the ion exchange media. This was accomplished on May 29, 1981. The general approach was first to affix a sampling chamber (see Figure 5) to the top of the liner using an electromagnetic clamping device. The chamber was then evacuated and the liner vent plug removed using a T-bar type wrench penetrating the sampling chamber through an elastomer seal. The chamber was fitted with a vacuum/pressure gauge calibrated in inches of mercury and readable to within, 0.5 inches of mercury. While the vent plug was being removed, the pressure/vacuum gauge was being continuously monitored. As the gas was released into the evacuated sampling chamber, the gauge indicated that the internal pressure did not exceed atmospheric pressure. After the chamber had filled, an evacuated one litre gas bottle, coupled to the system, was opened to collect a sample for analysis. Following this first sample collection, the vent plug was closed, the chamber was evacuated, and a 500 ml sample collected.

The gas samples were submitted for analysis using mass spectrometry followed by gas chromatography. The results of the analyses are shown in Table 2, the litre sample is designated sample 1 and the 500 ml sample is designated sample 2. Table clearly shows the gas is highly enriched in hydrogen and carbon dioxide while depleted in oxygen as compared to air. The samples also exhibit slightly higher concentrations of nitrogen and carbon monoxide than is expected in air. Several hydrocarbons were observed in small quantities, the most abundant concentration being 500 ppm methane. The 500 ml sample was analyzed using only mass spectrometry and not subjected to the same detailed analysis as the primary sample.

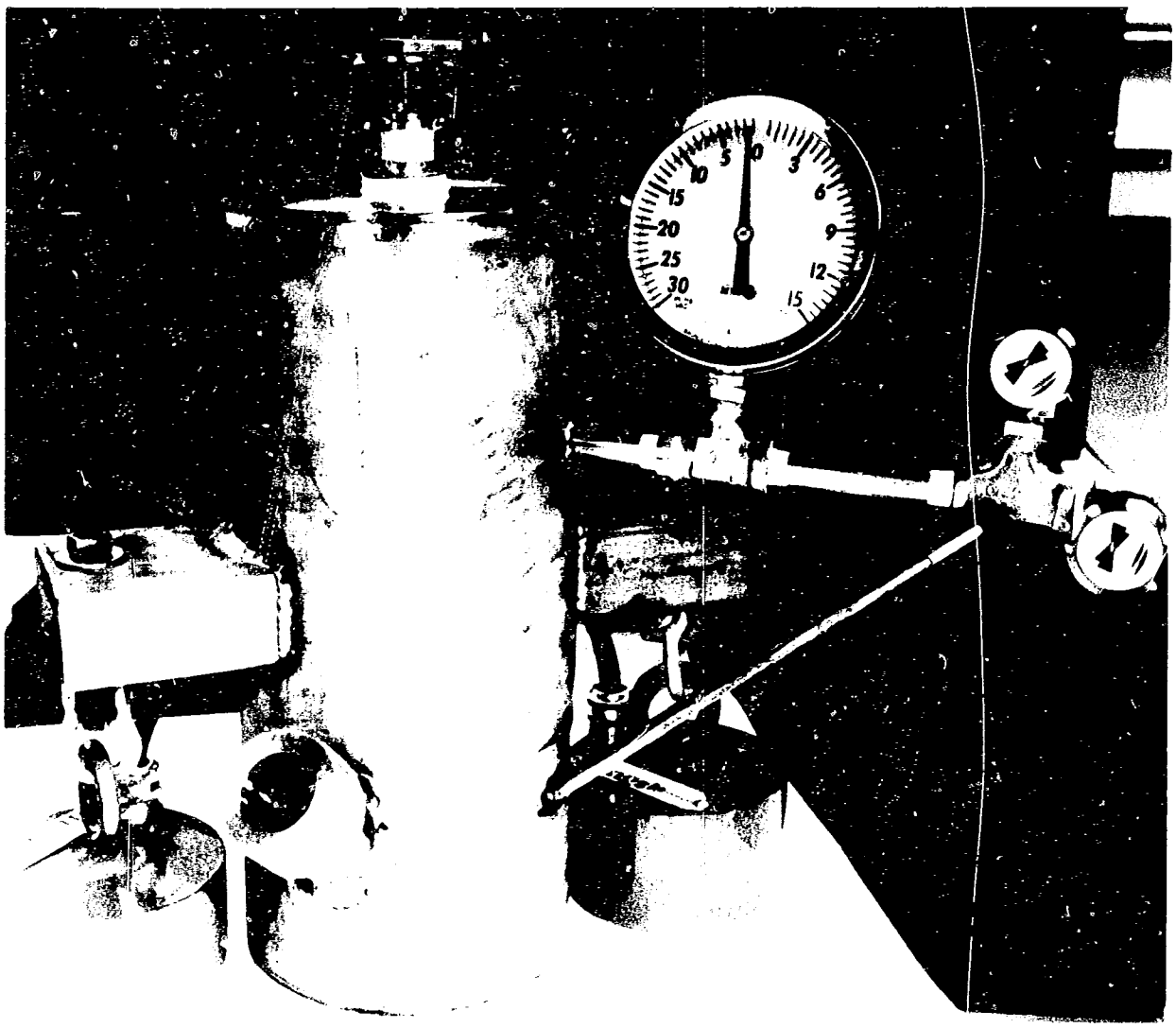

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FIGURE 5. Gas sampling device.

It was postulated that a gas layering effect might have resulted in a concentration of a heavy combustible gas near the bottom of the liner. A gas sample was drawn from the bottom of the effluent tube on June 2, 1981. The results of the analysis are shown in Table 2, designated Heavy Fraction. The composition appears to be very close to that of air with no indication of a large concentration of any heavy gases. However, the effluent plug had been removed for approximately seven hours before an attempt was made to draw a heavy gas sample. In addition, attempts had been made during this seven-hour period to obtain a liquid sample. Thus, there may have been considerable mixing of any gas fractions originally in the effluent tube with the cell air.

Table 2. GAS ANALYSIS.

	PF-16 Light Fraction Sample 1	PF-16 Light Fraction Sample 2[a]	PF-16 Heavy Fraction
	Volume Percent		
Carbon dioxide	5.52 ± 0.06	5.27 ± 0.06	0.30 ± 0.03
Argon	0.96 ± 0.05	0.96 ± 0.05	0.94 ± 0.05
Oxygen	0.20 ± 0.02	0.30 ± 0.05	20.2 ± 0.2
Nitrogen	80.6 ± 0.4	81.2[b] ± 0.5	78.0 ± 0.4
Carbon monoxide	0.2 ± 0.02	- - -	0.004 ± 0.001
Hydrogen	12.4 ± 0.2	12.2 ± 0.02	0.5 ± 0.05
	Parts per Million by Volume		
Methane	500. ± 2.5		45. ± 5.
Ethylene & Acetylene	0.7 ± 0.1		0.1
Ethane	42. ± 4		4. ± 1.
Propylene	0.1		0.1
Propane	6. ± 1		1. ± 0.2
Iso-butane	0.6 ± 0.1		0.4 ± 0.1
n-Butane	0.1		0.1
Hydrogen sulfide	20		20
Carbonyl sulfide	10		10
Sulfur dioxide	10		10
Unknown compounds	20		20

a. Not subjected to detailed analysis.

b. Includes CO.

VISUAL EXAMINATION

Visual examinations were performed on the liner interior and exterior surfaces.

The external visual examination was performed by both viewing the liner directly through the cell window and through the cell TV camera with an out-of-cell monitor. The operations involved are summarized in the following paragraphs.

The liner lifting bar was attached to the lifting lugs and the lifting bar was attached to the five ton in-cell crane hook. The liner was positioned in front of the cell window. The in-cell TV camera was positioned in such a way as to view the entire liner and was locked in position with the manipulator. The liner was then raised in front of the cell window and visually examined by both viewing through the window and watching the TV monitor. After the first pass, the liner was lowered, rotated 90^{0} and examined again. In all, six passes were made. The liner appearance in general was clean and in good condition. Paint on the surface was intact except the bottom rim where a few rust spots (1/2 to 1 diameter) were observed. Some surface scratches on the liner shell, though painted over, were clearly visable but appeared to be superficial. The top of the liner was examined with the TV camera. The plugs and the manway cover were in good condition. The plug that was removed and replaced at TMI could easily be identified. In addition to the three plugs, the top also contained the conductivity probe. All of the operations involving exterior visual examination were videotaped with verbal comments by the staff performing the examination.

The liner internal examination was initially performed manually using a fiber optics viewer. However, the fiber bundle was apparently damaged by the high radiation field and further examination was no longer possible. The interior of the liner was then examined using an in-cell TV camera. The manway cover was removed and the camera was positioned inside the liner and panned to view the entire inner surface. All of the internal examination was videotaped for permanent records.

The bottom side of the manway cover was rusty with black deposits on the surface. It appeared this surface had not been sealed with the protective coating. Some of the protective coating on the manway cover lip appeared to have peeled off and rust spots (1/4 to 1/2 inches in diameter) were observed in this area. Figure 6 shows the appearance of the area where the coating had peeled off. The protective coating on the inner surface of the liner appeared to be blistered, however, it seemed intact with only occasional rust spots ($\sim$1/8 inch in diameter).

One small area ($\sim$4 x 4 inches) of the liner interior surface appeared to be uncoated and covered with rust[a]. The underside of the liner top plate appeared to be in good condition with relatively less blistering of the protective coating than the liner internal surface. The top of the resin surface was dark, cursty, cracked, and caked with white material believed to be boric acid deposits (see Figures 7 and 8). The portions of the influent and effluent pipes and other braces which could be seen showed no visible evidence of corrosion. The areas around the welds joining the top plate to the shell and the shell axial weld also showed no visible corrosion.

Subsequently, a small stainless steel spade was used to remove a small part of the ion exchange media in contact with the liner so that the liner ion exchange media interface area could be examined. No visible corrosion of the liner surface was evident. Figure 9 shows the area of liner that was in contact with the ion exchange media.

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a. This area was purposely scraped, prior to liner use in the EPICOR-II System, to provide a better ground for the conductivity probe.

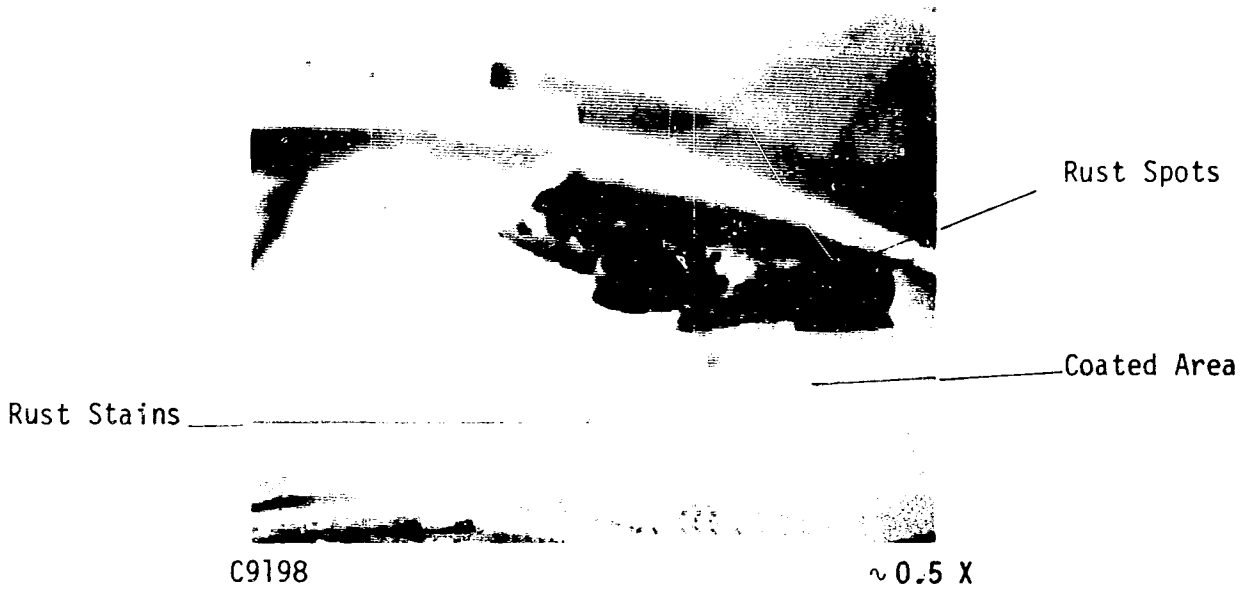

FIGURE 6. Corroded area on the manway cover lip where the protective coating has peeled off.