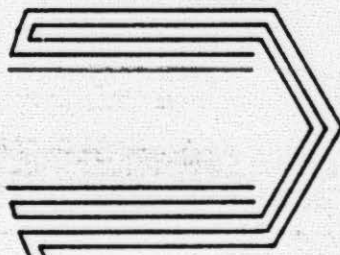


**GPU Service**

# THREE MILE ISLAND - UNIT 2

PLANNING STUDY  
FOR  
CONTAINMENT ENTRY  
AND  
DECONTAMINATION



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BECHTEL POWER CORPORATION • JULY 2, 1979

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BECHTEL POWER CORPORATION  
JULY 2, 1979

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1.0 INTRODUCTION1.1 Definition of Scope of Study

Shortly after the incident at the Three Mile Island Nuclear Facility on March 28, 1979, Bechtel Power Corporation was retained by GPU Service Corporation to develop a conceptual plan for reentry and decontamination of the containment. This report

- a. provides an analytical assessment of the radionuclear and physical status of the Unit 2 containment,
- b. weighs alternatives for containment decontamination and reentry, and
- c. develops conceptual designs for new systems or modifications to existing systems which may be required to support containment entry and decontamination.

The work was performed at Crawford Station in Middletown, Pennsylvania, from April 25 through July 1, 1979. Assistance was provided by GPU Service Corporation and Babcock & Wilcox personnel.

The tasks discussed in Section 1.1.1 through 1.1.4 define the scope of activities for this study. The study identifies the most probable containment status. The plans and concepts described in the report are based on this most probable condition. Alternate plans have been developed for containment entry and decontamination as appropriate for other possible conditions. This approach provides the basis for cost-benefit decisions and long range contingency planning.

1.1.1 Remote Decontamination

Remote decontamination included the following tasks:

- a. Develop methods to establish a detailed assessment of the containment radionuclear content.
- b. Estimate the resultant dose fields within the containment.
- c. Identify methods for collection, volume reduction, immobilization and transportation of the reactor coolant systems and sump water inventories.\*

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\* This task was deleted from the Bechtel scope by GPU Service Corporation on May 2, 1979, and reassigned to the TMI-2 Waste Management Group. Information generated by Bechtel on this task was transmitted to GPUSC on May 11, 1979, in a closeout note, Transmittal GPU/TMI-007.

- d. Develop a plan for remote decontamination of the containment.
- e. Recommend reagents or additives for reducing surface contamination and inhibiting corrosion.
- f. Develop a scheme for the filtration and eventual purging of the containment atmosphere to permit personnel entry.

### 1.1.2 Containment Entry

A plan has been developed for the initial entry into the containment. The plan includes appropriate safety precautions necessary to effect reentry without undue risk to public health and safety. This part of the study included the following tasks:

- a. Assess the radiation dose fields and identify the proper safety and health physics practices which should be followed.
- b. Identify the safety evaluations and precautions which should be made to support containment entry.
- c. Develop methods and plans that would limit worker doses, yet maximize radiation field mapping and data acquisition in the containment.
- d. Develop concepts for minimizing the spread of contamination during entry.

### 1.1.3 Data Acquisition and Damage Assessment

A plan has been developed to assess the status of the containment systems, components and structures following entry. This part of the study included the following tasks:

- a. Develop a plan for radiation field mapping and containment smear surveying.
- b. Develop methods and plans for data acquisition tasks related to assessment of the general condition of the containment and equipment therein.
- c. Identify potential hazards and make corresponding contingency plans.

1.1.4 Hands-on Containment Decontamination

Plans have been developed which could be used for completing containment decontamination. This part of the study included the following tasks:

- a. Provide recommended methods, reagents and equipment which could be used for hands-on containment decontamination.
- b. Identify health physics practices and procedures which may be applicable to the hands-on decontamination.
- c. Develop a decontamination scheme which is efficient and limits worker dose.
- d. Identify temporary facilities and service systems needed to accomplish containment decontamination.

## 1.2

Summary

This report presents the engineering planning activities performed by the Containment Engineering Group in response to the scope of this initial study as outlined in Section 1.1. The primary objective of this activity was to develop a plan for placing the containment in a configuration where reactor vessel head removal could begin. A cautionary note is warranted regarding the use of the assessments and recommendations presented in this report. Since containment reentry has not been made at this time, many uncertainties exist. As knowledge of the status of the containment improves, reentry and decontamination plans can be improved or refined.

The ideas and methods proposed in this report for reentry and decontamination form the best judgements based on the experience of the individuals assigned to the Containment Engineering Group. Many of these people have had significant, first-hand experience in decontamination and health physics practices that are directly applicable to TMI-2. Where time permitted in the preparation of the report, alternate methods were evaluated and the optimum plans presented.

The report provides an assessment of the physical and radionuclear status of the containment based on currently available information (Sections 2 and 3), outlines the design criteria and provides conceptual designs for new or altered facilities and systems (Section 4), and develops plans and presents conceptual engineering related to the recommended procedures for performing decontamination of the TMI-2 containment (Sections 5 through 11). As additional data becomes available it is expected that the report will be supplemented by Bechtel during subsequent planning activities.

Section 2 contains an assessment of lower, median, and upper bound containment radiation sources. These sources include airborne radioactivity, general plateout sources on walls and floors, and the plateout source that will remain when the sump liquid is drained from the building. An assessment of the containment sump liquid activity is also included. These containment source estimates are based on reactor coolant system liquid samples, containment atmosphere sample analyses, and direct radiation measurements, both Ge(Li) spectra taken at the containment equipment hatch and teletector dose rate measurements taken in the R-605 penetration at elevation 292', two feet above the sump water. The lower bound, median bound, and upper bound activity estimates are based on various scenarios regarding the manner in which radionuclides were deposited in the containment and various credible methods of interpreting the incomplete data base currently available. An assessment is presented of the estimated radionuclear contamination which will remain in the containment building after the remote decontamination activities described in Section 5 are carried out.

Based on source terms, both before and after containment remote decontamination as described above, radiation dose fields at various points within the containment building were estimated and are described in Section 2. In addition, dose field contributions from predictable hot spots within containment (e.g., containment air coolers, letdown coolers, containment sump hot spots, etc.) were estimated. Many hot spots will be unquantifiable prior to containment entry.

The variability of the bounding estimates of contamination source terms and dose fields in the containment is very large due to the fragmented nature of the available data base. It is believed, however, that these bounding estimates form a reasonable planning basis for developing procedures for the remote and hands-on decontamination of the containment. It should also be noted that the radiation dose fields are expected to vary greatly from one point to another within the containment, and any interpretation of the dose results contained in Section 2 should be made with careful consideration of both the dose field so defined, and the location of planned activities within the containment as they relate to in-containment decontamination procedures.

The anticipated physical status of the containment structure and in-containment systems is described in Section 3. The effects of various off-normal conditions in the containment are assessed, including:

- a. extended elevated pressure and temperature on March 28, 1979
- b. the apparent hydrogen detonation on March 28
- c. the containment spray actuation which occurred on March 28
- d. the corrosive effects of long-term submergence of equipment and structures in the containment sump
- e. the effect of extended operation at negative containment pressure
- f. the physical response of containment structures and equipment to integrated radiation doses which approach, or in some cases, exceed the expected qualification lifetimes.

Section 4 discusses new or altered facilities and systems which will be required to efficiently execute the decontamination and subsequent operations in containment. It is recommended that a containment service building and associated systems and facilities be erected in the area outside the Unit 2 equipment hatch. This facility would consist of a service building to facilitate the movement of personnel and

equipment into and out of the containment, a dry cleaning facility to allow expeditious cleaning of the large amounts of anti-contamination clothing and equipment that is expected to be generated during the decontamination and subsequent efforts, and a new personnel change and access facility to expedite the movement of large numbers of people in and out of the Unit 2 equipment hatch. The service building would have a large equipment decontamination station, and a separated solid radwaste staging facility. This radwaste staging facility would provide for interim storage of packaged contaminated equipment which will have to be removed from the containment building, (e.g., cable, conduit, contaminated cleaning materials, non-reusable anti-contamination clothing and equipment, etc.).

A number of new or altered systems have been identified as being required to execute the cleanup of the containment building. These systems include:

- remote decontamination
- spray and chemical additive
- ventilation and filtration
- lighting and power
- breathing air
- television
- communications
- vacuum
- steam supply
- chemical supply
- water supply and recycle
- radiation monitoring
- equipment decontamination
- service building HVAC

Section 5 describes a recommended plan and procedure for the remote decontamination of the TMI-2 containment. This remote decontamination plan utilizes the containment spray system to deliver water and other chemical solutions in an attempt to significantly reduce the levels of gross contamination on surfaces within the containment building. The recommended remote decontamination procedures can be summarized as follows:

1. High Volume Deionized Water Flush (250,000 gallons)

The initial high volume deionized water flush is designed to remove gross contamination from the areas that can be sprayed or flooded using the containment sprays. The major contribution to gross contamination is expected to be cesium which is highly soluble in most of the chemical forms that it is anticipated to be found in the containment. It is hoped that the initial deionized water flush will dissolve most of the cesium and other radionuclide contamination on the 347' operating floor and flush it to the sump where it can be processed using the high level waste processing system which will be utilized for processing the water now in the containment sump.

2. Multiple Cycles of Saturated Steam Delivery Through the Containment Sprays

The multiple steam cycles are intended to create condensation on building surfaces which cannot be sprayed or flooded by water delivery through the containment sprays. In particular, ceilings and walls at elevations below 347' may be decontaminated to a significant extent if large amounts of condensation can be induced in these areas. It is expected that these steam cycles will wash contamination from ceilings and walls to adjacent floors where it can be flushed to the containment sump in subsequent high volume water flushes.

3. High Volume Detergent Solution Flush (250,000 gallons)

The high volume detergent solution flush would be utilized if the previous deionized water and steam cycle flushes do not result in decontamination factors sufficient to allow entry and hands-on decontamination of the containment. It is anticipated that the detergent solution flush will aid in the removal of contamination adhering to dirt and also aid in degreasing building surfaces, thus removing adhering contamination. The high volume detergent solution flush would be followed by a high volume deionized water flush as described in Item 1 above, to move the contamination and detergent chemicals to the containment sump where they can be processed by liquid waste processing systems.



#### 4. Chemical Decontamination Via Injection Through the Building Sprays

If the deionized water, steam and detergent solution flushes are ineffective in removing gross contamination from areas that can be sprayed or flooded using the building spray system, there would be a strong implication of a need to resort to more effective (but less desirable) chemical decontamination procedures. Some suggestions for potential reagents that could be delivered through the building spray system are contained in Section 5.4. The discussion contained therein is by no means complete and any decision to utilize chemicals harsher than the detergents recommended in Section 5.3 would require careful analyses to identify what damage to in-containment systems, particularly NSSS components, might be expected from the utilization of such chemicals.

The initial high volume deionized water flush, multiple steam cycles, and subsequent deionized water flush described above, should constitute a minimum set of procedures which would not threaten further damage to in-containment components or pose extreme difficulties for the liquid radwaste processing systems. If these procedures are successful in reducing in-containment dose rates to levels that will permit containment entry for extended periods of time, then the detergent solution and chemical flushing procedures described above would not be instituted, in order to minimize damage to in-containment systems and avoid the introduction of difficult chemical processing problems into available liquid radwaste processing systems.

It is anticipated that execution of the high volume deionized water flush followed by multiple steam cycles, a detergent solution flush, and another deionized water flush would result in a decontamination factor (that is, a reduction in surface contamination) of between 800 and 80,000 for those surfaces which can be directly sprayed or heavily flooded by the containment spray system. It is predicted that a decontamination factor no greater than 4 will result for surfaces which cannot be sprayed directly or heavily flooded by the building sprays. This decontamination factor would result solely from the multiple steam condensation cycles discussed under Item 2. above. An assessment of the probable overall effectiveness of the proposed remote decontamination procedures in reducing radiation dose fields inside the containment will require a detailed assessment of anticipated spray and flooding patterns inside the containment. This assessment will be carried out in subsequent efforts by the Containment Engineering Group.

Section 6 discusses studies and recommended procedures for containment atmosphere filtration and purging to remove noble gases (predominantly Kr-85) and airborne particulate activity from the containment atmosphere prior to initial entry. These studies show that existing

installed systems (the containment hydrogen purge system and the containment high volume recycle filtration system) can be utilized in normal alignments to filter airborne particulate activity from the containment atmosphere and purge the remaining noble gas activity to the environment while remaining in compliance with the existing plant effluent technical specifications. This filtration and purging procedure is expected to take approximately 2 months and should be initiated as soon as feasible so as not to control the schedule for initial containment entry.

The initial entry into the containment is discussed in Section 7. Included in this discussion are criteria for entry, health physics procedures, general procedures related to communications, lighting, emergency planning, contamination control, procedures for the initial radiation mapping of the containment, procedures for the initial damage assessment of the containment, a discussion of potential problems and a hazards analysis related to initial containment entry.

This report outlines a sequence where it is assumed that initial containment reentry is preceded by remote decontamination. This is not intended to preclude the possibility of initial entry prior to remote decontamination should more definitive data regarding dose fields in containment indicate that early entry is possible. The sequencing presented in this report was chosen on the basis of lack of substantive data regarding the feasibility of early entry. Most of the thoughts and precautions outlined in Section 7 remain applicable to that alternate mode, if future data and safety assessments demonstrate its feasibility.

Section 7.9 discusses available remote controlled vehicles (robots). These might be needed for initial containment entry and radiation dose field mapping, should radiation levels exist to a degree sufficient to prevent manned entry following remote decontamination.

Section 8 details recommended health physics procedures for the hands-on decontamination of the TMI-2 containment. This section describes the anti-contamination and respiratory protection equipment that should be utilized by personnel executing the hands-on decontamination, contamination control procedures and facilities, personnel exposure control, monitoring, administrative limits, and other considerations that will dominate the progress of the hands-on decontamination procedure.

Given the very large numbers of personnel that will require entry and egress from the containment building during the hands-on decontamination procedure, it is imperative that detailed health physics procedures be developed which will minimize the impact of health physics on the productivity of personnel working in the containment, while at the same time providing maximum assurance that worker exposures will be maintained as low as reasonably achievable (ALARA). In addition, large volumes of anti-contamination clothing and respiratory protection gear will be required to complete the hands-on decontamination.

Section 9 presents an inventory of the equipment which is anticipated to be required. It appears imperative that careful planning be given to the timely procurement of this equipment and clothing, and

that detailed procedures for the cleaning, refurbishment and distribution of personal equipment be developed. Recommendations regarding these procedures are contained in Sections 4 and 8.

A detailed discussion of recommended hands-on decontamination procedures is contained in Section 9. This discussion includes considerations of personnel training and task planning, removal of gross surface contamination, mechanical and chemical decontamination procedures, quantifying the effectiveness of hands-on decontamination, decontamination of hot spots within the containment, decontamination of equipment, prevention of recontamination of areas which have previously been decontaminated, temporary shielding of hot spots within the containment to expedite the hands-on decontamination process, and a discussion of the possible procedures which may be instituted in the decontamination or removal of particular pieces of equipment which are anticipated to be found in a highly contaminated state.

Since the exact radionuclear contamination status of the containment which will be encountered on initial containment entry cannot be quantified until remote decontamination and initial entry procedures have been completed, it will be highly desirable to continually update the hands-on decontamination plan in light of available information, and to continually assess and evaluate the effectiveness of procedures as they are instituted. The discussion contained in Section 9 is based on a very preliminary assessment of the situation that may be encountered. It is planned that the procedures described in Section 9 will be updated on a continuing basis in subsequent Containment Engineering Group efforts as more data regarding the current status of the containment becomes available.

Recognizing that the initial hands-on decontamination activities will proceed during a time when the reactor still contains fuel (and thus will require cooling and maintenance of safety systems) Section 10 describes measures that should be instituted during the initial hands-on decontamination procedure to assure that systems which are required for long-term core cooling or to maintain the reactor in a safe configuration will be protected and maintained in an operable status. This section contains an inventory of in-containment systems and attempts to identify those which will require continued operability during the hands-on decontamination activity.

Section 11 addresses maintenance of nuclear steam supply system component integrity, in particular, prevention of corrosion, during remote and hands-on decontamination activities. An assessment is presented of the probable corrosive effects resulting from the March 28 incident on the external surfaces of NSSS components.

2.0 ASSESSMENT OF THE TMI-2 CONTAINMENT RADIATION ENVIRONMENT2.1 Introduction

Since the radiation environment in the TMI-2 containment will dictate considerations for all activities in the containment program, it is imperative that present bounding estimates of that radiation environment be accurate. However, at this point in time, July 1, 1979, no actual dose rate measurements have been made in the containment environment itself. Estimates of the dose rates and the radiation environment, therefore, must be made based on an interpretation of all data at hand. Presently this presents itself in three broad categories:

## a. Reactor Coolant System (RCS) Liquid Samples

These are the sample data obtained through the Met Ed Sample Coordinator which are periodically taken and assayed via a Ge(Li) detector, multichannel analyzer system.

## b. Containment Atmosphere Samples

These sample data are also obtained from radio-assays with the same type of equipment used for the above RCS samples.

## c. Direct Radiation Measurements and Experiments

These are a series of measurements from health physics surveys, a series of portable Ge(Li) detector scans of the containment equipment hatch, and the results of teletector maps of the R-605 containment penetration just above the sump water, up to the inboard penetration pressure boundary. Data is also used from the containment monitoring systems - in particular, the HP-R-214 containment dome monitor.

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## 2.2 Bounding Estimates of the Containment Radionuclide Environment

### 2.2.1 Major Radioisotopic Sources Prior to Remote Decontamination and Purging

This section considers three major sources which constitute the radionuclide environment in the containment prior to remote decontamination and purging. They are the airborne source, the general plateout sources, and the source that will be deposited on the 282' elevation walls and floor due to the containment sump inventory.

#### 2.2.1.1 Airborne Sources

##### 2.2.1.1.1 Lower Bound Scenario and Rationale

For the lower bound estimate of the airborne sources prior to remote decontamination and purging, the major assumption was that only the iodines and noble gases were released into the containment atmosphere. Iterative analyses of the airborne concentration were calculated using the Bechtel Standard Computer Code CONTDOSE, (see Section 2.2.2 for a detailed description) queued to the containment air sample data taken on March 29. Spray credit was taken for removal of the iodine via the injection of the sodium hydroxide solution through the containment spray headers using a spray time of about five minutes and a spray removal constant of  $100 \text{ hr}^{-1}$ . This scenario envisions the only major nongaseous species to be solely that of the iodine family. Based upon these iterative calculations it is estimated that 44% of the noble gases and 27% of the iodines were released to the containment atmosphere. These CONTDOSE predictions for other assay dates have produced consistent agreement based upon these initial release fractions. See Table 2-1 (A) for the airborne specific activities. See Figures 2-10 and 2-11 for the transient dose rates and integral doses for both airborne beta and gamma sources.

##### 2.2.1.1.2 Median Bound Scenario and Rationale

For the median airborne source, it was assumed that other volatile species would be included along with the iodine and noble gases described in the previous low bounding estimate scenario. Release fractions for the other volatile species and nonvolatile species are based solely upon best estimates of core release fractions, first to the primary coolant, and then to the atmosphere with a partition factor of 10. Although only Cs-137 was initially observed to be present in the March 29 containment air sample, there has been one other air sample in which nongaseous activity other than iodine has been observed. It appears that this case, as presented here, would represent a median scenario useful in assessing minimum detectable activities for the major isotopes that must be addressed for health physics maximum permissible airborne concentrations (MPC's). See Table 2-1 (B) for airborne specific activities. See Figures 2-12 and 2-13 for the transient dose rates and integral doses for both beta and gamma sources.

### 2.2.1.1.3 Upper Bound Scenario and Rationale

The rationale for the high bounding airborne source is that no spray credit will be given at all for the case of a 44% noble gas and a 27% iodine release. It is realized, then, that this would be inconsistent with any airborne containment assays that have been done; however, it would assess an upper bound airborne concentration for those areas within the plant on which the sprays had little or no effect for removing iodine from the air. For example, see those areas in Chapter 6 of the FSAR which deal with the sprayed and unsprayed regions of the containment. See Table 2-1 (C) for the airborne specific activities. See Figures 2-14 and 2-15 for the transient dose rates and integral doses for both airborne beta and gamma sources.

### 2.2.1.2 General Plateout Sources

#### 2.2.1.2.1 Lower Bound Scenario and Rationale

For the lower bound general plateout scenario and rationale, it is assumed that iodine is the only major plateout source and that it has uniformly plated out over all the available surface area of the containment. This includes the walls of the containment and the major horizontal surfaces (floors) of the three different elevations, which is a total of about 100,000 square feet of surface area. This lower bound general plateout source is calculated with the CONTDOSE Code assuming that the same 27% initial airborne activity of iodine has plated out on the 100,000 square feet. This is equivalent to assuming that the sprays were ineffective in removing airborne iodine and that the iodine then plated out over a period of time to all vertical and horizontal surfaces. See Table 2-2 for the specific activity of the iodine plateout source.

#### 2.2.1.2.2 Median Bound Scenario and Rationale

For the median general plateout source, the results of the SAI Ge(Li) detector experiments (No. TDR-TMI-123) on the containment equipment hatch were used. In that series of experiments, five different detector positions were used to define the plateout source on the 305' elevation inside the containment as to both species and photon flux reaching the Ge(Li) detector. Table 2-3 recaps the raw data taken in those series of experiments. Note that the photon fluxes reported are at the entrance to the lead collimator used in the Ge(Li) detector experiments. A sketch of the Ge(Li) detector collimator hole is shown in Figure 2-1. The detector locations and the areas subtended by the solid angles of the detector/collimator configurations are shown in Figure 2-2. For the purpose of this report, only the results of the uncollimated Position 1 detector data were analyzed quantitatively. The results from the other Ge(Li) detector positions will be analyzed at a later time, although the results can be interpreted qualitatively.

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As can be seen in Figure 2-2, the Position 1 experiment looked out into the region immediately in front of the equipment hatch and in the direction of the southwest side of the 1A steam generator secondary shield wall on the 305' elevation. The major areas visible to Position 1 are the vertical walls of the steam generator compartment and the floor directly in front of the equipment hatch.

Two possible median bound plateout sources can be inferred from this Position 1 Ge(Li) detector data. One can assume that the response of the Ge(Li) was due to a plateout source which was only on the equipment hatch itself or, alternatively, was solely due to the plateout of material on the floor area that could be seen from Position 1. Shielding calculations were performed for these two plateout sources, normalized to the 60 mr/hr measured at contact with the hatch at the point where the Position 1 detector was pointed. See Figure 2-3 for a depiction of the dose rates that were measured by the GM detector as a function of position on the equipment hatch.

The shielding calculations used basic point kernel theory with point isotropic infinite medium buildup factors for steel<sup>1,2,3</sup> and mass attenuation coefficients for steel<sup>4</sup>, both parameters for discrete energies rather than group average energies. Dose conversion factors were taken from ANS 6.1.1.

The results of the calculations assuming the plateout is all on the hatch, are shown in Table 2-4. The table lists each isotope detected by the Ge(Li) experiment, with the following data for each isotope:

- a. The energy in Mev of the major gamma resulting from the disintegration of that isotope;
- b. The attenuation factor for that gamma photon through 1.5 inches of steel;

- 
- 1 O. J. Wallace, "Gamma-Ray Dose and Energy Absorption Build-up Factor Data for Use in Reactor Shield Calculations", WAPD-TM-1012, June, 1974.
  - 2 "Guidelines on the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants", ANSI/ANS-6.4-1977 (N403), Page 43.
  - 3 L. V. Spencer and G. L. Simmons, "Improved Moment Method Calculations of Gamma-Ray Transport: Application to Point Isotropic Sources in Water", NSE:50, 20-31 (1973).
  - 4 J. H. Hubbell, "Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 Kev to 100 Gev", NSRDS-NBS-29, August, 1969.

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- c. The activity plated out on the inside of the hatch, in  $\mu\text{Ci}/\text{cm}^2$ ;
- d. The dose rate from that isotope at the outside of the hatch
- e. The dose rate at the inside surface of the equipment hatch from that isotope.

Table 2-5 is a similar listing of data for each isotope for the scenario wherein all the plateout occurs solely on the floor in front of the Position 1 detector configuration. The GM tube dose rate measurement was then used as the normalization number to calculate the implied activity present on that area of the floor. The method used to calculate this number was that of Hubbell, et al; outlined in Shaffer's Reactor Shielding For Nuclear Engineers, page 362. Table 2-5 lists data for each isotope in a manner similar to the above; i.e., for each isotope we have the following information:

- a. The energy in Mev of the major photon of that isotope;
- b. The attenuation factor through 1.5 inches of steel for that isotope;
- c. The dose rate on the floor in front of the equipment hatch;
- d. The activity ( $\mu\text{Ci}/\text{cm}^2$ ) of that isotope on the 305' elevation floor in front of the hatch.

As can be seen in Tables 2-4 and 2-5, the overall effect of having the entire plateout source on the floor rather than on the hatch is about a factor of 2 in terms of activity ( $\mu\text{Ci}/\text{cm}^2$ ). Table 2-6 summarizes the total curies plated out on elevation 305' and other elevations. The assumption in the table was that the plateout on the hatch itself would be used for all vertical surfaces and the plateout activity on the floor would be used for the horizontal floor surfaces. Clearly, this approach results in an overestimate of the plateout sources. It is anticipated that careful analysis of the collimated Ge(Li) spectra will allow refinement of the median bound plateout source.

#### 2.2.1.2.3 Upper Bound Scenario and Rationale

The rationale for the upper bound scenario for the general plateout source is primarily tied to the interpretation of the readings of the HP-R-214 containment dome monitor. This monitor is a Victoreen Model 847-1 ionization chamber. The ionization chamber is inside a 1.56 inch lead cylindrical shield and is located atop the elevator shaft in the containment at elevation 372'. The monitor was hermetically sealed in the lead shield via an amphenol connector. The amphenol connector is constructed with Kovar, a resin capable of withstanding high

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temperature, humidity, pressure, and radiation (100 megarads integrated dose). The ionization chamber is integral to its own preamplifier. The limiting component of that preamplifier is a field effect transistor whose individual damage threshold has been placed at 100,000 rads. However, due to the variability of radiation damage data on individual components, it is not unreasonable to assume that this monitor could easily withstand an integrated dose of 300,000 or even 500,000 rads. The expected response from a failing detector, which has been observed by Victoreen in actual applications in hot cells, would be a rapidly oscillating readout (a period of approximately one second) on the readout panel indicator, accompanied by a gradual monotonic decrease in the magnitude of the panel readout. Figure 2-4 is a graph of the dose rate measured inside the lead shield housing as read out in the control room since the incident.

Note that Figure 2-4 also includes the approximate dates when integrated doses of 100,000, 200,000 and 300,000 rads occurred. An integrated dose of 100,000 rads was not reached until about April 8. Therefore, barring physical damage by the hydrogen detonation, the monitor reading inside the lead shield should have been accurate to within plus or minus 10% (the monitor's stated accuracy) until that time. Observing Figure 2-4, the initial peak and rapid drop off appears to be the result of the initial release and decay of short-lived airborne fission products. The containment has over one million cubic feet of free volume above the 347' elevation operating deck. Longer-lived isotopes released to this volume would settle out on the horizontal surfaces, including the top of the elevator shaft on which the monitor is mounted, the tops of the secondary shield, and the 347' floor. This appears to be reflected in the buildup between days 2 and 10. At this point, radiological decay begins to lower the activity as the airborne particulates continue to settle, which could explain the gradual decrease between day 10 and day 33. From day 33 to day 37, the detector response undergoes several changes which correspond to changes in plant operating conditions. The first change occurs on day 33 which coincides with the initiation of natural circulation in the primary coolant system. The second change occurs one day later, which coincides with the cessation of reactor coolant system venting through the pressurizer EMOV and vent valve. On day 37, another sharp change in the detector response occurs which corresponds to the time when the containment air coolers were secured. The fact that the monitor was responding to the above changes implies proper operation of the monitor, although the design accuracy of plus or minus 10% might not have remained valid after April 8. From day 37 to day 47, the readings decrease with an apparent 12 day half-life (possibly Ba/La-140), before finally stabilizing at a constant dose rate of 40 rads/hr.

The actual reading outside of the lead shield enclosure for the HP-R-214 containment dome monitor is a complex function of the transmission characteristics of the 1.56" lead shield itself. The transmission characteristics of the lead are dependent on the following factors:

- a. The relative abundance of the different isotopic species at any given time. This means that due to different half-lives, the effective isotopic distribution (and thus the gamma energy spectrum) is changing. This will change the attenuation characteristics of the shield.
- b. The attenuation afforded by the lead shield is a function of the energy of the gamma photons emitted for each isotope. For example, I-131, which decays with a gamma energy of 0.365 Mev would be reduced by a factor of 150,000; whereas the 1.596 Mev photon associated with the decay of La-140 would only be reduced a factor of 5. For the purposes of quantifying the plateau source on elevation 347', it was assumed that the relative proportions of the activities that were observed on elevation 305' with the Ge(Li) spectrometer would exist at elevation 347' in the vicinity of the containment dome monitor. Table 2-7 summarizes the activities (in  $\mu\text{Ci}/\text{cm}^2$ ) at elevation 347' along with the following data for each isotope:
  1. The energy (in Mev) of the major gamma photon from the disintegration of that isotope;
  2. The overall attenuation factor for that isotope through 1.56 inches of lead;
  3. The dose rate contribution for the specific isotope to the dose rate inside the lead shield;
  4. The contribution of that isotope to the dose rate predicted outside the lead shield.

Under these assumptions, the apparent composite attenuation factor of the lead shield appears to be about 9. Victoreen's suggested attenuation factor of 100 is based on calibration of the detector with a point source of Cs-137. This difference in transmission factors is due to the presence of the high energy photon (1.596 Mev of La-140).

It should be noted, however, that Table 2-7 would demand that the HP-R-214 dose rate inside the lead shield be following a half-life of about 13 days (associated with the decay of Ba/La-140) during the month of June, because approximately 75% of the total dose rate inside the shield is indicated to be due to the La-140, if the equipment hatch Ge(Li) data isotopic mix is presumed to be representative

of the 347' elevation. Therefore, only two possible explanations are possible to resolve this conflict:

- a. The relative abundance of the isotopes derived from the Ge(Li) detector experiment at elevation 305' is not applicable to elevation 347', and the dome monitor is actually seeing a presence of Cs-137 exclusively; or
- b. The dome monitor is no longer reading correctly because the integrated dose to the monitor has exceeded the working damage threshold of the monitor and its preamplifier.

At this point in time, the apparent paradox cannot be resolved, and further data must be obtained from experimental programs to be performed at a later time in order to resolve the conflict. However, for the purposes of this report, results for both possible source terms (i.e., the Ba/La-140 dominated and the Cs-137 dominated plateout sources) will be evaluated for all dose rate calculations.

#### 2.2.1.3 Containment Sump Plateout Sources

For all containment sump plateout scenarios, a plateout coefficient of 0.1 cm was assumed. The plateout coefficient is defined as follows:

Activity plated out on the wall (in  $\mu\text{Ci}/\text{cm}^2$ ) equals the plateout coefficient (cm) times the concentration of the isotope in the sump water (in  $\mu\text{Ci}/\text{cm}^3$ ).

The value of 0.1 cm is based upon actual operating experience with other accidents where mixed fission products have plated out on surfaces that were submerged in liquids containing mixed fission products. <sup>1,2</sup>

#### 2.2.1.3.1 Lower Bound Scenario and Rationale

This scenario envisions no release of any activity to the sump during the series of uncoveries and recoveries (both full and partial) of the water level over the core during the incident. This is equivalent to the assumption that the reactor coolant system retained all of the activity released from the core and that the first 300,000 gallons of sump water was relatively free of activity at the time the reactor coolant pump was restarted at about 1900 hours on March 28, 1979. This scenario then postulates a slow rate of RCS leakage into the sump (at the reported early value of 1.74 gallons per minute) with partitioning of the

<sup>1</sup> Personal communication - E. Walker, derived from operating experience with test reactors.

<sup>2</sup> The plateout coefficient model does not account for the extensive hot spots which will result from fission products that precipitate from adsorbed moisture or from undrainable pools of water which will evaporate after the sump is drained. See Section 2.3.7 for an assessment of these hot spots. 871122

radioisotopic inventory between the RCS and the sump queued to the primary coolant assay taken on April 10. This sump water is then diluted with an additional 100,000 gallons of intermediate closed cooling loop system leakage for a total sump volume of 500,000 gallons. No further dilution due to in-leakage to the sump has been used in this report. The core release fractions for this scenario, along with the other release fractions, are listed in Table 2-8 (A). Table 2-8 (B) lists the major radioisotopes in the core shortly after scram. This inventory was calculated with the ORIGEN code using the actual power history (94 effective full power days). It is assumed that the sump containing this lower bound radionuclide concentration inventory is drained and the resultant plateout source is listed in Table 2-9. This is the plateout source that would be present on elevation 282' on December 1, 1979. Table 2-10 lists the sump water specific activity decayed to December 1, 1979, from which this plateout source would result.

#### 2.2.1.3.2 Median Bound Scenario and Rationale

This scenario envisions both the release outlined above for the lower bound estimate, and the addition of a release to the sump which occurs early in the incident via water solid conditions from the reactor pressure vessel through the hot leg to the pressurizer and across the EMOV. This water solid condition appears to have occurred in at least two time intervals on March 28, based on the available thermal-hydraulic data, i.e., from 1140 to 1455 hours and 1625 to 1650 hours. By this time, the majority of the core damage (i.e., significant cladding failure) had occurred and significant fractions of the radioisotope inventories were released to the primary coolant. This primary coolant was washed to the sump at a rate of about 380 gpm (assuming choked flow of saturated water through the EMOV). This water was then mixed over the next 40 days with the slow leak of 1.74 gpm. This simulation was queued to the April 10 primary coolant assay (i.e., the assay was used as initial and boundary conditions for the differential equations in the simulation). The overall core release fractions for this scenario are also listed in Table 2-8 (A). The plateout activity is shown in Table 2-10 and the sump water specific activity on which this was based is given in Table 2-9. The plateout source term for this scenario was then created in the same fashion as that for the low bound estimate by assuming plateout factor of 0.1 cm.

The validity of this median bound sump inventory was verified with the results of one of the ongoing Containment Assessment Task Force experiments (No. TDR-TMI-126). On June 20, a detector was inserted into penetration R-605 to the inner flange. The detector was encased in a lead shield with a hole to allow determination of directional dose rates. The detector read 30 rem/hour when aimed at the sump through the one inch steel penetration sleeve at the inboard side of the penetration. The detector was approximately 10" inside the containment wall and about 2' above the surface of the water. Calculations performed with the median bound sump inventory decayed to June 20 (see Table 2-11) using the PIPEND shielding code (see Section 2.3.1) predicted a dose rate of 53 rem/hr over the axial centerline of the sump

two feet above the surface of the water through one inch of steel. It is estimated that the dose field at the edge of the sump (measurement location) should be about one-half the dose field at the center of the sump. This is a result of measuring what is essentially a semi-infinite half-space volumetric source and comparing to a calculational model which simulated an infinite half-space volumetric source. This approximation yields a predicted dose rate of about 27 rem/hour which is in excellent agreement with the observed 30 rem/hour for the experiment. This agreement should be carefully interpreted, however, since the detector, being a GM tube pulse counting device, cannot be extremely accurate for an attenuated polyenergetic gamma spectrum unless it was previously calibrated for an identical incident spectrum. This agreement is probably only sufficient to infer that the median bound sump activity estimate is accurate to about the same degree as the measurement.

#### 2.2.1.3.3 Upper Bound Scenario and Rationale

This scenario envisions that all the activity released from the core eventually will enter the sump, i.e., the content of the sump as outlined in the median estimate, plus the contents of the reactor coolant, and the curie content from all plateout sources on the 305' and 347' elevations. For the purposes of the sump model, this is equivalent to dumping the core release fractions outlined in Table 2-8 (A) into 500,000 gallons of water, and decaying it for a decay period of 248 days (which corresponds to December 1, 1979). The method for obtaining the plateout itself is then followed in the same manner as for the previous plateout source. A plateout coefficient of 0.1 cm was used for determining the sump plateout. The plateout activity inventory for the high bounding estimate is listed in Table 2-10, and the associated sump water specific activity in Table 2-9.

#### 2.2.2 Radiation Dose Rates - Prior to Remote Decontamination and Purging

The analytical methods employed in calculating the dose rates in this section are as follows:

##### a. Airborne Dose Rates

These dose rates were calculated with the Bechtel CONTDOSE Code. This computer code uses a finite cloud model to calculate airborne gamma dose rates and a semi-infinite cloud model for beta dose rates from isotopic distributions in the building atmosphere that are calculated as a function of time. These isotopic distributions account for daughter and granddaughter decay products and utilize a mechanistic treatment of spray washout of airborne fission products. The code also performs a numerical integration of the dose rates to arrive at integrated doses as a function of time from the airborne species.

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## b. Contact Dose Rates Due to Plated Out Activity

## 1. Contact Beta Dose Rates

Contact beta dose rates were calculated for plateout sources from the relationship:

$$D_{\beta} = 0.5 \bar{E}_{\beta} S_A \frac{\nu}{F} K F(\nu, t) \quad \text{Eqn. 2-1}$$

Where  $\bar{E}_{\beta}$  is equal to 1/3 of the maximum energy of the beta;  $S_A$  is the beta source strength which is equal to the number of betas per second per unit area from the plateout source;  $\nu/F$  is equal to the mass attenuation coefficient for tissue from the work of Burger (Health Physics, 26: pages 1-12);  $F(\nu, t)$  is equal to the dead skin layer correction factor<sup>1</sup>, i.e., the fraction of the beta dose which is attenuated by the dead skin layer, and thus does not reach live tissue beneath that layer;  $K$  is the dose conversion factor for tissue, (rads/hr/Mev/sec/gm).

Note that the factor 0.5 assumes a normally bi-directional planar source and a net current of zero. It also should be noted that this formulation results in the maximum theoretical beta dose rates which can be observed, where, in reality, the beta plateout source will have a finite thickness, i.e., the plateout will be a mixed fission product source encapsulated in boric acid crystals and hydroxides of the various isotopic species along with a halogen ionic crystalline content. This presupposed nature of the plateout means that the dose rates calculated by the above formulation would be approximately a factor of 10 times higher than would be actually observed with a beta survey meter, due to the internal self-absorption of the betas in the crystalline plateout source itself. An actual effect of all these contact dose rates will only be observed within about 1 to 2 meters from any planar source. Therefore, all personnel entering the containment should be warned to stay as far away as is feasible from all vertical surfaces. This is because the range of betas in air is approximately one meter for the mixed fission product spectrum anticipated. Provisions should be made for incorporating shoe inserts in the Anti-C suits or

<sup>1</sup> Loevinger, et al. "Discrete Radioisotope Sources", Radiation Dosimetry, Academic Press Inc., New York, 1956.

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booties until gross decontamination of the floor has been completed. These inserts should have a sufficient shielding value such that the beta dose to the feet from the floor is insignificant.

## 2. Contact Gamma Dose Rates

The contact gamma dose rates were calculated according to the classical planar boundary crossing estimator used in Monte Carlo analyses, i.e.,

$$D_{\gamma} = 0.5 \sum_{j=1}^n S_{A_j} E_{\gamma_j} k_j \quad \text{Eqn. 2-2}$$

Where  $E_{\gamma_j}$  is equal to the energy of the photon in Mev in the  $j$ th energy group from the isotope;  $S_{A_j}$  is the gamma source strength at the planar surface, equal to microcuries per square centimeter multiplied by the number of photons emitted in energy group  $E_j$  per microcurie. This assumes that the flux is equal to the current, which implies that the particles are entering perpendicular to the surface of the plane crossing;  $k_j$  is equal to the dose conversion factor for the  $j$ th energy group in units of rad/hour/Mev/cm<sup>2</sup>/second. The factor of 0.5 assumes a normally bi-directional planar source and a net current of zero; i.e., half of the particles go into the surface and half go out of the surface.

### c. Gamma Dose Rates from Cylindrical Surface Sources

Dose rates were calculated using the following relationship which gives the dose rate at a dose point on the horizontal midplane of the cylinder along the axis of the cylinder:

$$D_i = D_o \tan^{-1} \left( \frac{H}{2R} \right) \quad \text{Eqn. 2-3}$$

Where  $D_o$  equals twice the contact gamma dose rate as calculated via equation 2-2,  $H$  equals the height of the cylinder;  $R$  equals the radius of the cylinder;  $D_i$  equals the dose rate in rads per hour at the dose point inside the cylinder.

## d. Gamma Dose Rates From Planar Surface Sources

The formulation used to calculate doses at some given distance from a finite rectangular surface source is that due to Hubbell et al. Equation 2-4 which follows, expresses Hubbell's relationship:

$$D_i = D_o \frac{2}{\pi} \tan^{-1} \left[ \frac{ab}{\sqrt{1 + a^2 + b^2}} \right] \quad \text{Eqn. 2-4}$$

Where  $D_i$  is the gamma dose rate at the distance  $Z$  from the planar source;  $D_o$  equals twice the contact gamma dose rate as calculated in Equation 2-2 above in rads per hour;  $a$  equals the ratio of half-height to the distance  $Z$  away from the source;  $b$  equals the ratio of the half-width to the distance  $Z$  away from the source. See Figure 2-22 for the geometry of Hubbell's formula.

The relationship in Equations 2-3 through 2-4 were programmed into two new computer codes. The computer codes are:

**PROSURF** - This program calculates the plateout source ( $\mu\text{Ci}/\text{cm}^2$ ) for any given time increment for any initial given source. The program accounts for daughter - grand-daughter decay. The contact beta dose rates for each time increment are also calculated using the relation in Equation 2-1. The gamma source spectrum for the plateout activity is calculated and is written to an intermediate file to be bootstrapped into the following code called SURFDOSE.

**SURFDOSE** - This computer code calculates gamma dose rates at contact with the plateout source generated by PROSURF at the following points: 1) contact, using Equation 2-2; 2) from a cylindrical surface source using Equation 2-3; 3) from a rectangular surface source using Equation 2-4.

#### 2.2.2.1 Best Estimate Scenario for the 282' Elevation Radiation Dose Rates

Tables 2-12 (A) and (B) summarize the dose rates, both beta and gamma, for all elevations prior to remote decontamination and purging of the containment. These dose rates are also broken down into their individual components, i.e., airborne, contact, doses transmitted through floors or ceilings (if applicable), and doses from the vertical and horizontal plateout on walls to a dose point as indicated in Figure 2-5. No attempt has been made to assess the possible presence of fuel fines on the 282' elevation.



For elevation 282', the sources that were used were as follows:

- a. The airborne source was that source as outlined in Section 2.2.1.1.2 as the median bound airborne source. Corrections were made in the CONTDOSE run for this source at this elevation to account for the finite size of the volume of the airborne cloud, i.e., a radius of 15 feet was used for the sphere which represents the largest sphere which could be totally inscribed in the 282' elevation. See Figures 2-16 and 2-17 for the transient dose rates and integral doses for both airborne beta and gamma sources.
- b. The median bound containment sump plateau source was used for calculating both contact dose rates and dose rates to the dose points depicted in Figure 2-5. The height of the cylindrical surface source was equal to 7 feet, the maximum depth of the containment sump water observed to this date. The radius of the source was that of the largest cylinder which could be inscribed in the 282' elevation between the inner wall of the containment and the outer wall of the B steam generator B cavity wall. The planar source that was calculated used the dimensions of a height equal to that of the height of the cylindrical source, but with a width equal to twice the radius of the source and a dose point equal to the radius of the cylindrical surface source. As can be seen, the major contributor to the dose rate at 282' was due to the gamma contact dose rate on the floor at elevation 282', extrapolated to 3' above the floor, which will be representative of the dose rate seen by the workers who would enter this region. Table 2-10 lists the specific activity of the plateau dose from which the plateau dose rates were calculated. Table 2-1 (B) represents the airborne isotopic distribution. All dose rates and distributions are keyed to December 1, 1979.

2.2.2.2 Best Estimate of the Radiation Dose Rates at the 305' Elevation Prior to Remote Decontamination and Purging

As above, Tables 2-12 (A) and (B) list the beta and gamma dose estimated for the 305' elevation. The dose rates are further divided into their individual contribution from the various components to the total dose rate. The sources used in calculating the dose rates for the 305' elevation were as follows:

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- a. Airborne - The airborne source was calculated with the CONTDOSE code using the airborne source described in Section 2.2.1.1.2, the median bound airborne source scenario. As before, the volume of the largest sphere which could be inscribed between the inner wall of the containment and the outer wall of the steam generator cavity was used as the volume of the finite cloud airborne source, radius equal to 25 feet. See Figures 2-18 and 2-19 for the transient dose rates and integral doses for both airborne beta and gamma sources.
- b. The contact gamma dose rates on the floor and wall were calculated using the general plateau median bound source as outlined in Section 2.2.1.2.2.
- c. Doses away from the floors and walls to the dose points indicated in Figure 2-6 were calculated using the SURFDOSE code with the height of the inscribed cylinder equal to the difference in elevations between 305' and 347', and the radius equal to the largest inscribed cylinder that can be inscribed in the 305' elevation between the inner wall of the containment and the outer wall of the steam generator cavity. Planar source dimensions were set at a height equal to the height of the inscribed cylindrical surface source, width equal to twice that radius, and the distance away from the source as equal to the radius of the inscribed cylinder.
- d. Dose rates due to transmission from the plateau source on the 347' elevation were calculated using both possibilities for the upper bound scenario of the plateau source on the 347' elevation as outlined in Section 2.2.1.2.3, (i.e., assuming the HP-R-214 monitor was reading correctly on June 1, indicating only cesium plateau and another assuming that the isotopic mix on the 347' elevation is the same as measured at equipment hatch). The dose rate to the dose point shown (the man) in Figure 2-6 was calculated using the SURFDOSE code after correcting the contact dose rate for gammas with an attenuation of 7 inches of concrete, equal to the floor thickness on the 347' elevation.

The dose from containment sump plateau to the dose point at elevation 305' was also calculated in an analogous manner using the median bound estimate for the containment sump plateau source with a correction for attenuation through the 7 inch 305' elevation floor slab.

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2.2.2.3 Best Estimate of the 347' Elevation Radiation Dose Rates Prior to Remote Decontamination and Purging

Tables 2-12 (A) and (B) list the total beta and gamma dose rates on elevation 347' as well as the magnitude of the individual contributing sources. The sources used to calculate these dose rates were as follows:

- a. Airborne Sources - The median bound scenario airborne source in Section 2.2.1.1.2 was used as input to the CONTDOSE code. A finite cloud correction was used with a volume equal to the largest sphere that could be drawn inside of the 347' elevation to the top of the containment dome, a radius of 73 feet. See Figures 2-20 and 2-21 for the transient dose rates and integral doses for both beta and gamma airborne sources.
- b. Contact dose rates were calculated using the general plateau source term for the high bound scenario found in Section 2.2.1.2.3, taking both possible plateau sources in the scenario, i.e., Cs-137 dominated plateau source or the Ba/La-140 dominated source.
- c. Gamma dose rates from the cylindrical and planar surface sources were calculated in an analogous manner using the method of the inscribed cylinder and the planar surface source equal to a planar section of the cylinder along the diameter parallel to the axis of the cylinder. The wall surface source, however, was assumed to be that of the median bound general plateau source at elevation 305' for the 305' floor elevation. The rationale for this was that the 347' floor elevation is very contaminated because the plateau occurred primarily on horizontal surfaces over a long period of time and that the sprays were most effective on the 347' elevation and above in washing the walls.

The plateau sources used in calculating the plateau contribution for the various dose rates in Tables 2-12 (A) and (B) are listed in Table 2-7. The airborne sources (specific activities) are shown for elevation 347' in Table 2-1. The geometry for the calculation is shown in Figure 2-7.

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#### 2.2.2.4 Radiation Dose Rates Prior to Remote Decontamination and Purging at the Elevation of the Polar Crane Cab

The dose rates, both beta and gamma, for the dose point located at the polar crane cab prior to remote decontamination and purging are also listed in Tables 2-12 (A) and (B). The sources used in generating those dose rates are as follows:

- a. Airborne Sources - The same geometry and airborne source concentration was assumed for the polar crane cab as that used in the calculation for the airborne dose rates for the 347' elevation.
- b. Contact Dose Rates - All contact dose rate listings are the same as those calculated for the 347' elevation.
- c. Dose rates<sup>1</sup> from the ceiling, floor and walls, however, were calculated based upon a dose point at the elevation of the crane cab (elevation 415') positioned at the center line of the containment. SURFDOSE was used to calculate these dose rates with the same plateout surface activities as those used in the 347' elevation dose rate calculation.

Since the basic surface source terms were the same for the 347' and polar crane cab elevations, Tables 2-1 (B) and 2-7 reflect the respective airborne concentrations and plateout source concentrations which could be expected in the vicinity of the polar crane cab.

#### 2.2.3 Major Radioisotopic Sources After Remote Decontamination and Purge

##### 2.2.3.1 Introduction

In this section, only two major sources that comprise the radionuclide environment after remote decontamination and purging has taken place are considered. Only the general plateout source for the 347' elevation will be analyzed because it is difficult to predict, with any degree of confidence, the effective DF's that can be obtained via the remote decontamination methods outlined in Section 5 for other than the 347' elevation. It may be feasible to do a detailed study at a later time to analyze spray patterns and flooding on the other elevations, at which time quantitative estimates of the specific activities and corresponding dose rates can be made. As outlined in Section 5.0, an overall effective DF of 800 to 80,000 may be achieved on the 347' elevation through the carefully repeated application of the remote decontamination techniques in Section 5.

Note that, unlike Section 2.2.1, there will be no quantitative assessment of the airborne source because the containment will have been purged. The primary airborne contributor, as noted in

<sup>1</sup> See Figure 2-8 for geometry used in calculation.

Section 2.2.1.1, is Kr-85, a noble gas, which will be removed by the purge. The only airborne then will be a resuspension of the plated out activity which itself will have been reduced by the process of remote decontamination and atmospheric filtration.

2.2.3.2 Best Estimate of the General Plateout Source on the 347' Elevation

The scenario and rationale will remain the same as those outlined in Section 2.2.1.2, except that an upper and lower bound estimates of the plateout activity is assessed by reducing the activity by a factor of 800 or 80,000, corresponding to high and low bound plateout estimates, respectively. The results of applying these ratios are presented in Table 2-13 along with the total curies remaining on the walls and floors of elevation 347'. Note again that two assessments were made for the 347' elevation plateout because of the unresolved paradox of the HP-R-214 dome monitor dose rates. It should be noted that this model effectively assumes an instantaneous remote decontamination occurrence on December 1, 1979. In reality, as outlined in Section 5, there will be a multi-step procedure lasting over a period of several weeks. This means that radioactive decay will reduce the concentration of some of the isotopic species with intermediate half-lives (about 50 days).

2.2.4 Radiation Dose Rates After Remote Decontamination and Purge

2.2.4.1 Best Estimate of the 347' Elevation Dose Rates

Using the source described in Section 2.2.3.2, dose rates (both beta and gamma) were calculated with the PROSURF and SURFDOSE codes for the geometries outlined in Section 2.2.2.3. Those results are presented in Table 2-14 which also lists the contributions to the total dose rate from each source, i.e., the walls and the floor.

2.2.4.2 Best Estimate of the Dose Rates at the Polar Crane Cab

Using the source described in 2.2.3.2, dose rates (both beta and gamma) were calculated with the PROSURF and SURFDOSE codes for the geometries outlined in Section 2.2.2.4. These results are presented in Table 2-14 which also lists the contributions to the total dose rate from each source, i.e., the walls and floor.

## 2.3 Assessment of the Radiation Environment for Predictable Hot Spots

### 2.3.1 Introduction

The hot spots analyzed in this section were selected for analysis because of the following reasons:

- a. These areas/equipment will deviate greatly from the dose rates which will generally prevail in the containment, or
- b. These areas/equipment are critical items to the the containment decontamination effort.

For all the following cases, it was assumed that remote decontamination had occurred but the DF credit was taken only for those areas/equipment on the 347' elevation.

For volumetric cylindrical sources the PIPEND code was used. This code utilizes Rockwell's methods modified with the theory of the ORNL code, SDC, which accounts for deficiencies of the Rockwell method for highly self-attenuating (optically thick) cylindrical sources. Buildup factors are calculated from Capo's formulation and multi-layer shield buildup is accounted for via Broder's method. The volumetric source terms were calculated with the PROCESS code which accounts for daughter-granddaughter decay. This code produces a volumetric energy flux spectrum source term which is input to the PIPEND code. Dose rates were calculated for the dates of June 15 and December 1, 1979, for all volumetric sources.

### 2.3.2 Dose Points Near the Steam Generator on the 347' Operating Deck

Estimates were made to dose points listed in Table 2-17 from the following possible sources associated with the steam generator:

- a. The primary coolant activity in the steam generator
- b. A pile of fuel pellets or debris representing about 1% of the total core laying on the top of the steam generator tube sheet

The rationale for postulating this particular source is that about 12% - 15% of the total initial core fission product inventory has been released. This estimate is based upon failed fuel fractions, and an isotherm plot (see Figure 2-9) of the thermocouple readings for the core. Assuming that about 10% of this released inventory, i.e., 1% of the total, was transported by the hydraulic flow of the reactor coolant pumps into and up the candy cane hotlegs, a pile representing the equivalent of one entire fuel assembly could be

laying on the steam generator tube sheet. This assumption should be viewed as an extreme upper bounding case. The fuel source was derived from an ORIGEN run which reflected the actual power history of the core and is listed in Table 2-15. The dose rates for the dose points of interest are shown in Table 2-17.

### 2.3.3 Dose Points Near the Reactor Coolant Drain Tank

Estimates were made to dose points listed in Table 2-17. The primary coolant source terms used for the Section 2.3.2 calculations were used for the analyses. Contributions from the 14 inch pressurizer relief discharge header were also calculated. Results of these analyses are listed in Table 2-17.

### 2.3.4 Dose Points Near the Letdown Coolers

Estimates were made to dose points listed in Table 2-17. The primary coolant source terms used in Section 2.3.2 were also used for the tube side of the coolers. The tubes were then homogenized to an equivalent volumetric source with correct self-attenuation. Results of this analysis is shown in Table 2-17.

### 2.3.5 Dose Points Near the Containment Air Coolers

Estimates were made to the dose points listed in Table 2-17. The source term for the cooling coils is expected to result from condensation on the coils and was simulated with the PROCESS code by assuming a 18 ft<sup>3</sup> filter model with a flow rate of 42,500 CFM, a filter efficiency of 40%, and running time of 20 days. This is equivalent to an assumption that the vast majority of the plateout on the cooling coils occurred in the first 20 days of the incident. The median bound airborne source in Section 2.2.1.1.2 at t=0 was used and is listed in Table 2-16. The results of the analyses are listed in Table 2-17.

### 2.3.6 Dose Points Near the East Stairwell/Elevator Shaft

Estimates were made to dose points listed in Table 2-17 resulting from the plateout source term described in Section 2.2.1.2.3. The plateout was assumed to be on both the inside and outside of the masonry block walls. The block walls were reinforced in every third hole with mortar and rebar; therefore, shielding credit was only taken for an equivalent thickness of normal weight concrete. The results of these calculations are listed in Table 2-21.

### 2.3.7 Containment Sump Hot Spots

In Section 2.2.1.3, a model for containment sump plateout was presented which used the concept of a plateout coefficient. Implicit in this model are several assumptions which limit its utility in predicting dose rate fields which may exist after the sump is drained. These can be summarized as follows:

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1. The radioisotopes are assumed to exist as soluble chemical compounds in the sump water.
2. The bottom containment floor, elevation 282', can be completely drained leaving no standing water.
3. The bottom containment floor is clean of debris and dirt on which sump water contaminants may adsorb.

The first assumption is dependent on the nature of the accelerated radiochemical reactions that took place during the time the core went through a series of partial/full uncoveries, and how much sodium hydroxide was injected to the reactor coolant system. The period of several weeks following the incident, when the fuel pellets were being exposed to primary coolant and, thus, the potential for additional leaching, also complicates the assessment of the chemical nature of the sump water. However, because of the measurements outlined in Sections 2.2.1.2.2 and 2.2.1.3.2, preliminary indications are that after several months, the controlling isotopes for plateout will be Cs-134 and Cs-137. Since the vast majority of plausible cesium compounds that may have been formed ( $CsI$ ,  $CsBr$ ,  $CsIO_3$ , etc.) are highly soluble in water at 25°C (see Handbook of Chemistry and Physics), the assumption of soluble compounds appears to be valid.

The second assumption, that the bottom floor at elevation 282' can be completely drained is, of course, false. As can be seen in Figure 11-1, there will be about two inches of sump water under each steam generator standing in a pool about 11 feet in diameter. Using the median sump inventory in Table 2-9 and assuming that this 2 inches of sump water will then evaporate yields a plateout activity of about 2500 uCi/cm<sup>2</sup>. This activity would yield a gamma dose rate of about 100 rads/hour assuming the same relative isotopic abundance shown in Table 2-10.

A second area which cannot be drained is the actual containment sump itself. Because of the configuration of the drop lines from the sump to the decay heat removal system, about 6 inches of water will remain in the containment sump after it is drained. This water, when evaporated, would yield a plateout gamma dose rate of 300 rads/hour.

In addition to these two areas, which can be defined explicitly, there will also be many random hot spots from small puddles on the floor. These are due to the departure of the floor from a true flat surface, resulting from customary construction tolerances for floors. These small hot spot "puddles" could range up to 20 rads/hour assuming the evaporation of one centimeter (about 1/4 inch) of sump water with a diameter greater than one foot.



Deviation from the third assumption that the floor is clean of debris and dirt on which sump water can adsorb can also cause hot spots. In fact, if the debris and dirt participates in ion exchange with sump water fission products over the long period before the sump is drained, then this dirt and debris will concentrate the activity in much the same manner as ion exchange resins. This dirt and debris could either cause local hot spots or the entire floor of elevation 282' could be uniformly contaminated in this manner creating a much larger sump plateout dose rate roughly equal to the upper bound dose rate listed in Table 2-12 (A). For example, if the dirt acts like a diatomaceous earth with a DF of 10, then the plateout activity could easily be  $500 \mu\text{Ci}/\text{cm}^2$  with an associated dose rate of 20 rads/hour.

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TABLE 2-1 (A)

LOW ESTIMATE OF CONTAINMENT  
AIRBORNE SPECIFIC ACTIVITIES AROUND DECEMBER 1, 1979\*

( $\mu\text{Ci/cc}$ )

ISOTOPE NAME	5360.00 HRS
KR-85	7.2992-01
SR-89	9.1802-04
Y-89M	8.2622-08
I-129	2.9588-10
I-131	2.7785-11
I-133	.0000
XE131M	1.1952-06
XE133M	4.9622-33
XE-133	3.7816-12
CS-135	2.1867-07
CS-137	2.3543-04
BA137M	2.2272-04
TOTAL	7.3130-01

\*NOTE: The actual decay time for this activity was 253 days. Taken from CONTDOSE Run No. X4251 dated 6-14-79.

TABLE 2-1 (B)

MEDIAN ESTIMATE OF CONTAINMENT AIRBORNE  
SPECIFIC ACTIVITIES AROUND DECEMBER 1, 1979\*

( $\mu\text{Ci/cc}$ )

ISOTOPE NAME	5360.00 HRS	ISOTOPE NAME	5360.00 HRS
KR-85	7.2998-01	I-133	.0000
SR-89	4.4446-06	XE131M	1.1952-06
SR-90	1.4882-06	XE133M	4.9622-33
Y-89M	4.0002-10	XE-133	3.7816-12
Y-90	1.4827-06	CS-135	1.2622-07
Y-91	7.3909-06	CS-136	3.0750-12
ZR-95	1.0678-05	CS-137	1.7138-06
ZR-97	.0000	BA137M	1.6213-06
NB-95	2.2652-05	BA-140	2.7769-10
NB-95M	1.1328-05	LA-140	3.1935-10
NB-97	.0000	CE-141	1.0065-07
NO-99	1.4197-31	CE-143	.0000
TC-99	1.8632-11	CE-144	2.5303-05
RU-103	1.3742-06	PR-143	8.1906-12
RU-106	4.5746-06	PR-144	2.5304-05
RH-105	2.4259-05	ND-147	1.1573-11
AG-111	2.1982-16	PM-147	5.3360-06
SN-125	1.4079-14	PM-149	2.1011-39
SB-125	7.2494-08	PM-151	.0000
SB-127	6.8685-26	SM-153	.0000
TE125M	7.2774-08	EU-155	1.3701-07
TE127M	1.1226-07	EU-156	1.6486-13
TE-127	1.1266-07		
TE129M	6.5535-08	TOTAL	7.3013-01
TE-129	4.2001-08		
TE131M	.0000		
TE-131	.0000		
TE-132	6.6509-28		
I-129	2.9595-10		
I-131	2.7787-11		
I-132	6.8513-28		

\*NOTE: The actual decay time for this activity was 253 days.  
Taken from CONTDOSE Run No. X4102 dated 6-14-79.

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TABLE 2-1 (C)

HIGH ESTIMATE OF CONTAINMENT AIRBORNE  
SPECIFIC ACTIVITIES AROUND DECEMBER 1, 1979\*

( $\mu\text{Ci/cc}$ )

ISOTOPE NAME	5360.00 HRS	ISOTOPE NAME	5360.00 HRS
KR-85	7.2998-01	XE131M	2.8657-06
SR-89	1.8337-02	XE133M	6.5445-33
SR-90	6.1400-03	XE-133	4.1073-12
Y-89M	1.6504-06	CS-135	2.8791-07
Y-90	6.1170-03	CS-136	1.2687-08
Y-91	3.0493-02	CS-137	7.0708-03
ZR-95	4.4053-02	BA137M	6.6890-03
ZR-97	.0000	BA-140	1.1457-06
NB-95	9.3458-02	LA-140	1.3176-06
NB-95M	4.6736-02	CE-141	4.1525-04
NB-97	.0000	CE-143	.0000
MO-99	5.8573-28	CE-144	1.0439-01
TC-99	7.6872-08	PR-143	3.3792-08
RU-103	5.6694-03	PR-144	1.0440-01
RU-106	1.8874-02	ND-147	4.7745-08
RH-105	1.0008-01	PH-147	2.2015-02
PD-109	.0000	PH-149	8.6685-36
AG-111	9.0691-13	PH-151	.0000
SM-125	5.8087-11	SM-153	.0000
SB-125	2.9909-04	EU-155	5.6527-04
SB-127	2.8338-22	EU-156	6.8019-10
TE125M	3.0025-04		
TE127M	4.6317-04	TOTAL	1.3475+00
TE-127	4.6483-04		
TE129M	2.7038-04		
TE-129	1.7329-04		
TE131M	.0000		
TE-131	.0000		
TE-132	2.7440-24		
I-129	1.2210-06		
I-131	1.1464-07		
I-132	2.8267-24		
I-133	.0000		

\*NOTE: The actual decay time for this activity was 253 days.  
Taken from CONTOSE Run No. X4431, 6-14-79.

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ORIGINAL

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TABLE 2-2

LOWER BOUND GENERAL PLATEOUT SOURCE\*  
ON DECEMBER 1, 1979

<u>Isotope</u>	<u>Plateout Activity</u> <u>(<math>\mu\text{Ci}/\text{cm}^2</math>)</u>
I-129	$7.8 \times 10^{-4}$
I-131	$7.3 \times 10^{-5}$
I-132	$1.8 \times 10^{-21}$
I-133	$\sim 0.0$

\*NOTE: Assumes plateout of iodine only.  
See Section 2.2.1.2.1 for rationale

TABLE 2-3  
RAW SUMMARY SHEET  
Ge(Li) GAMMA-RAY MEASUREMENTS OF TMI-2 CONTAINMENT  
EQUIPMENT HATCH ( $\mu\text{cm}^2\text{-sec.}$ )

E $\gamma$ (Kev)	Position 1		Position 2		2A	2B	Hatch Window		
	No Plug	1-cm Diam.	1-cm Diam.	0.5-cm Diam.	1-cm Diam.	1-cm Diam.	No Plug	1-cm Diam.	0.5-cm Diam.
<u>85 Kr</u>									
514.0	52.9	-	26.8	-	24.9	8.1	17.4	5.9	-
<u>131m Xe</u>									
163.0	5.6	-	-	-	-	-	2.3	1.3	0.6
<u>131 I</u>									
284.3	9.4	-	-	-	-	-	-	-	-
364.5	162.2	11.9	15.1	3.6	14.3	7.4	15.8	3.9	0.16
637.0	28.9	4.5	5.1	-	3.1	0.8	3.4	1.9	-
722.9	10.4	-	-	-	-	-	1.9	0.6	-
<u>134 Cs</u>									
569.3	8.7	-	-	-	2.1	0.85	1.3	0.6	-
604.7	44.6	0.3	11.5	1.5	11.6	0.62	6.9	1.9	-
795.8	59.3	3.8	23.8	7.2	20.1	1.01	11.5	5.2	-
801.8	6.7	-	-	-	-	-	-	1.14	0.32
1365.1	7.1	-	3.9	-	-	1.4	2.8	0.25	-
<u>136 Cs</u>									
163.9	-	-	-	-	-	-	-	-	-
340.6	-	-	-	-	-	-	-	-	-
818.5	-	-	-	-	-	-	-	-	-
1048.1	7.8	3.4	7.0	4.2	3.3	0.5	2.5	-	-
1235.5	-	-	0.4	2.3	2.7	3.0	0.2	0.3	-
<u>137 Cs</u>									
661.6	185.1	2.7	53.5	12.9	49.6	4.4	33.5	14.4	1.3
<u>140 Ba</u>									
537.3	6.0	-	19.1	-	1.7	-	1.6	-	-
<u>140 La</u>									
328.8	-	-	-	-	-	-	-	-	-
487.0	16.0	1.2	-	-	-	-	2.9	1.3	-
752.0	-	1.5	-	-	-	-	0.86	0.63	-
815.9	25.5	-	5.7	1.5	7.9	1.7	5.2	3.5	-
868	5.1	-	3.2	-	-	-	1.1	-	-
925.2	7.3	-	-	-	-	2.7	2.4	0.6	-
1596.5	315.9	42.6	175.9	202.1	179.0	21.8	106.1	54.3	17.2
2348.1	4.6	4.5	4.1	5.9	1.5	-	2.1	1.6	-
2521.7	21.3	11.4	20.7	16.7	10.8	1.5	8.0	4.0	-
2547	0.74	0.28	1.4	1.4	-	-	0.27	0.20	-
*Dates taken	*6/1/79		*6/2/79		*6/2/79	*6/2/79		*6/5/79	

TABLE 2-4  
EXPECTED ACTIVITY<sup>(2)</sup> AND GAMMA DOSE RATES<sup>(3)</sup> ON  
EQUIPMENT HATCH ASSUMING ALL ACTIVITY IS ON HATCH

<u>Isotope</u>	<u>Major Photon Energy (Mev)</u>	<u>Attenuation Factor (1)</u>	<u>Activity on Inside of Hatch (<math>\mu\text{Ci}/\text{cm}^2</math>)</u>	<u>Gamma Dose Rate on Inside of Hatch (mr/hr)</u>	<u>Gamma Dose Rate on Outside of Hatch (mr/hr)</u>
Cs-137	0.662	3.3	1.6	38.	12.
La-140	1.596	2.5	1.9	94.	38.
I-131	0.365	4.9	2.2	31.	6.4
Cs-134	0.796	2.7	0.44	12.	4.3
Cs-136	1.048	2.2	0.052	1.5	0.7
TOTAL	-	-	6.4	180.	60.

NOTES: (1) Attenuation through 1.5" of steel.

(2) Based on Position 1, Uncollimated Ge(Li) Experiment by SAI on June 1, 1979.

(3) Dose Rates normalized to 60 mr/hr reading from Eberline 520 Standard GM probe.

(4) All numbers listed to two significant figures.

CAUTION: These dose rates are due to plateout only. See Tables 2-12 (A) and (B) for additional dose rate components. For hot spots see Table 2-17.

TABLE 2-5

EXPECTED ACTIVITY<sup>(2)</sup> AND GAMMA DOSE RATES<sup>(3)</sup> AT EQUIPMENT HATCH  
 ASSUMING ALL ACTIVITY IS ON FLOOR ELEVATION 305'

Isotope	Major Photon Energy (Mev)	Attenuation Factor <sup>(1)</sup>	Dose Rate on Floor in Front of Hatch (mr/hr)	Activity on Floor In Front of Hatch ( $\mu\text{Ci}/\text{cm}^2$ )
Cs-137	0.662	3.3	95	4.0
La-140	1.596	2.5	240	4.8
I-131	0.365	4.9	79	5.8
Cs-134	0.796	2.7	29	1.1
Cs-136	1.048	2.2	4	0.13
TOTAL	-	-	443	16.

- NOTES: (1) Attenuation through 1.5" of steel
- (2) Based on Position 1, Uncollimated Ge(Li) Experiment by SAI on June 1, 1979
- (3) Dose rates normalized to 60 mr/hr reading from Eberline 520 Standard GM probe
- (4) All numbers listed to two significant figures

CAUTION: These dose rates are due to plateout only. See Table 2-12 (A) and (B) for additional dose rate components. For hot spots see Table 2-17.



TABLE 2-6

TOTAL PLATEOUT ACTIVITIES IN CURIES ON EACH ELEVATION

<u>Elevation</u>	<u>Total Area (cm<sup>2</sup>) (1)</u>	<u>Activities in Curies</u>	<u>Tables for Plateout Isotopic Distribution</u>	<u>Section For Rationale</u>
282'	1.66 x 10 <sup>7</sup>	930.	2-10	2.2.1.3.2
305'	3.80 x 10 <sup>7</sup>	220.	2-5	2.2.1.2.1
347'	7.60 x 10 <sup>7</sup>	86,000 <sup>(2)</sup>		2.2.1.2.3.

NOTES: (1) Includes walls and floors.

(2) Assumes the same relative concentrations of the radioisotopes observed on the 305' elevation by the Ge(Li) detector at Position 1 exist on the elevation 347' floor.

TABLE 2-7

EXPECTED ACTIVITY AND GAMMA DOSE RATES FOR LEAD SHIELD  
AROUND THE HP-R-214 DOME MONITOR ON JUNE 1, 1979

Isotope	Major Photon Energy (Mev)	Attenuation Factor <sup>(3)</sup>	Dose Rate Inside Shield (mr/hr)	Dose Rate Outside Shield (mr/hr)	Activities <sup>(1)(2)</sup> ( $\mu\text{Ci}/\text{cm}^2$ )
Cs-137	0.662	69	1.1E+3	7.6E+4	3200
La-140	1.596	5	3.8E+4	1.9E+5	3800
I-131	0.365	1.6E+5	3.9E-1	6.3E+4	4600
Cs-134	0.796	28	8.7E+2	2.3E+4	880
Cs-136	1.048	11	2.9E+2	3.2E+3	100
TOTAL		8.8	4.0E+4	3.5E+5	13,000

NOTES: (1) Assuming the same relative concentrations of the radioisotopes observed on the 305' elevation by the Ge(Li) detector at Position 1

(2) If due to Cs-137 alone, the  $\mu\text{Ci}/\text{cm}^2$  would be  $5.81 \times 10^4 \mu\text{Ci}/\text{cm}^2$  and the dose rate outside would be 2760 rads/hour

(3) Effective attenuation factor for this isotopic mix is:

$$8.8 = \frac{3.5 \text{ E}+5 \text{ mr/hr}}{4.0 \text{ E}+4 \text{ mr/hr}}$$

All attenuation factors are through 1.56" of lead

(4) All numbers listed to two significant figures

CAUTION: These dose rates are due to plateout only. See Table 2-12 (A) and (B) for additional dose rate components. For hot spots see Table 2-17.

TABLE 2-8 (A)

SUMMARY OF SCENARIO CORE INVENTORY RELEASE FRACTIONS  
FOR VARIOUS ISOTOPE CLASSES

<u>Class</u>	<u>High Estimate Section 2.2.1.3.3</u>	<u>Median Estimate Section 2.2.1.3.2</u>	<u>Low Estimate Section 2.2.1.3.1</u>
Noble Gases	0.44	0.44	0.44
Halogens	0.55	0.55	0.13
Solubles	0.02	0.02	0.004
Mo, Y	0.01	0.01	0.01
Cs, Rb	0.50	0.30	0.13
Insoluble	0.005	0.005	0.0013
Assay Queue Date	-	4-10-79	4-10-79

- NOTES:
1. See Table 2-9 for sump specific activities ( $\mu\text{Ci}/\text{cc}$ ) for these release fractions
  2. See Table 2-10 for sump plateout activity ( $\mu\text{Ci}/\text{cm}^2$ ) for these release fractions

TABLE 2-8 (B)

TMI-2 CORE INVENTORY OF MAJOR RADIOISOTOPES  
AT  $t=0^+$  (SHORTLY AFTER SCRAM)  
BASED ON ACTUAL POWER HISTORY

ISOTOPE	TOTAL CURIES	ISOTOPE	TOTAL CURIES
KR-83M	1.13E+07	TE-133	9.10E+07
KR-85M	2.71E+07	TE-134	1.47E+08
KR-85	1.01E+05	BA-137M	8.44E+05
KR-87	5.19E+07	BA-139	1.48E+08
KR-88	7.34E+07	BA-140	1.43E+08
KR-89	9.43E+07	BA-141	1.34E+08
XE-131M	4.80E+05	BA-142	1.31E+08
XE-133M	2.04E+07	RU-103	7.07E+07
XE-133	1.51E+08	RU-106	3.32E+06
XE-135M	2.75E+07	LA-140	1.44E+08
XE-135	3.25E+07	LA-141	1.35E+08
XE-137	1.43E+08	LA-142	1.34E+08
XE-138	1.40E+08	LA-143	1.32E+08
I-129	1.78E-01	CE-141	1.17E+08
I-131	6.94E+07	CE-143	1.33E+08
I-132	1.04E+08	CE-144	2.54E+07
I-133	1.59E+08	PR-143	1.30E+08
I-134	1.76E+08	PR-144	2.63E+07
I-135	1.48E+08	EU-155	1.63E+04
I-136	7.08E+07	EU-156	1.78E+06
I-137	7.45E+07	ND-147	5.30E+07
I-138	3.84E+07	NB-95M	1.08E+06
BR-83	1.13E+07	NB-95	5.70E+07
BR-84*6	5.19E+05	MO/TC99	1.19E+02
BR-84	2.02E+07	Y-89M	2.02E+01
BR-85	2.67E+07	Y-90M	6.44E+02
BR-87	4.49E+07	Y-90	8.00E+05
BR-88	5.07E+07	Y-91M	7.06E+07
RB-88	7.42E+07	Y-91	8.52E+07
RB-89	9.84E+07	Y-92	1.25E+08
RB-90	9.59E+07	Y-93	1.38E+08
SR-89	7.40E+07	Y-94	1.40E+08
SR-90	8.12E+05	Y-95	1.43E+08
SR-91	1.23E+08	CS-134	2.88E+05
SR-92	1.75E+08	CS-135	2.46E+00
SR-93	1.34E+08	CS-136	6.86E+05
SR-94	1.30E+08	CS-137	8.77E+05
SR-95	1.18E+08	CS-138	1.48E+08
TE-129M	3.89E+06	CS-139	1.45E+08
TE-129	1.70E+07	ZR-95	9.26E+07
TE-131M	9.51E+06	AG-110M	2.20E+04
TE-131	6.25E+07		
TE-132	1.03E+08	TOTALS:	6.05E+09
TE-133M	6.60E+07		

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- NOTES: (1) This is not the entire inventory, only the major radioisotopes. Total inventory is  $1.3 \times 10^{10}$  curies.
- (2) Based on PSU ORIGEN run for 94 effective full power days - Run No. R4591338, dated 4-9-1979.

TABLE 2-9

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CONTAINMENT SUMP ACTIVITY ON DECEMBER 1, 1979  
FOR HIGH, MEDIAN AND LOW SCENARIOS

ISOTOPE	ACTIVITIES* ( $\mu\text{Ci}/\text{cm}^3$ )		ISOTOPE	ACTIVITIES ( $\mu\text{Ci}/\text{cm}^3$ )
I-129	5.17E-05	5.97E-05	SR-89	7.05E+00
I-131	1.07E-05	1.85E-05	SR-90	1.85E+00
I-132	1.25E-20	1.15E-20	Y-89M	5.34E-04
I-133	0.00E-01	0.00E-01	Y-91	1.85E+00
SR-89	2.61E+01	3.12E+01	ZK-75	4.14E+00
SR-90	5.44E+00	9.26E+00	NR-95	5.38E+00
IE-129M	2.23E-01	7.64E-02	NR-95M	2.29E+01
IE-129	1.43E-01	4.70E-02	NO-99	6.24E+00
IE-131M	1.95E-58	2.58E-57	KU-102	4.65E-24
IE-131	3.56E-59	4.71E-58	KU-106	8.47E-01
IE-132	1.21E-20	1.12E-20	KU-106	1.76E+00
EA-137M	2.16E+02	1.44E+02	AG-110M	9.55E-03
IA-140	2.23E-03	8.59E-04	IE-129M	2.31E-02
KU-103	9.93E+00	3.26E+00	IE-129	1.48E-02
KU-106	2.20E+01	6.76E+00	IE-131M	6.70E-58
LA-140	2.57E-03	9.88E-04	IE-131	1.22E-58
CE-141	6.31E+00	2.11E+00	IE-132	2.90E-21
CE-143	7.36E-52	6.24E-51	I-129	1.40E-05
CE-144	1.47E+02	4.53E+01	I-131	4.51E-06
FR-143	5.49E-03	3.79E-03	I-132	2.98E-21
FR-144	1.47E+02	4.53E+01	I-133	0.00E-01
EU-155	1.31E-01	1.48E-01	YE-131M	1.87E-05
EU-156	1.97E-04	2.71E-04	CS-134	1.75E+01
NO-147	1.08E-04	1.53E-04	CS-135	2.39E-01
NR-95M	3.72E-01	4.76E-01	CS-136	2.34E-04
NR-95	3.86E+01	4.18E+01	CS-137	6.58E+01
NO-137 <sup>o</sup>	4.53E-31	3.45E-24	EA-137M	6.23E+01
Y-89M	2.35E-03	2.81E-03	EA-140	2.16E-04
Y-90	3.45E+00	9.27E+00	LA-140	2.49E-04
Y-91	2.49E+01	4.16E+00	LE-141	5.47E-01
CS-134	6.05E+01	4.04E+01	CE-143	1.52E-51
CS-135	6.50E-04	5.52E-01	CE-144	1.18E+01
CS-136	3.31E-04	3.06E-04	FR-143	1.85E-05
CS-137	2.38E+02	1.52E+02	FR-144	1.18E+01
ZR-95	1.75E+01	2.24E+01	NO-147	2.80E-05
AG-110M	3.98E-02	3.79E-02	LU-155	3.45E-02
			LU-156	6.30E-05
TOTALS:	9.61E+02	5.58E+02	TOTALS:	2.22E+02
	High Estimate	Median Estimate		Low Estimate

\* Tritium (H-3) activity in the sump is estimated at 0.5 to 1.5  $\mu\text{Ci}/\text{cm}^3$  based on normalization to the 6-19-79 RCS sample using Cs-137 as a queuing isotope.

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TABLE 2-10

CONTAINMENT SUMP PLATEOUT ACTIVITY  
ON DECEMBER 1, 1979 FOR HIGH, MEDIAN AND LOW SCENARIOS

ISOTOPE	ACTIVITIES ( $\mu\text{Ci}/\text{cm}^2$ )		ISOTOPE	ACTIVITIES ( $\mu\text{Ci}/\text{cm}^2$ )
XE-131M	4.88E-06	8.42E-06	SR-89	7.05E-01
I-129	5.19E-06	5.93E-06	SR-90	1.85E-01
I-131	1.07E-06	1.85E-06	Y-89M	6.34E-05
I-132	1.25E-21	1.15E-21	Y-90	1.85E-01
I-133	0.00E+01	0.00E+01	Y-91	4.14E-01
SR-89	2.61E+00	3.12E+00	ZR-95	5.88E-01
SR-90	8.44E-01	9.26E-01	NB-95	2.29E+00
TE-129M	2.23E-02	7.64E-03	NB-95M	6.24E-01
TE-129	1.43E-02	4.90E-03	RO-99	4.65E-25
TE-131M	1.95E-59	2.58E-58	KU-103	8.47E-02
TE-131	3.56E-60	4.71E-59	KU-106	1.76E-01
TE-132	1.21E-21	1.12E-21	AG-110M	9.55E-04
RA-137M	2.16E+01	1.44E+01	TE-129M	2.31E-03
RA-140	2.23E-04	8.59E-05	IE-129	1.48E-03
KU-103	9.93E-01	3.26E-01	IE-131M	6.70E-59
KU-106	2.20E+00	6.76E-01	IE-131	1.22E-59
LA-140	2.57E-04	9.88E-05	IE-132	2.90E-22
CE-141	6.31E-01	2.11E-01	I-129	1.40E-06
CE-143	7.36E-53	6.24E-52	I-131	4.51E-07
CE-144	1.47E+01	4.53E+00	I-132	2.98E-22
PR-143	5.49E-04	3.79E-04	I-133	0.00E-01
IR-144	1.47E+01	4.53E+00	XE-131M	1.87E-06
EU-155	1.31E-02	1.48E-02	CS-134	1.75E+00
EU-156	1.97E-05	2.71E-05	CS-135	2.39E-02
ND-147	1.08E-05	1.53E-05	CS-136	2.34E-05
NB-95M	3.72E-02	4.76E-02	CS-137	6.58E+00
NB-95	3.86E+00	4.18E+00	BA-137M	6.23E+00
RO/TC99	4.53E-32	3.45E-25	FA-140	2.16E-05
Y-89M	2.35E-04	2.81E-04	LA-140	2.49E-05
Y-90	8.45E-01	9.27E-01	IE-141	5.47E-02
Y-91	2.49E+00	4.16E-01	IE-143	1.62E-52
CS-134	6.05E+00	4.04E+00	IE-144	1.18E+00
CS-135	6.50E-05	5.52E-02	FR-143	1.85E-06
CS-136	3.31E-05	3.06E-05	FR-144	1.18E+00
CS-137	2.28E+01	1.52E+01	RO-147	2.80E-06
ZR-95	1.75E+00	2.24E+00	EU-155	3.45E-03
AG-110M	3.08E-03	3.79E-03	EU-156	6.30E-06
TOTALS:	9.61E+01	5.58E+01	TOTALS:	2.22E+01
	High Estimate	Median Estimate		Low Estimate

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TABLE 2-11

## MEDIAN BOUND SUMP INVENTORY JUNE 20, 1979

ISOTOPE *	ACTIVITIES ( $\mu\text{Ci}/\text{cm}^3$ )
XE-131M	7.64E-01
XE-133M	4.74E-15
XE-133	1.09E-10
I-129	5.93E-05
I-131	2.51E+01
I-132	1.74E-05
I-133	1.20E-22
SR-89	2.97E+02
SR-90	9.37E+00
TE-129M	2.40E+00
TE-129	1.54E+00
TE-131P	7.91E-18
TE-131	1.44E-18
TE-132	1.69E-05
BA-137I	1.45E+02
BA-140	6.17E+00
RU-103	5.68E+01
RU-106	9.21E+00
LA-140	7.10E+00
CE-141	6.95E+01
CE-143	4.92E-15
CE-144	6.75E+01
PR-143	1.51E+01
PR-144	6.75E+01
EU-155	1.78E-01
EU-156	5.31E-01
ND-147	4.22E+00
ND-95M	2.78E+00
ND-95	1.02E+02
MO/TC9I	3.06E-06
Y-89M	2.67E-02
Y-90	9.37E+00
Y-91	2.86E+01
CS-134	4.70E+01
CS-135	5.52E-01
CS-136	1.91E+00
CS-137	1.54E+02
ZR-95	1.28E+02
AG-110I	5.77E-02
TOTALS	1.26E+03

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\* Tritium (H-3) activity in the sump is estimated at 0.5 to 1.5  $\mu\text{Ci}/\text{cm}^3$  based on normalization to the 6-19-79 RCS sample using Cs-137 as a queuing isotope.

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TABLE 2-12 (A)

GAMMA DOSE RATES AT ALL ELEVATIONS

(Rads/hr)

<u>Elevation</u> <sup>(4)</sup>	<u>Dose Rate From Floor Plateout</u>	<u>Dose Rate From Wall Plateout</u>	<u>Airborne Dose Rate</u>	<u>Dose Rate Through Floor</u>	<u>Dose Rate Through Ceiling</u>	<u>Total Dose Rate</u>
282	[1.9-19.] <sup>(6)</sup>	0.27	0.046	-	0.0075	[2.2-22.] <sup>(6)</sup>
305						
Case A	0.40	0.14	0.077	0.073	6.0	6.7
Case B	0.40	0.14	0.077	0.073	46.	46.
347						
Case A	320.	0.48	0.22	-	-	320.
Case B	2400.	3.6	0.22	-	-	2400.
Polar Crane						
Case A	88.	0.30	0.22	-	-	88.
Case B	680.	0.30	0.22	-	-	680.

- NOTES: 1. Case A - Assumes the same relative concentrations of the radioisotopes observed on the 305' elevation by the Ge(Li) detector at Position 1 exist at the 347' elevation.
2. Case B - Assumes that the dose rate on elevation 347' is entirely due to Cs-137.
3. All dose rates are for 12/1/79 assuming sump is drained, and are listed for two significant figures only.
4. Refer to Figures 2-5, 2-6, 2-7, and 2-8 for geometry.
5. CAUTION: See Table 2-12(B) for corresponding additional dose rates from beta radiation. For hot spots see Table 2-17.
6. Dose rates in [] represent possible ranges due to uncertainty of chemical solubility of isotopes drained from the sump. See Section 2.3.7 - hot spots.

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TABLE 2-12 (B)

BETA DOSE RATES AT ALL ELEVATIONS(Rads/hr)

<u>Elevation</u>	<u>Contact Dose Rates</u>	<u>Airborne Dose Rates</u>	<u>Dose Rates Total</u>
282	510.	210.	720.
305	42.	210.	250.
347			
Case A	$3.4 \times 10^4$	210.	$3.4 \times 10^4$
Case B	$2.6 \times 10^5$	210.	$2.6 \times 10^5$
Polar Crane	-	210.	210.

- NOTES:
1. Case A - Assumes the same relative concentrations of the radioisotopes observed on the 305' elevation by the Ge(Li) detector at Position 1 exist at the 347' elevation.
  2. Case B - Assumes that the dose rate on elevation 347' is entirely due to Cs-137.
  3. All dose rates are for 12/1/79 assuming sump is drained, and are listed for two significant figures only.
  4. Refer to Figures 2-5, 2-6, 2-7, and 2-8 for geometry.
  5. CAUTION: See Table 2-12(A) for corresponding additional dose rates from gamma radiation. For hot spots see Table 2-17.
  6. Dose rates in [ ] represent possible ranges due to uncertainty of chemical solubility of isotopes drained from the sump. See Section 2.3.7 - hot spots.

TABLE 2-13POST REMOTE DECONTAMINATION  
PLATEOUT ACTIVITIES ON ELEVATION 347'

<u>Isotope</u>	<u>On 12/1/79 in <math>\mu\text{Ci}/\text{cm}^2</math></u>	
	<u>High Estimate</u>	<u>Low Estimate</u>
I-131	$8.4 \times 10^{-7}$	$8.4 \times 10^{-9}$
La-140	$6.8 \times 10^{-33}$	$6.8 \times 10^{-35}$
Cs-134	$9.4 \times 10^{-1}$	$9.4 \times 10^{-3}$
Cs-136	$7.6 \times 10^{-6}$	$7.6 \times 10^{-8}$
Cs-137	4.0	$4.0 \times 10^{-2}$

TABLE 2-14

BETA AND GAMMA DOSE RATES AFTER REMOTE DECONTAMINATION  
(Rads/Hour)

<u>Elevation</u>	<u>Beta Dose Rates</u>		<u>Gamma Dose Rates</u>	
	<u>High Estimate</u>	<u>Low Estimate</u>	<u>High Estimate</u>	<u>Low Estimate</u>
347'				
Case A	42.	$4.2 \times 10^{-1}$	$4.0 \times 10^{-1}$	$4.0 \times 10^{-3}$
Case B	320.	3.2	3.1	$3.1 \times 10^{-2}$
At Polar Crane				
Case A	-	-	$1.1 \times 10^{-1}$	$1.1 \times 10^{-3}$
Case B	-	-	$8.5 \times 10^{-1}$	$8.5 \times 10^{-3}$

- Notes: 1. Case A - Assumes the same relative concentrations of the radioisotopes observed on the 305' elevation by the Ge(Li) detector at Position 1
2. Case B - Assumes that the dose rate is entirely due to Cs-137
3. All dose rates are for 12/1/79
4. For hot spots, see Table 2-17

TABLE 2-15

VOLUMETRIC SOURCE STRENGTH FOR PELLET PILE  
ON S/G TUBE SHEET

ISOTOPE	ACTIVITIES ( $\mu\text{Ci}/\text{CM}^3$ )	
	June 15	December 1
KR-85	3.46E+04	3.36E+04
SR-89	1.45E+06	1.44E+05
SR-90	4.63E+04	4.58E+04
Y-89M	1.30E+02	1.30E+01
Y-90	4.61E+04	4.56E+04
Y-91	1.94E+06	2.65E+05
ZR-95	2.30E+06	3.85E+05
NB-95	5.96E+06	1.60E+06
NB-95M	2.44E+06	4.08E+05
MO-99	1.72E-08	7.02E-27
TC-99	2.42E-07	2.42E-07
RU-103	1.02E+06	5.38E+04
RU-106	1.64E+05	1.19E+05
AG-110M	1.02E+03	6.46E+02
TE-129M	4.48E+04	1.45E+03
TE-129	2.87E+04	9.28E+02
TE-132	2.89E-01	6.58E-17
I-129	5.21E-02	5.24E-02
I-131	2.25E+04	1.10E-02
I-132	2.97E-01	6.78E-17
XE-131M	3.95E+03	2.33E-01
XE-133M	2.36E-04	7.26E-27
XE-133	2.04E+03	4.58E-07
CS-134	1.07E+05	9.17E+04
CS-135	9.71E-01	9.71E-01
CS-136	4.04E+03	4.85E-01
CS-137	3.50E+05	3.46E+05
BA-137M	3.31E+05	3.28E+05
BA-140	1.13E+05	1.17E+01
LA-140	1.30E+05	1.34E+01
CE-141	1.25E+06	3.42E+04
CE-143	3.91E-11	3.99E-48
CE-144	1.20E+06	7.96E+05
PR-143	1.48E+05	2.68E+01
PR-144	1.20E+06	7.96E+05
ND-147	2.13E+04	5.25E-01
PM-147	3.32E+04	2.96E+04
EU-155	9.07E+02	8.51E+02
EU-156	2.80E+03	1.28E+00
TOTALS:	2.04E+07	5.52E+06

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TABLE 2-16

AIRBORNE SPECIFIC ACTIVITY FOR CONTAINMENT  
AIR COOLER COIL SOURCE SIMULATION  
@  $t=0^+$  POST INCIDENT

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ISOTOPE      ACTIVITIES (  $\mu\text{Ci}/\text{CM}^3$  )

I-131	4.74E+01
I-132	8.24E+01
I-133	1.15E+02
I-134	2.15E+02
I-135	2.50E+02
I-136	7.70E+01
I-137	1.86E+02
BR-83	3.46E+02
BR-84*6	4.81E+02
BR-84	6.13E+02
BA-139	2.16E+00
CE-143	1.22E+00
PR-143	3.29E+02
PR-144	4.23E+02
EU-155	6.56E+02
EU-156	7.84E+02
ND-147	6.20E+02
NB-95M	2.93E+02
NB-95	4.09E+02
MO/TC99	2.83E+02
Y-89M	2.85E+00
Y-90M	2.55E+01
Y-90	1.05E+03
Y-91M	2.59E+02
Y-91	1.75E+02
Y-92	9.55E+02
Y-93	9.32E+02
CS-137	1.16E+00
CS-139	1.16E+00
TOTALS:	9.64E+03

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TABLE 2-17 (Page 1 of 3)

HOT SPOT DOSE RATES AND DOSE POINT DESCRIPTIONS (1)  
PROJECTED TO DECEMBER 1, 1979

<u>Hot Spot</u>	<u>Description</u>	<u>Volumetric Gamma Dose Rate (mr/hr)</u>	<u>Plateout Gamma Dose Rate (mr/hr)</u>	<u>Total Gamma Dose Rate (mr/hr)</u>	<u>Plateout Beta Dose Rate (mr/hr)</u>
1. Fuel Pellet Pile on S/G Tube Sheet - Assumes no water in S/G Upper Plenum	A. HP-R-214 Dome Monitor	< 1	- (5)	< 1	- (5)
	B. East Wall of S/G Con- tainment at El. 347'	< 1	- (5)	< 1	- (5)
	C. Over the Axial Cen- ter Line of the S/G	3500	- (5)	3500	- (5)
	D. At Polar Crane Cab El. 419'	280	- (5)	280	- (5)
	E. Contact Dose on S/G Dome	$2.5 \times 10^4$	Low 0.54 (2) High 4.2 (3)	$2.5 \times 10^4$	Low 200 (2) High - $1.6 \times 10^5$ (3)
2. Reactor Coolant Drain Tank	A. Outside SW Wall of RCDT Room	0.9	2000	2000	$5.1 \times 10^5$
	B. Over Tank at El. 305'	55.0	2000	2060	$5.1 \times 10^5$
	C. Contact with Tank full of RCS water	$1.3 \times 10^4$	2000	$1.3 \times 10^4$	$5.1 \times 10^5$
	D. 14" Reactor Coolant Pressurizer Relief Valve Discharge Header Thru SW RCDT Room Wall	1.8	2000	2000	$5.1 \times 10^5$

TABLE 2-17 (Page 2 of 3)

<u>Hot Spot</u>	<u>Description</u>	<u>Volumetric Gamma Dose Rate (<math>\mu</math>r/hr)</u>	<u>Plateout Gamma Dose Rate (<math>\mu</math>r/hr)</u>	<u>Total Gamma Dose Rate (<math>\mu</math>r/hr)</u>	<u>Plateout Beta Dose Rate (<math>\mu</math>r/hr)</u>
3. Letdown Coolers <sup>(8)</sup>	A. North side Wall of Letdown Cooler Room	< 1?	2000	2000?	$5.1 \times 10^5$
	B. West Side Wall of Letdown Cooler Room	< 1?	2000	2000?	$5.1 \times 10^5$
	C. Contact on Cooler	6800?	2000	8800?	$5.1 \times 10^5$
4. Contain- ment Air Coolers	A. 1 Ft from side of Air Cooler Coils	$4.6 \times 10^4$	400 (6)	$4.6 \times 10^4$	$4.2 \times 10^4$ (6)
	B. 1 Ft from side of Air Cooler Hous- ing Base	$1.2 \times 10^4$	400 (6)	$1.2 \times 10^4$	$4.2 \times 10^4$ (6)
	C. 10 Ft from side of Air Cooler Coils	$1.0 \times 10^4$	400 (6)	$1.0 \times 10^4$	$4.2 \times 10^4$ (6)
	D. 10 Ft from side of Air Cooler Hous- ing Base	9000	400 (6)	9400	$4.2 \times 10^4$ (6)
	E. 1 Ft from End of Air Cooler Coils	$2.8 \times 10^5$	400 (6)	$2.8 \times 10^5$	$4.2 \times 10^4$ (6)
	F. 1 Ft from End of Air Cooler Housing Base	5400	400 (6)	5800	$4.2 \times 10^4$ (6)
	G. 10 Ft from End of Air Cooler Coils	3200	400 (6)	3600	$4.2 \times 10^4$ (6)
	H. 10 Ft from End of Air Cooler Housing Base	2400	400 (6)	2800	$4.2 \times 10^4$ (6)

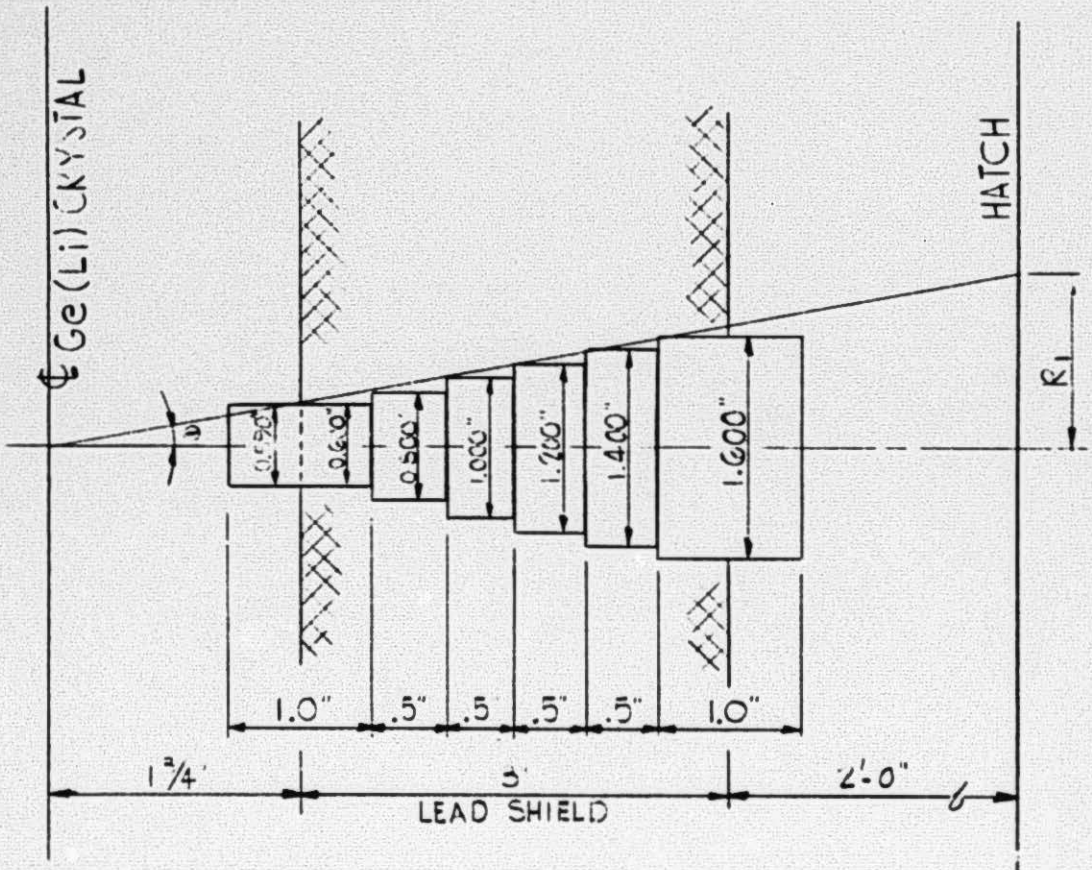
TABLE 2-17 (Page 3 of 3)

<u>Hot Spot</u>	<u>Description</u>	<u>Volumetric Gamma Dose Rate (<math>\mu</math>r/hr)</u>	<u>Plateout Gamma Dose Rate (<math>\mu</math>r/hr)</u>	<u>Total Gamma Dose Rate (<math>\mu</math>r/hr)</u>	<u>Plateout Beta Dose Rate (<math>\mu</math>r/hr)</u>
5. #2 Stair- well/Elevator Shaft	A. Contact				
	El. 282'	-	1900	1900	$5.1 \times 10^5$
	El. 305'	-	400	400	$4.2 \times 10^4$
	El. 347'	-	$3.2 \times 10^5$	$3.2 \times 10^5$	$3.4 \times 10^7$
	B. At 10' from Elevator				
	El. 282'	-	470	470	-
	El. 305'	-	134	134	-
	El. 347'	-	$6.6 \times 10^4$	$6.6 \times 10^4$	-
	C. Inside the Elevator Shaft-Axial Center Line				
	El. 282'	-	1700	1700	-
	El. 305'	-	500	500	-
	El. 347'	-	$2.4 \times 10^5$	$2.4 \times 10^5$	-

## NOTES:

1. After sprays with DF credit only taken for El. 347' and above
2. Assuming a DF = 20,000 for remote decontamination
3. Assuming a DF = 800 for remote decontamination
4. High and low post remote decontamination dose rates also bound the range of El. 347' dose rates. - See Tables 2-12 (A) and 2-12 (B)
5. Plateout in local areas exceeds the contribution from plateout on the S/G - See Tables 2-12 (A) and 2-12 (B).
6. Plateout on outside of Air Coolers only.
7. Total gamma dose rates should be added to those general area dose rates for the appropriate elevation given in Table 2-12 (A) to arrive at the true total gamma dose rate.
8. Dose rates with ? reflect inability to model fission product deposition in cooler tubes due to boric acid precipitation.





Ge(Li) LEAD COLLIMATOR GEOMETRY

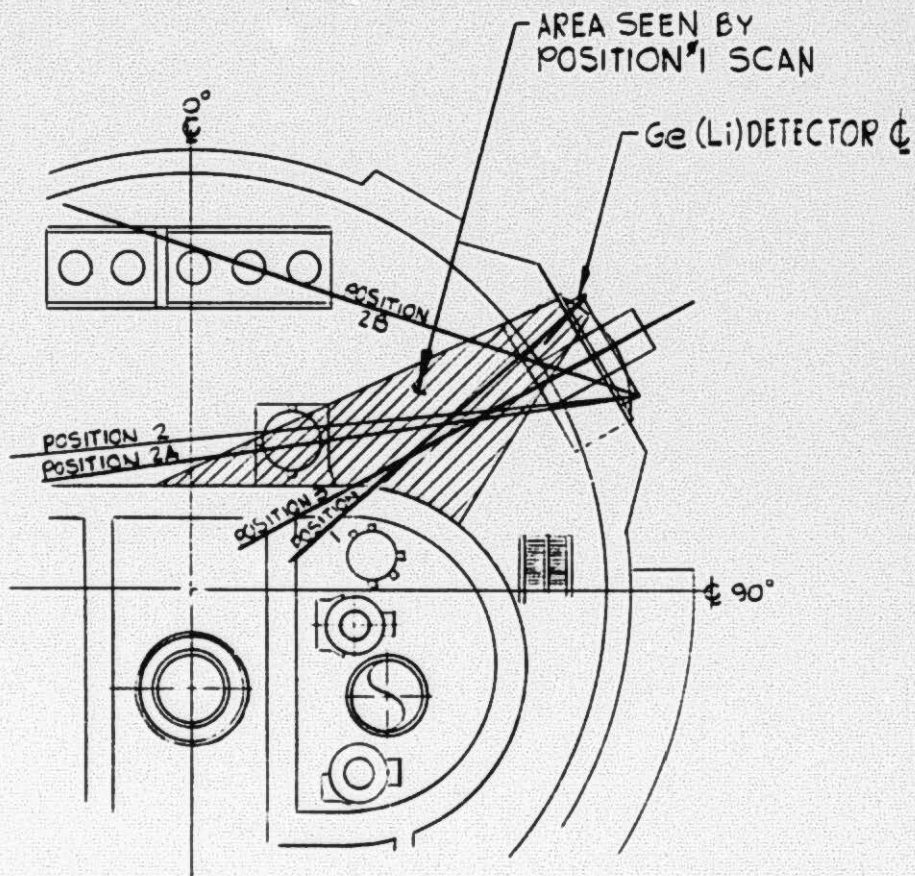
$$\theta = \tan^{-1} \frac{0.75}{4.75} = \tan^{-1} 0.1578 = 8.97^\circ = 0.157 \text{ radians}$$

$$R_1 = 26.75'' \tan \theta = 4.5''$$

POOR  
ORIGINAL

971160

LEAD SHIELD & COLLIMATOR  
FIG. 2-1



PARTIAL CTMT. PLAN  
@ EL 305'0"

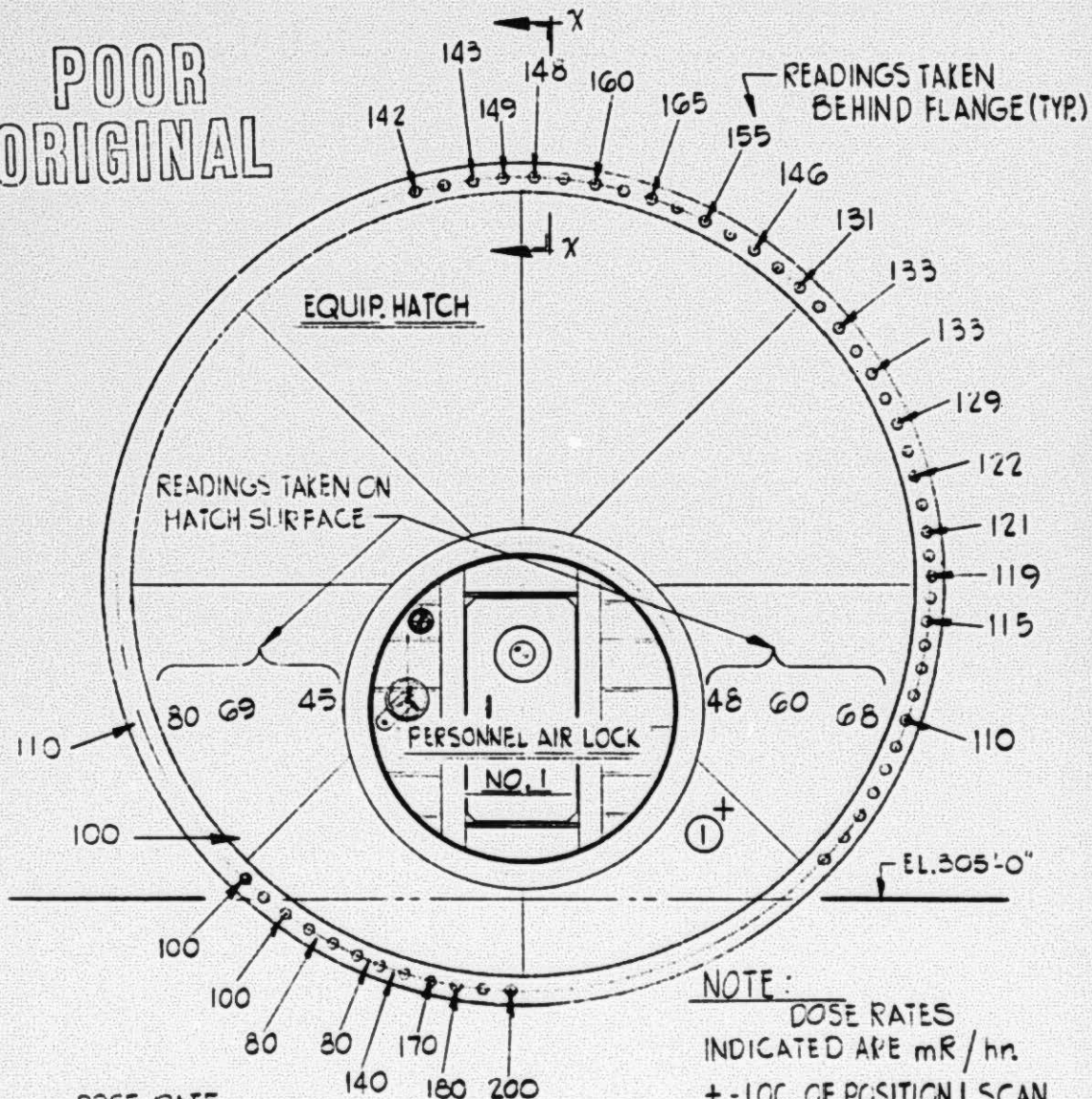
971161

POOR  
ORIGINAL

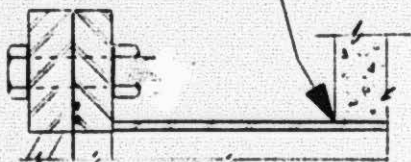
AREA OF EL 305'0" FLR. SEEN BY  
Ge (Li) DETECTOR, FROM POSITION 1

FIG. 2-2

POOR ORIGINAL



DOSE RATE READING LOCATION



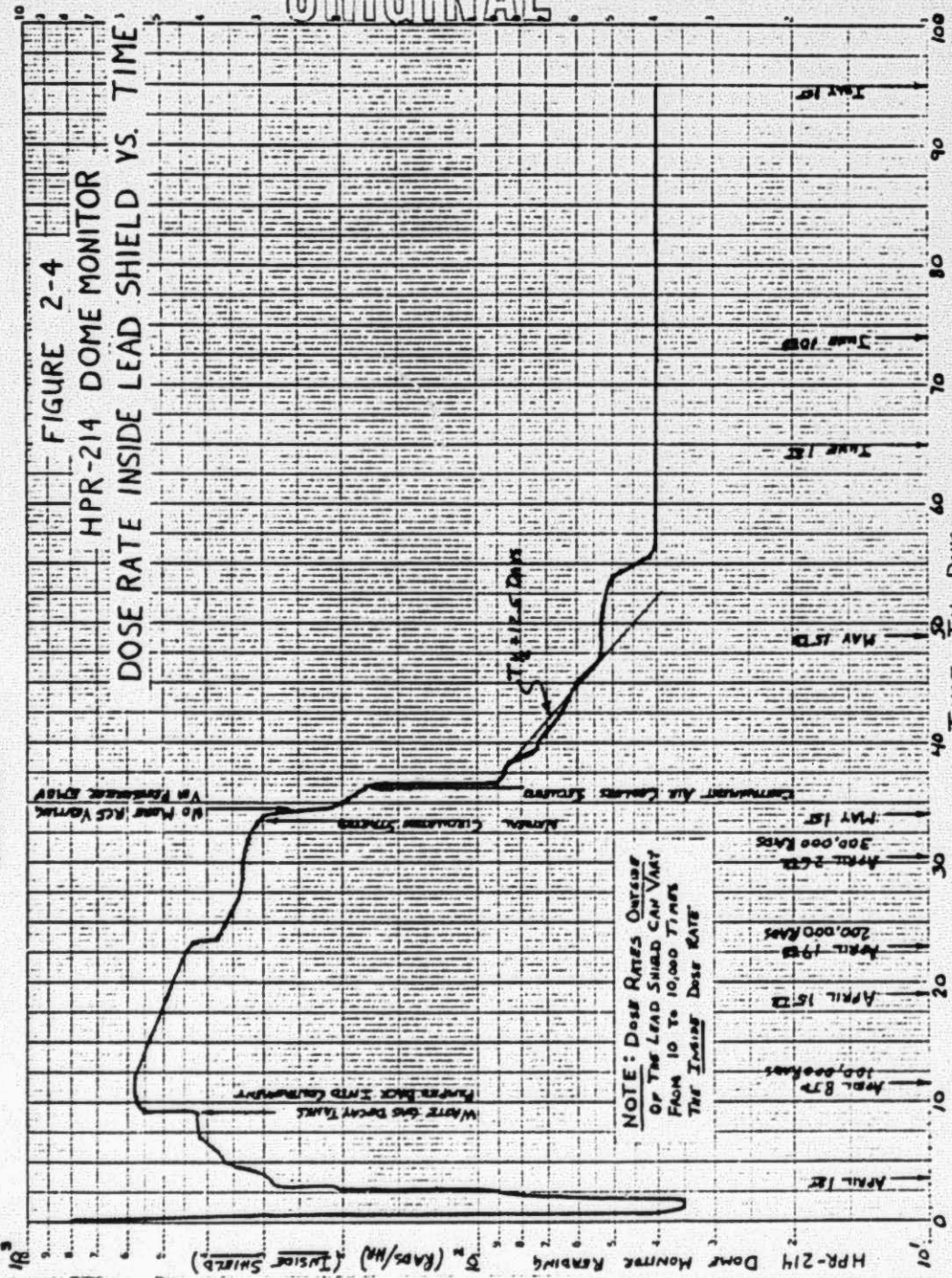
SECTION X-X  
TYP @ FLANGE

971152  
DOSE RATE MEASUREMENTS  
@ EQUIPMENT HATCH  
(TAKEN ON LINE 1 1979 WITH  
EBERLINE E-520 STD. GM PROBE)  
FIG. 2-3

# POOR ORIGINAL

K-E SEMILOGARITHMIC 46 5253  
 3 CYLES X 200 DIVISIONS  
 SCOPPEL & SEVER CO.

FIGURE 2-4  
 HPR-214 DOME MONITOR  
 DOSE RATE INSIDE LEAD SHIELD VS. TIME



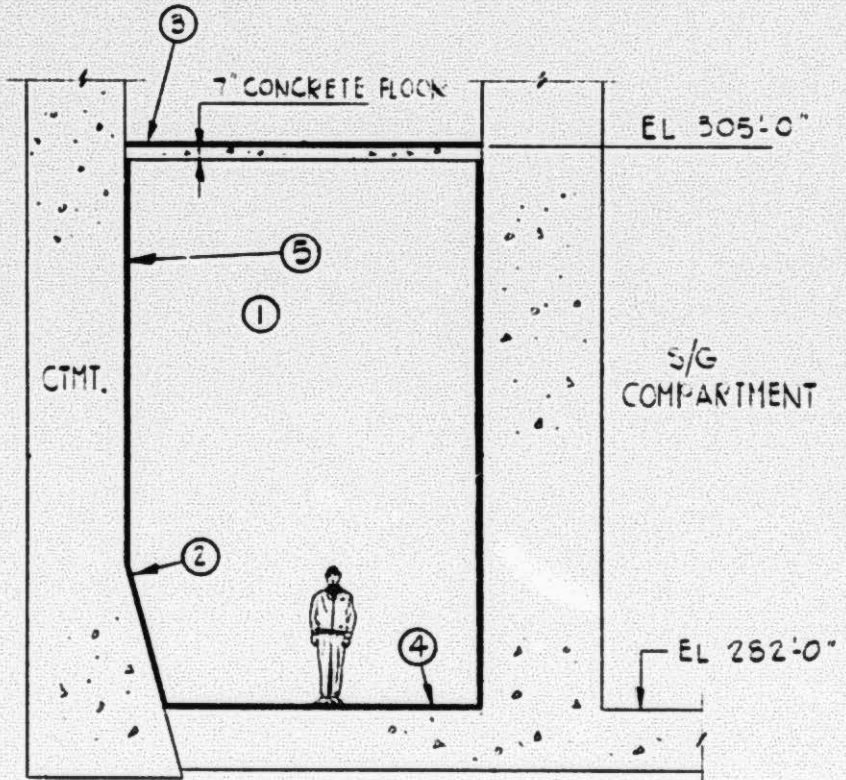
NOTE: Dose Rates Outside  
 Of The Lead Shield Can Vary  
 From 10 To 10,000 Times  
 The Inside Dose Rate

891746

LEGEND:

— PLATEOUT

- ① AIRBOURNE SOURCE
- ② SUMP PLATEOUT ON WALLS
- ③ GENERAL PLATEOUT ON 305'-0 ELEVATION FLOORS
- ④ SUMP PLATEOUT ON FLOOR
- ⑤ PLATEOUT (NEGLECTED ABOVE EL 289'-0')



371164

POOR ORIGINAL

SOURCES OF DOSE RATES  
AT EL. 282'-0

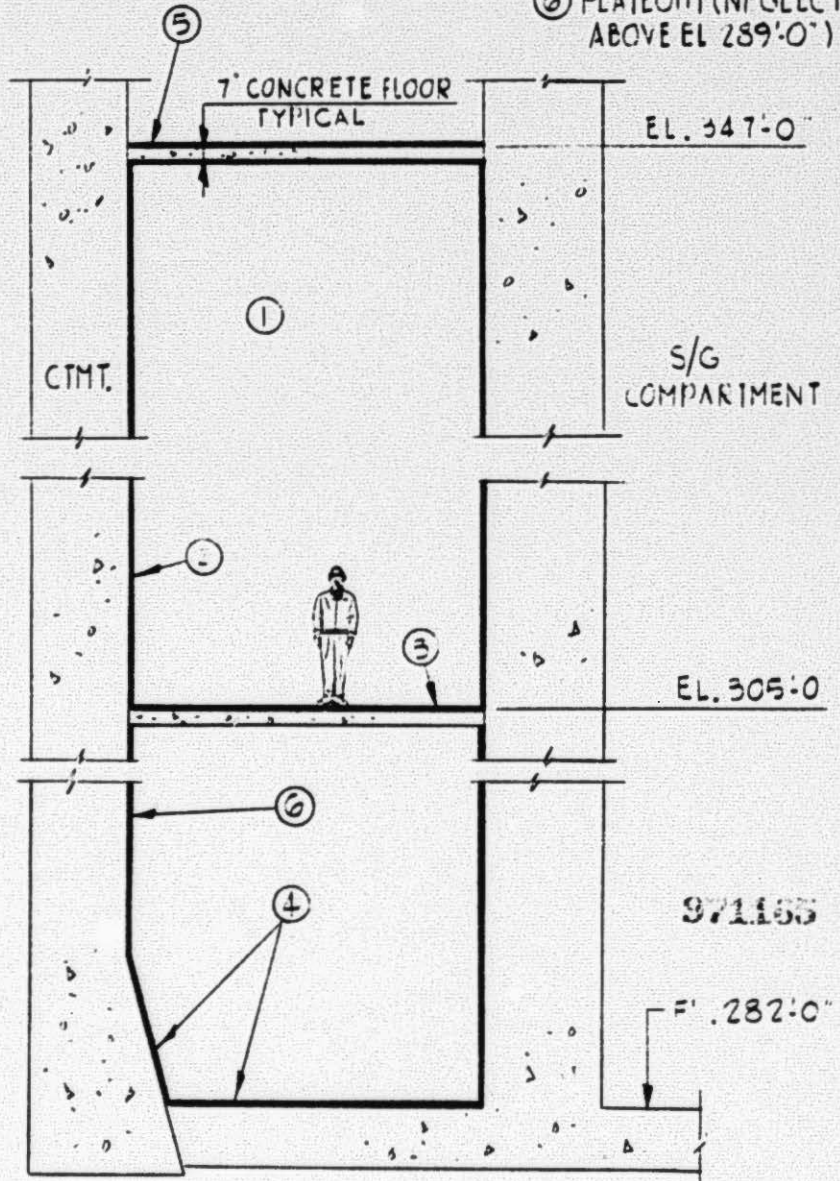
FIG. 2-5

LEGEND:

— PLATEOUT

- ① AIRBORNE SOURCE
- ② PLATEOUT ON WALLS EL 305'-0"
- ③ PLATEOUT ON FLOOR, EL 305'-0"

- ④ SUMP PLATEOUT
- ⑤ PLATEOUT ON FLOOR EL. 347'-0"
- ⑥ PLATEOUT (NEGLECTED ABOVE EL 289'-0")



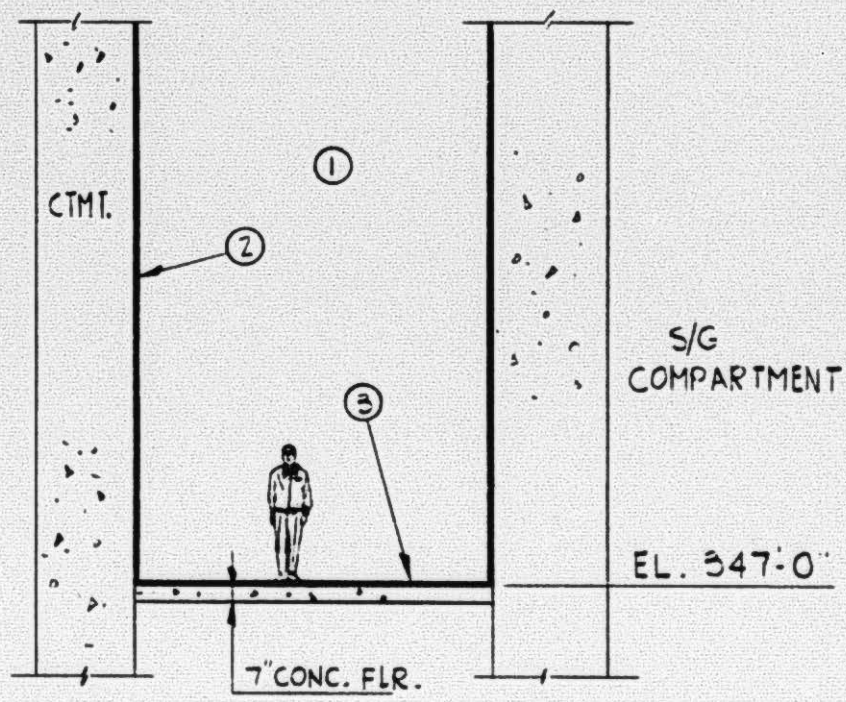
POOR ORIGINAL

SOURCES OF DOSE RATES  
AT EL. 305'-0"

FIG. 2-6

LEGEND:

- PLATEOUT
- ① AIRBORNE SOURCE
- ② PLATEOUT ON WALLS EL 347'-0"
- ③ PLATEOUT ON FLOOR EL 347'-0"



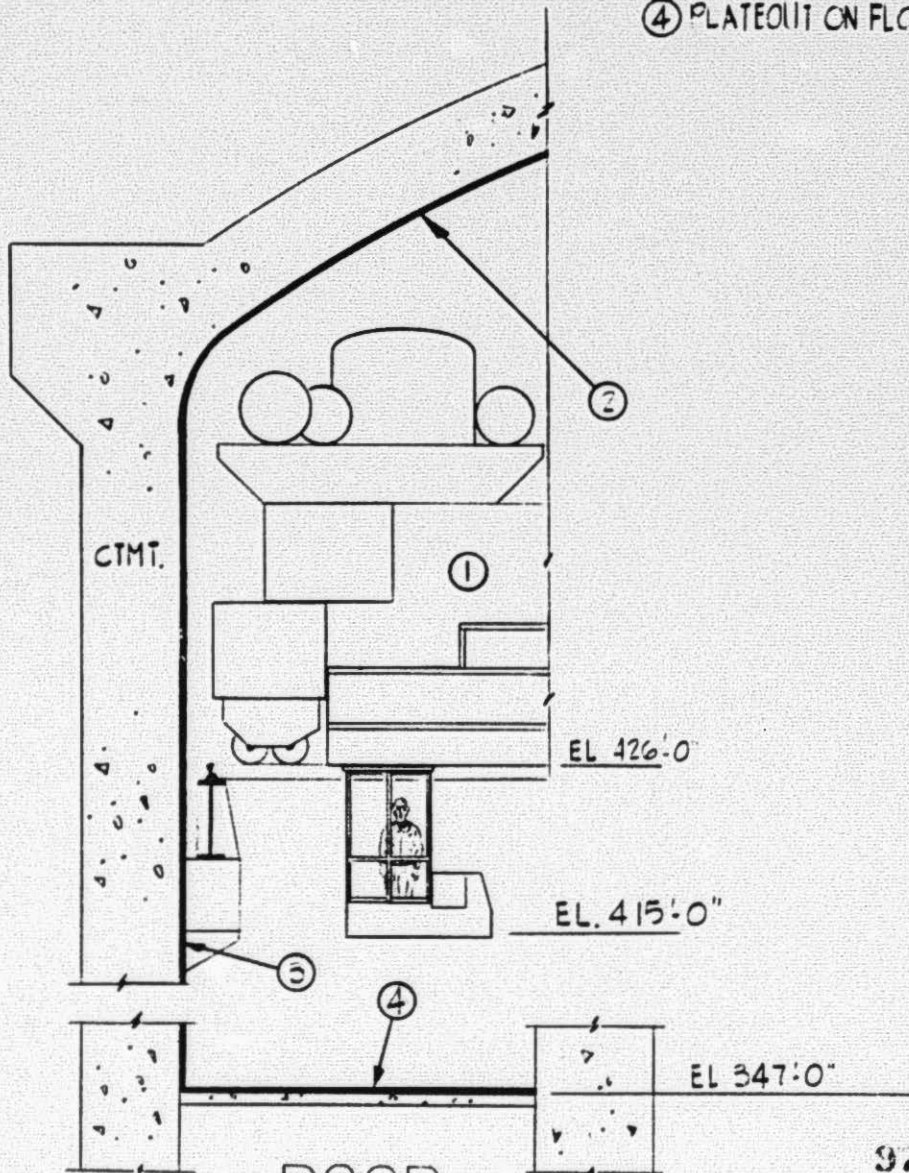
971156

**POOR ORIGINAL** SOURCES OF DOSE RATES  
AT EL. 347'-0"  
FIG. 2-7

LEGEND :

— PLATEOUT

- ① AIRBORNE SOURCE
- ② PLATEOUT ON CTMT DOME
- ③ PLATEOUT ON WALLS EL 347.0
- ④ PLATEOUT ON FLOOR EL 347.0



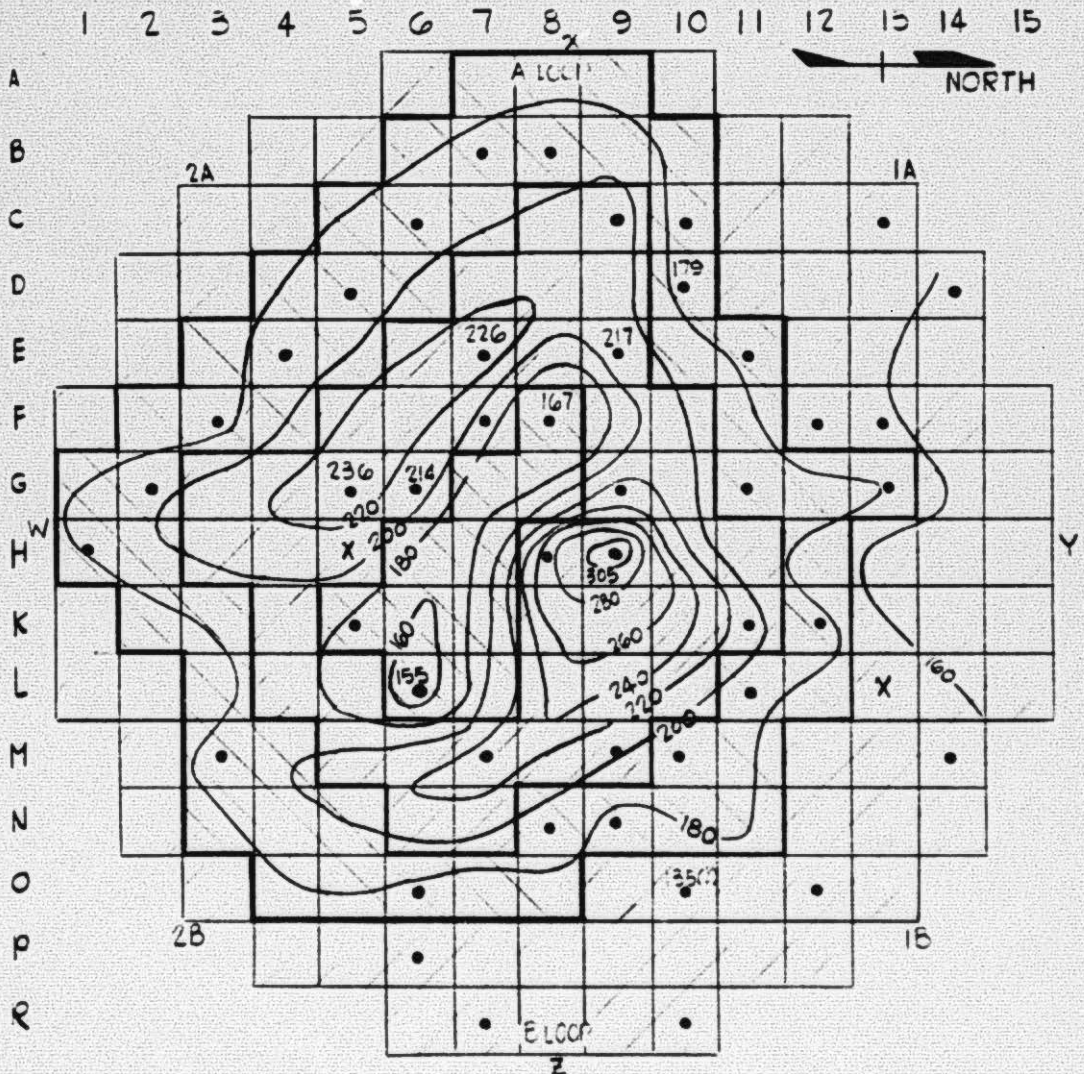
POOR ORIGINAL

SOURCE OF DOSE RATES  
AT POLAR CRANE CAB

FIG. 4-8

971157





TIME 11:30 5/11/79  
 RCA IN 160°F  
 RCB IN 120°F  
 P 500 PSIG  
 NATL. CIRC.  
 5G 'B' ISOLATED

3RD. ITERATION  
 (ASSUME OPEN FLOW AREA @ ~G-7)

ASSUMED DAMAGE  
 40% INTACT < 180°F  
 30% DAMAGED 180-200°F  
 25% DISASSEMBLED > 200°F  
 5% DESTROYED > 250°F

971168

• - ACTIVE "TC"  
 X - FAILED "TC"

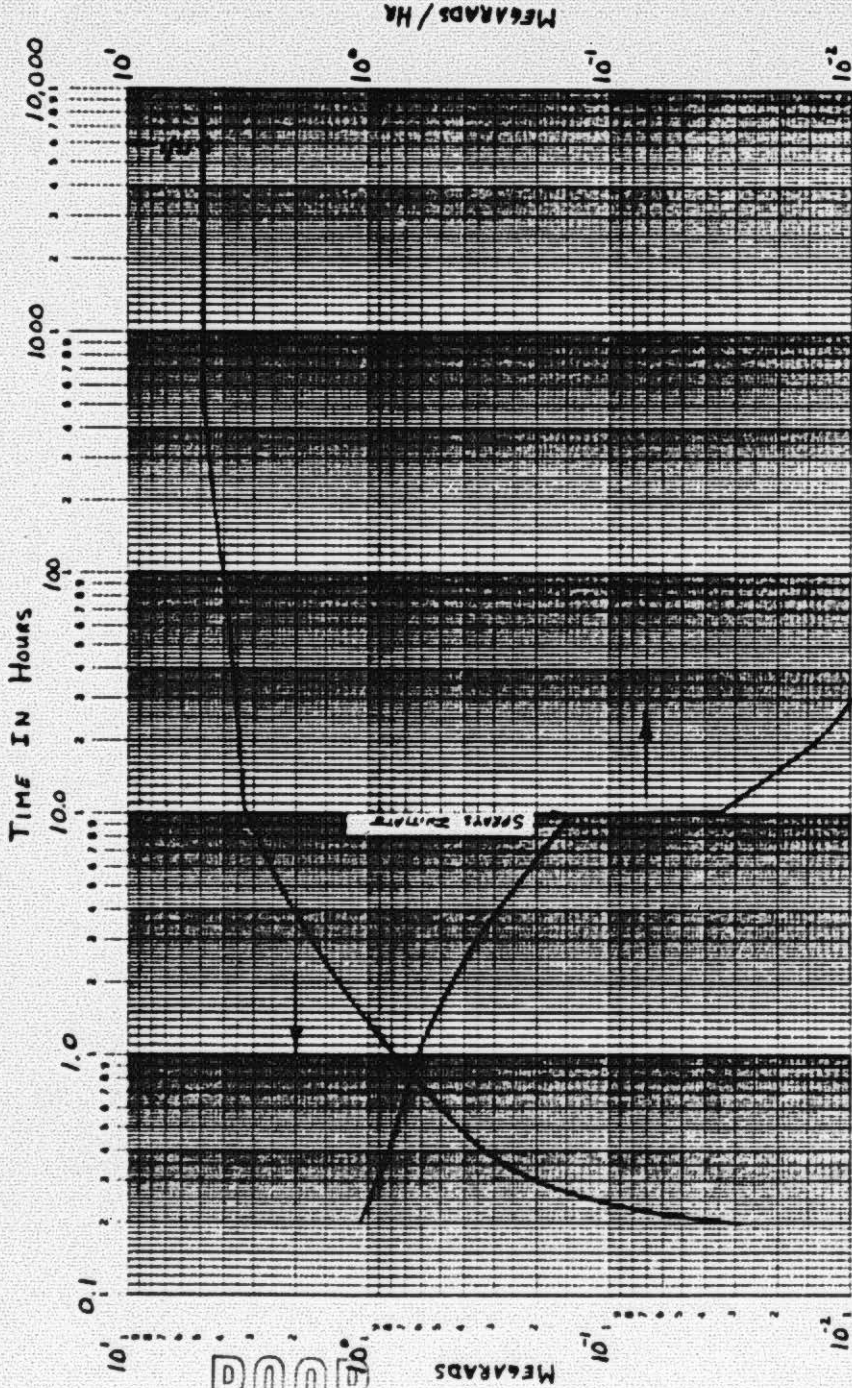
POOR ORIGINAL

TMI-2 COKE TEMPERATURES

FIG. 2-9 SK TMI/CKE-6

KOE LOGARITHMIC 3.5 CYCLES  
REPRODUCED BY THE U.S. GOVERNMENT

46 7522



44% NOBLE GASES  
27% IODINE

Figure 2-10a  
LOWER BOUND  
AIRBORNE GAMMA DOSES AND DOSE RATES  
UP TO 1 YEAR  
TOTAL CONTAINMENT VALUE

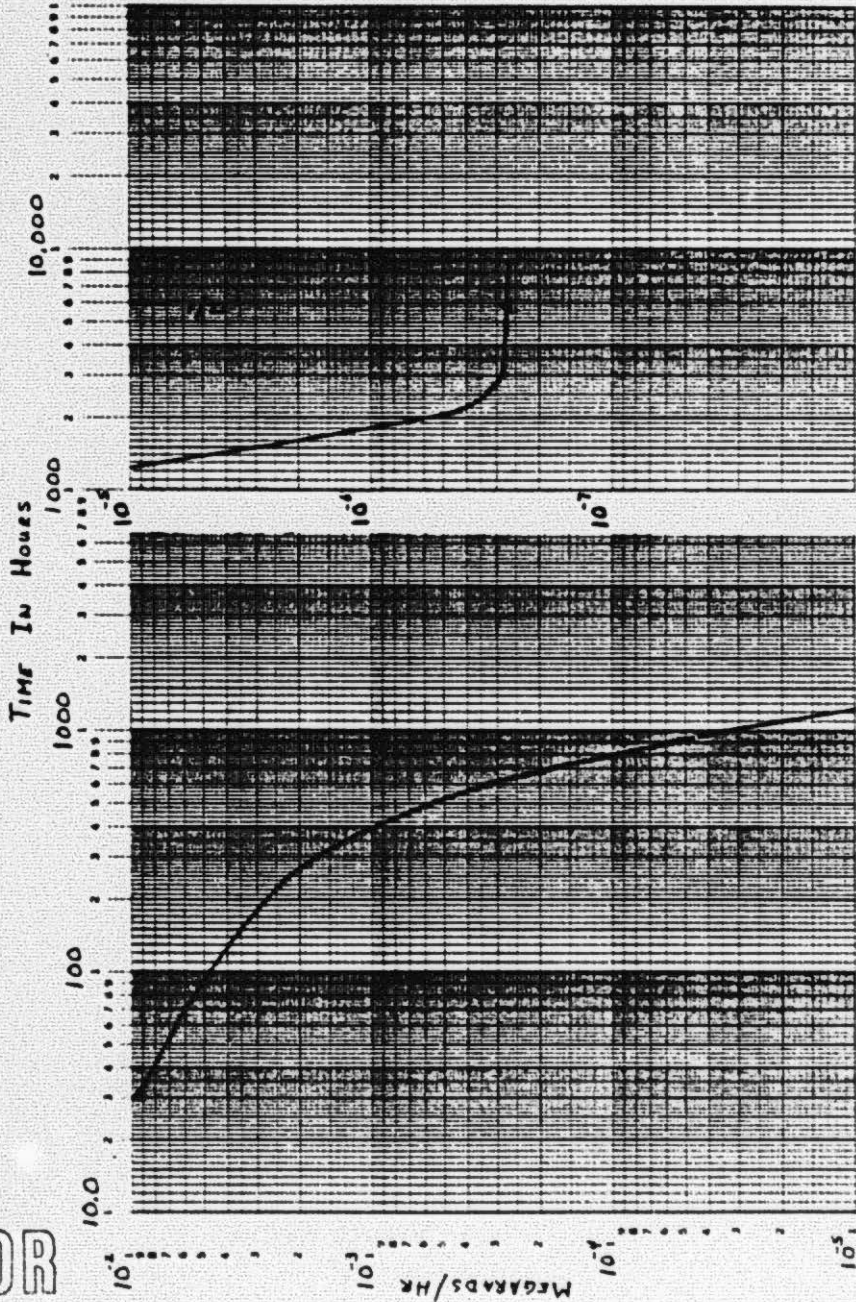
WITH SPRAYS  
SEE 2.2.1.1.1

POOR ORIGINAL

971169

K&E LOGARITHMIC 2 1/2 CYCLES  
REPLIES & TEMPLATES

46 7522



44% NOBLE GASES  
27% IODINE

FIGURE 2-10b

LOWER DOWD  
AIRBORNE GAMMA DOSES AND DOSE RATES  
UP TO 1 YEAR  
TOTAL CONTAINMENT VOLUME

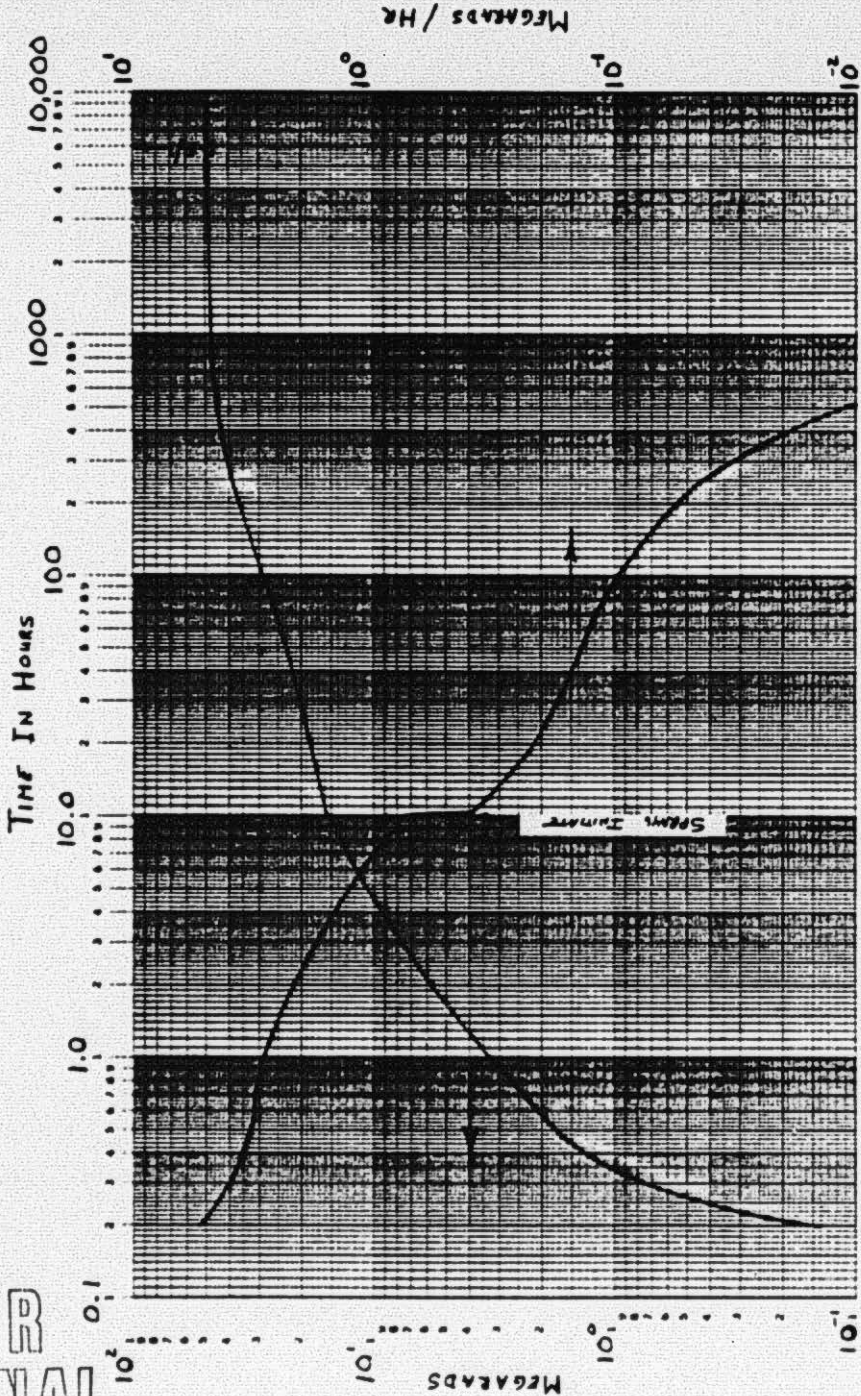
WITH SPRAYS  
SEE 2.2.1.1.1

POOR ORIGINAL

041178

46 7522

K-E LOGARITHMIC 3-3 CYCLES  
SCALE & UNITS AS SHOWN



44% NOBLE GASES  
27% IODINE

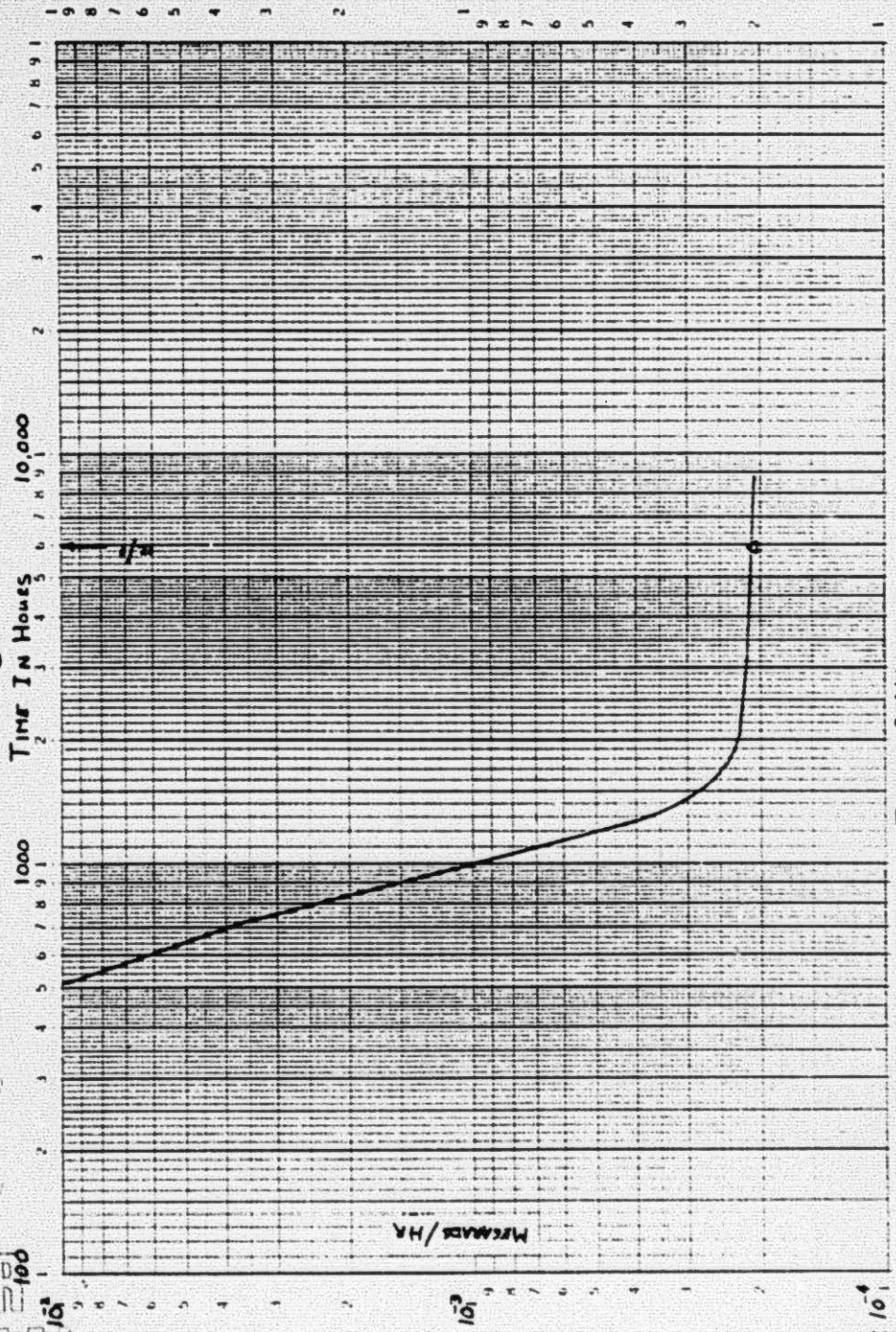
Figure 2-11a  
Lower Bound  
AIRBORNE BETA DOSES AND DOSE RATES  
UP TO 1 YEAR  
TOTAL CONTAINMENT VOLUME

WITH SPRAYS  
SEE 2.2.1.1.1

POOR ORIGINAL

46 7320

K-E LOGAN (FBI) INC. - 31-11527  
 SUPPLY & SERVICE CO. - 31-11527



44% NOBLE GASES  
 27% IODINE

FIGURE 2-11b  
 LOWER BOUND AIRBORNE BETA DOSES AND DOSE RATES UP TO 1 YR  
 TOTAL CONTAINMENT VOLUME

WITH SPRAYS  
 SEE 2.2.1.1.1

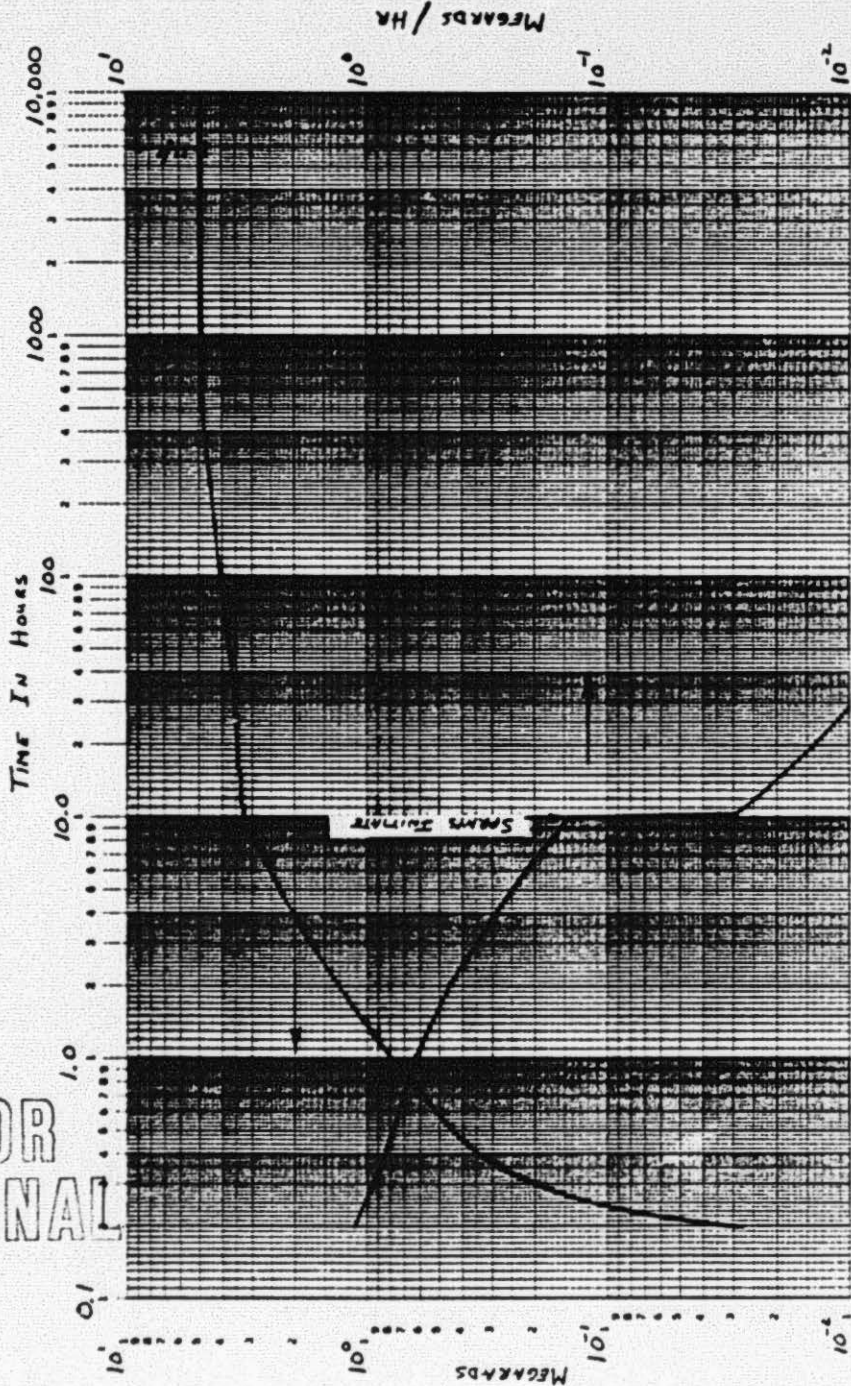
POOR ORIGINAL

971173

46 7522

KVE LOGARITHMIC 3-4.5 CYCLES  
REPERTAL & SUMAR CU 2000 0115

POOR ORIGINAL



44% NOBLE GASES  
27% IODINE  
0.05% ALL OTHERS

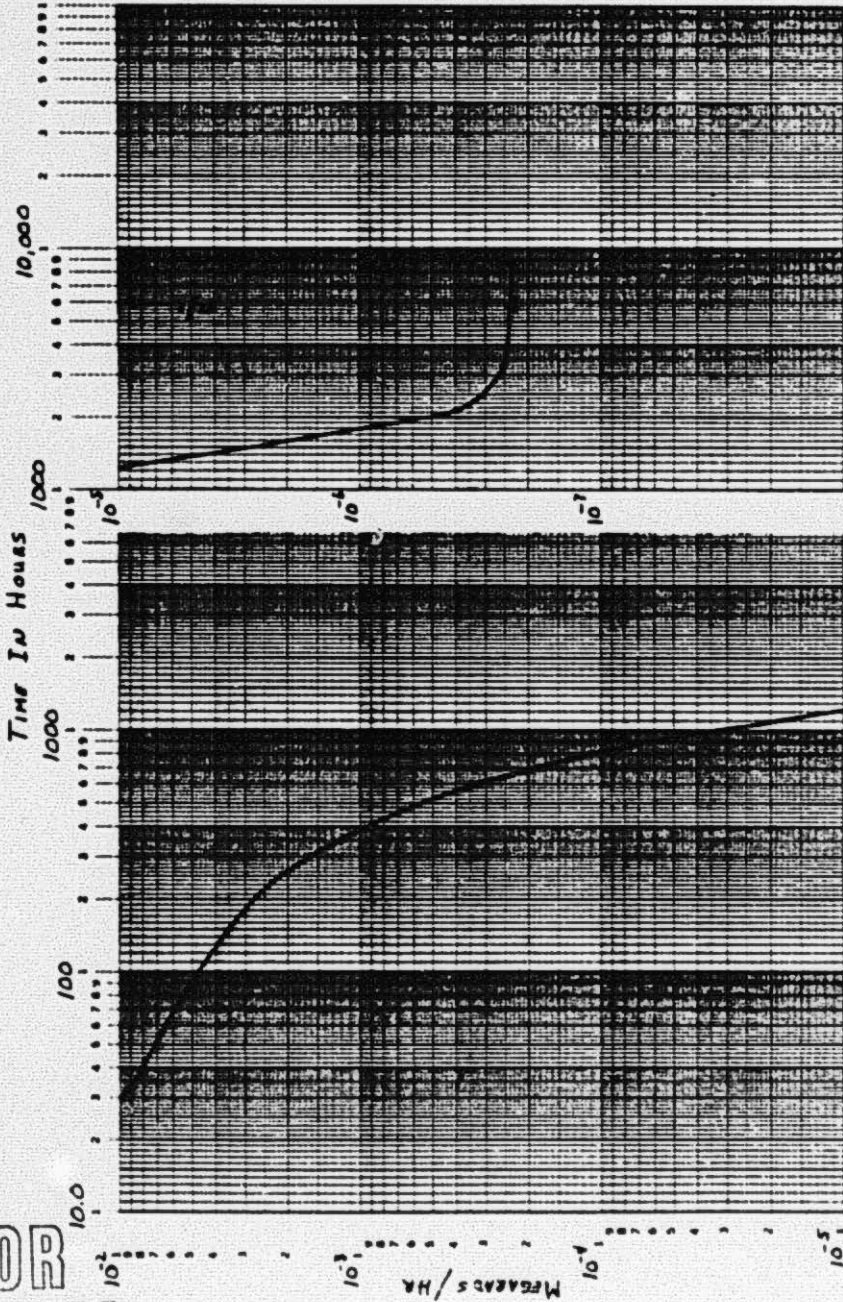
FIGURE 2-12 a  
MEDIAN BOUND  
AIRBORNE GAMMA DOSES AND DOSE RATES  
UP TO 1 YEAR  
TOTAL CONTAINMENT VOLUME

WITH SPRAYS  
SEE 2.2.1.1.2

971173

46 7522

K-E LOGARITHMIC 3.5 CYCLES  
METHOD, 8 LINES CU, 1000 1000



44% NOBLE GASES  
27% IODINE  
0.05% ALL OTHERS

FIGURE 2-12b  
MEDIAN BOUND  
AIRBORNE GAMMA DOSES AND DOSE RATES  
UP TO 1 YEAR  
TOTAL CONTAINMENT VOLUME

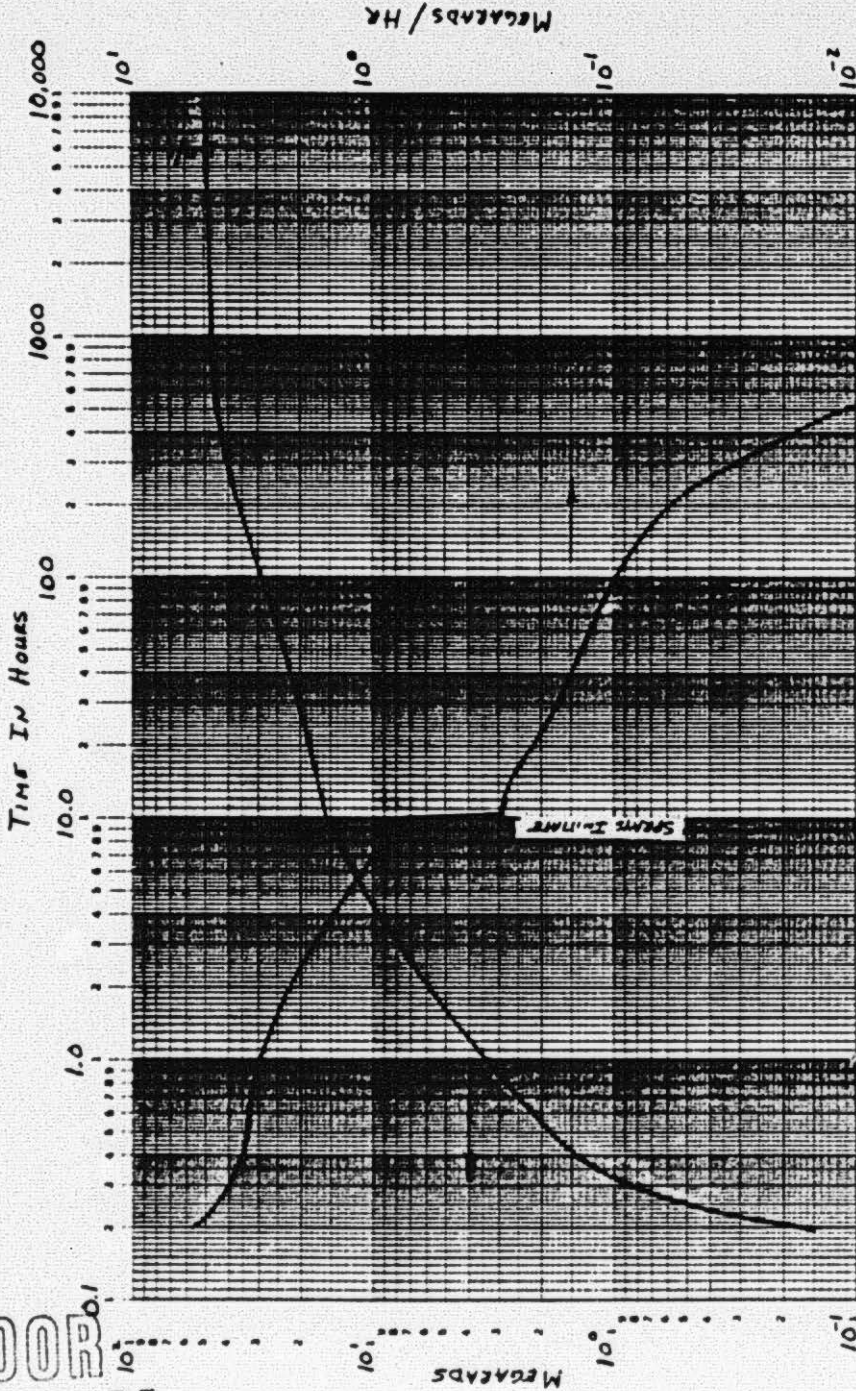
WITH SPRAYS  
SEE 2.2.1.1.2

POOR ORIGINAL

5/11/74

46 7522

KOE  
1 QUARTINMIC 3-8 CYCLES  
REDFIL & USAR CO. (MILWAUKEE)



{ 44% NOBLE GASES  
27% IODINE  
0.05% ALL OTHERS

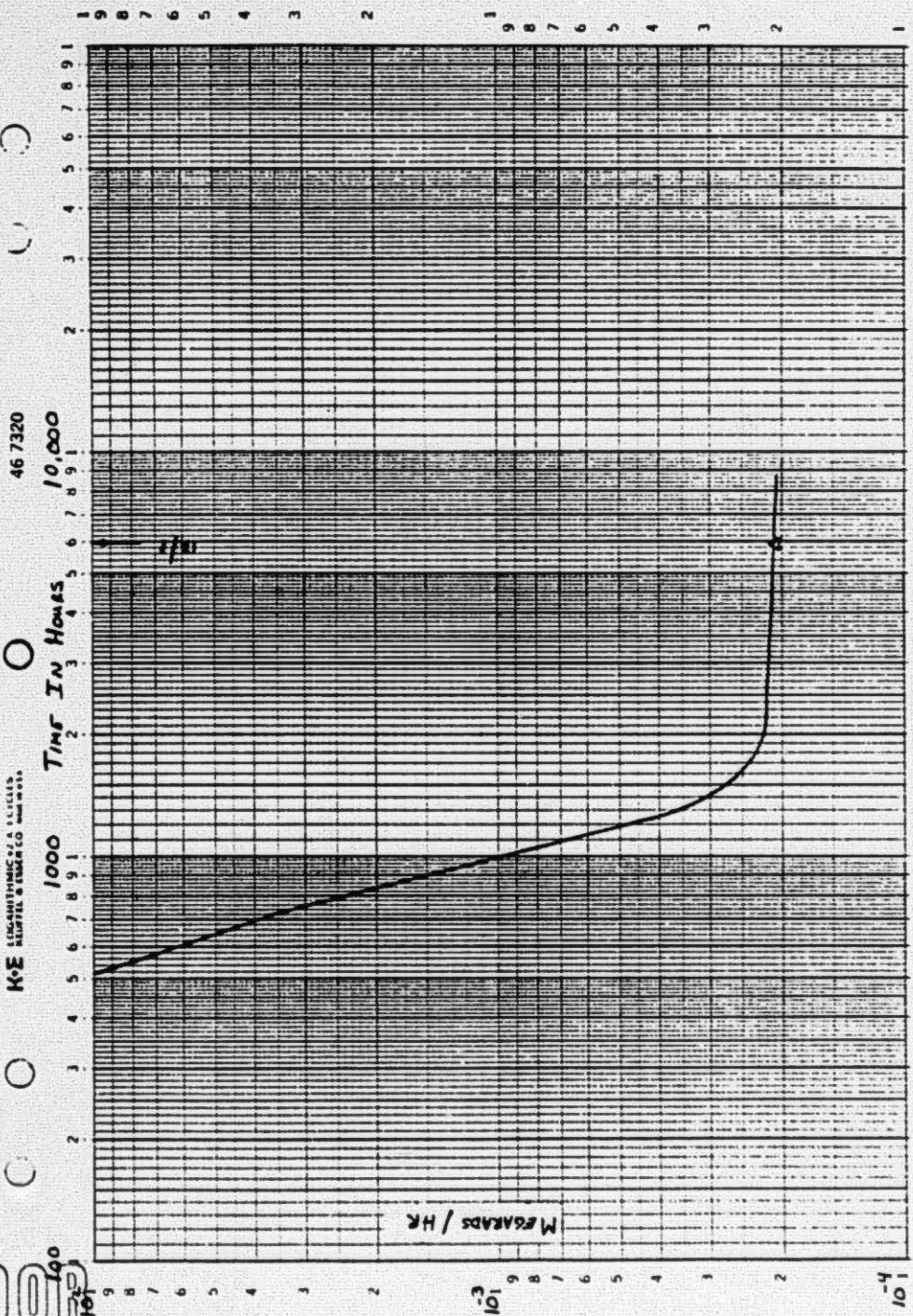
Figure 2-13 a  
MEDIAN BOUNDS  
AIRBORNE BETA DOSES AND DOSE RATES  
UP TO 1 YEAR  
TOTAL CONTAINMENT VOLUME

WITH SPRAYS  
SEE 2.2.1.1.2

POOR ORIGINAL

971175





44% NOBLE GASES  
27% IODINE  
0.05% ALLOYS

WITH SPRAYS  
SEE 2.2.1.1.2

Figure 2-13b  
MEDIAN BOUND AIRBORNE BETA DOSES AND DOSE RATES UP TO 1 Yr  
TOTAL CONTAINMENT VOLUME

POOR ORIGINAL

SPRAYS

POOR ORIGINAL

K-E LOGARITHMIC 3 x 3 CYCLES  
ACQUIRED & DRAWN BY MWH-8511

46 7522

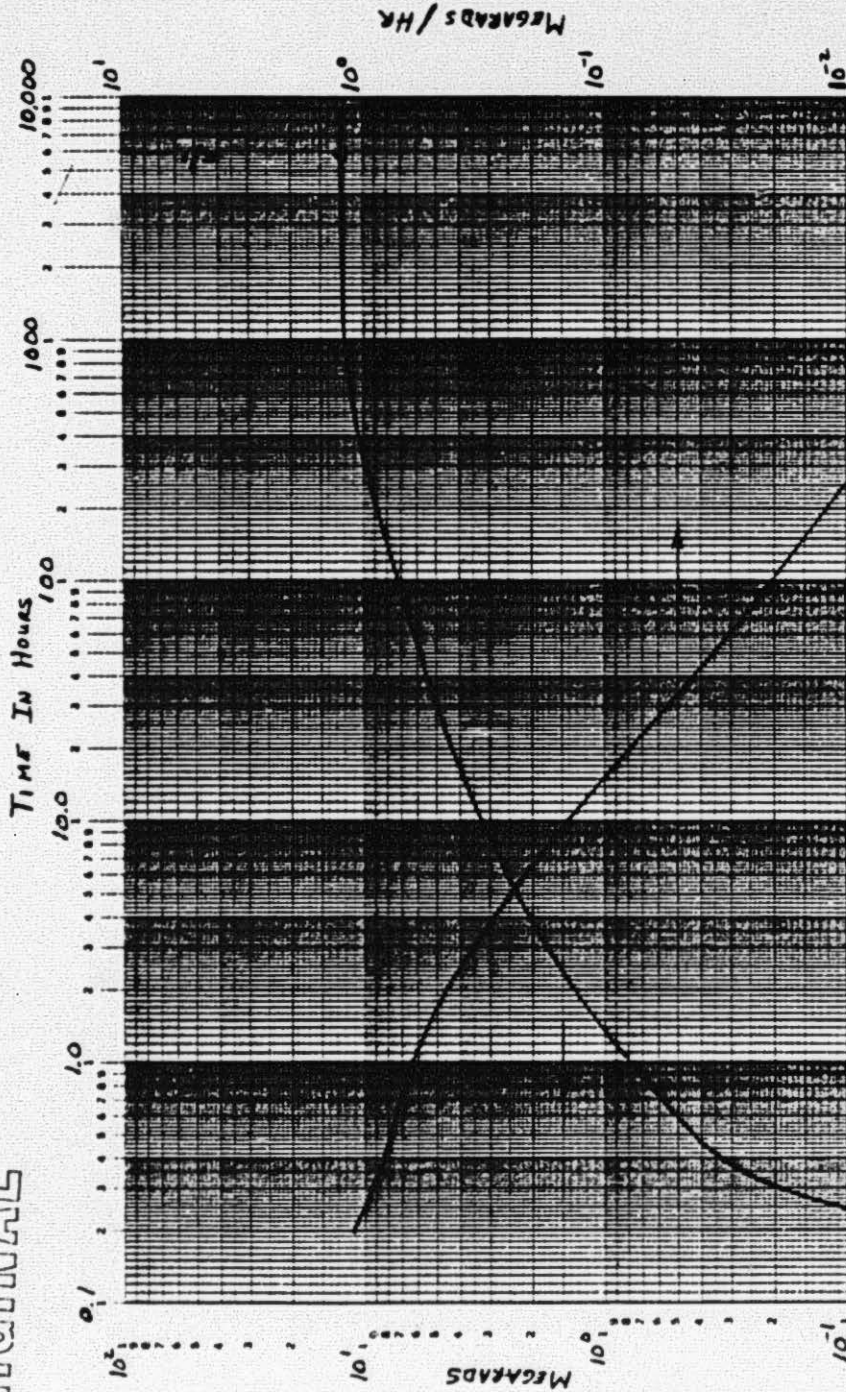


Figure 2-14a

Upper Bound

AIRBORNE GAMMA DOSES AND DOSE RATES

UP TO 1 YEAR

TOTAL CONTAINMENT VOLUME

44% NOBLE GASES  
27% IODINE  
0.05% ALL OTHERS

NO SPRAYS

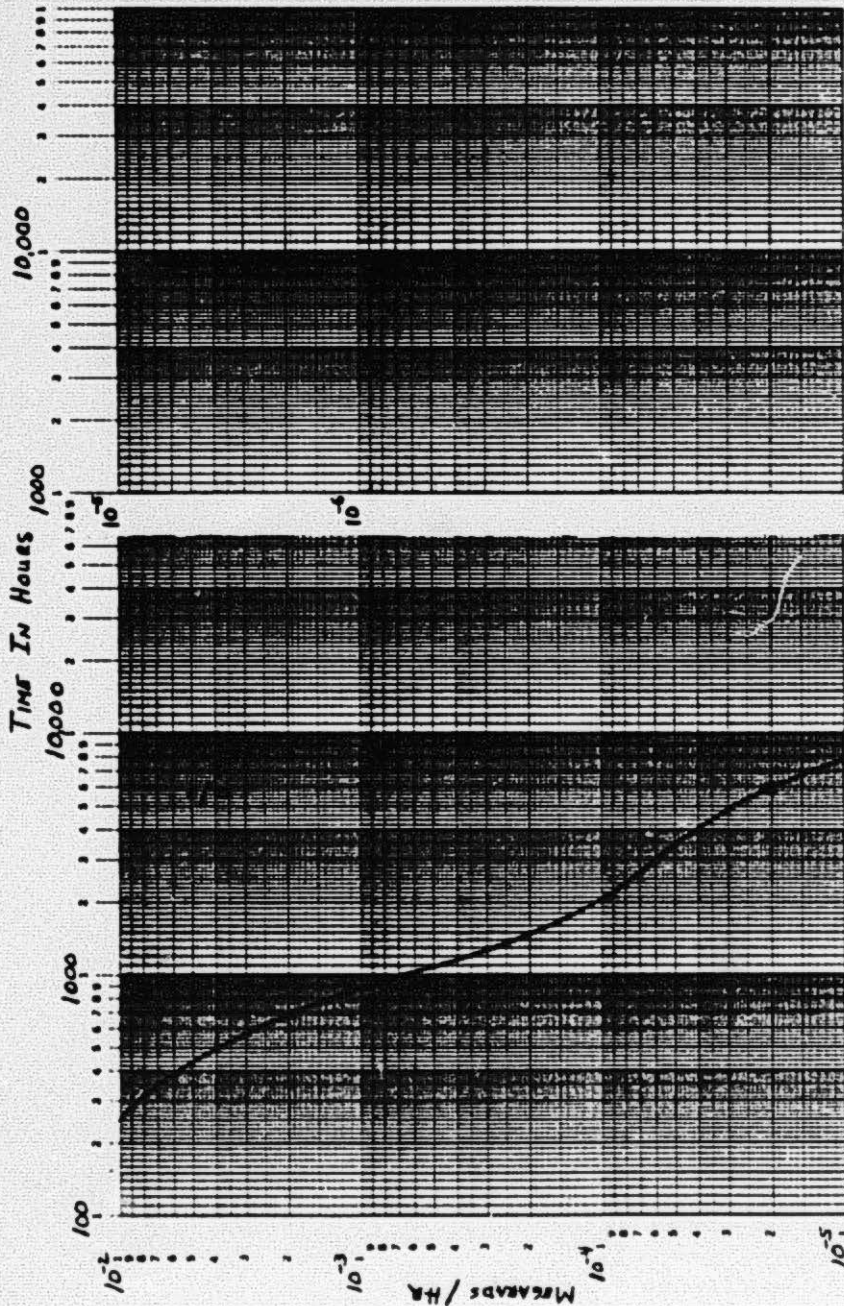
SEE 2.2.1.1.3

2/27/68

POOR ORIGINAL

K&E LOGARITHMIC 3 1/2 CYCLES  
REPROD. & CHASE CO. NEW YORK

46 7522



811178

NO SPRAYS  
SEE 2.2.1.1.3

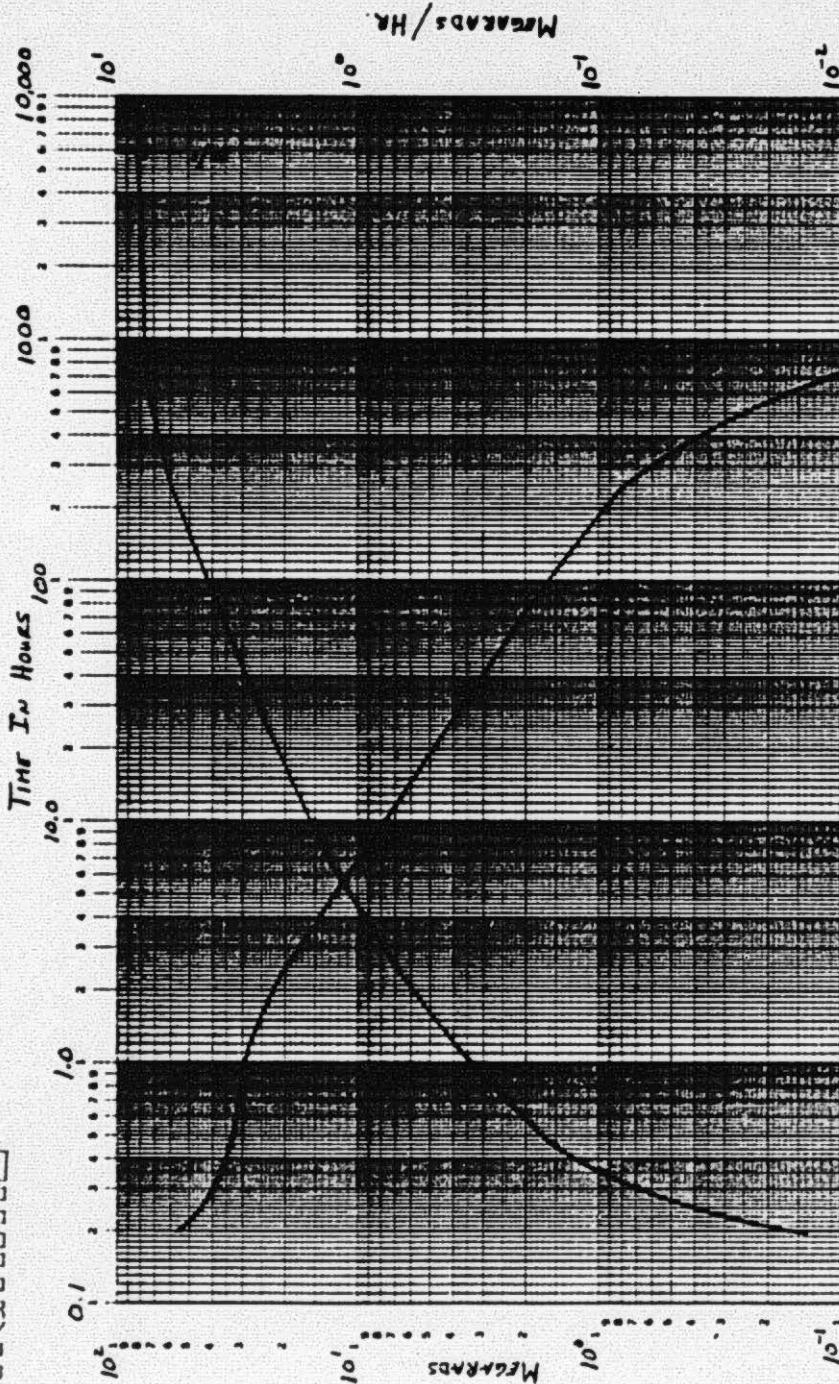
FIGURE 2-14b  
UPPER BOUND  
AIRBORNE GAMMA DOSES AND DWR RATES  
UP TO 1 YEAR  
TOTAL CONTAINMENT VOLUME

44% NOBLE GASES  
27% IODINES  
0.05% ALL OTHERS

POOR ORIGINAL

K&E LOGARITHMIC 3-B CYCLER  
HARTFORD & STAMFORD CO. MADE IN U.S.A.

46 7522



{ 44% NOBLE GASES  
 27% IODINE  
 0.05% ALL OTHERS

FIGURE 2-15a  
 UPPER BOUND  
 AIRBORNE BETA DOSES AND DOSE RATES  
 UP TO 1 YEAR  
 TOTAL CONTAINMENT VOLUME

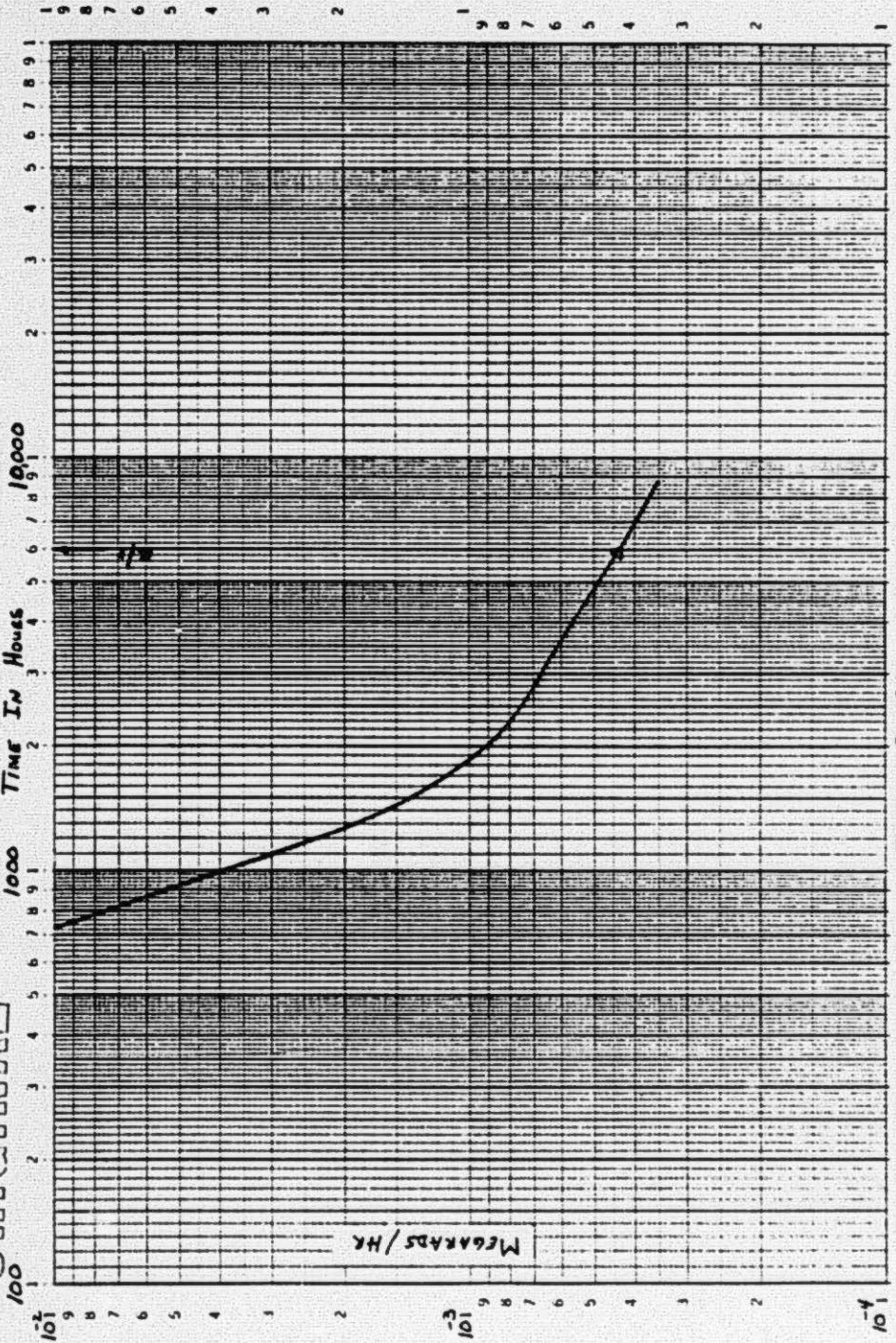
NO SPRAYS  
 SEE 2.2.1.1.3

621176

POOR ORIGINAL

KOE LOGARITHMIC SCALE  
 REPRODUCED FROM TMI-2

46 7320



44% NOBLE GASES  
 27% IODINE  
 0.05% ALL OTHERS

FIGURE 2-15 b  
 UPPER BOUND AIRBORNE BETA DOSES AND DOSE RATES UP TO 1 Yr  
 TOTAL CONTAINMENT VOLUME

NO SPRAYS  
 SEE 2.2.1.1.3

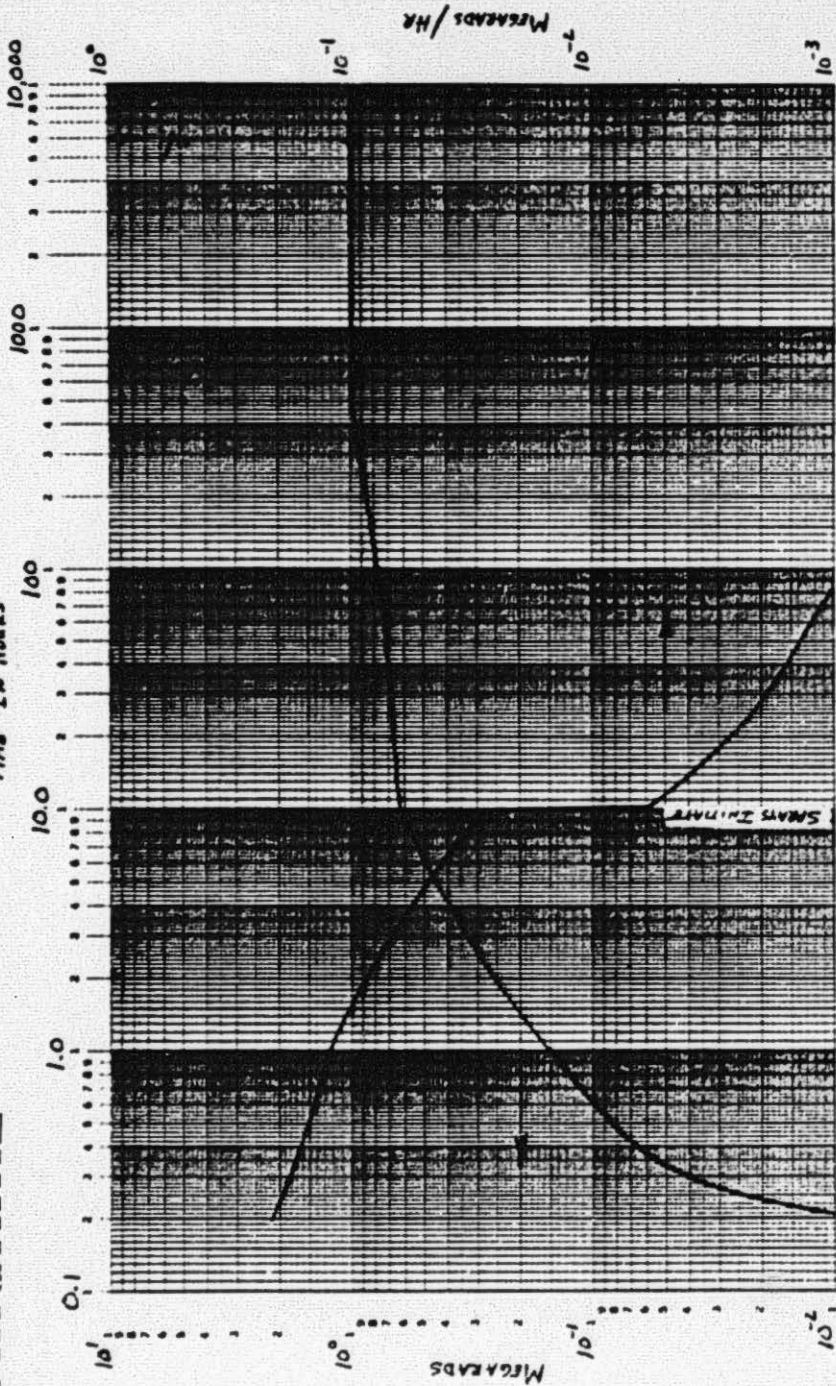
871180

POOR ORIGINAL

K&E LOWARITHMIC P-A-C CYCLES  
SERIAL & RANGE CO. INCORPORATED

46 7522

Time In Hours



44% Noble Gases  
27% Iodine  
0.05% All Others

FIGURE 2-160  
MEDIAN BOUND  
AIRBORNE GAMMA DOSES AND DOSE RATES  
UP TO 1 YEAR  
VOLUME BETWEEN EL 282 - EL 305

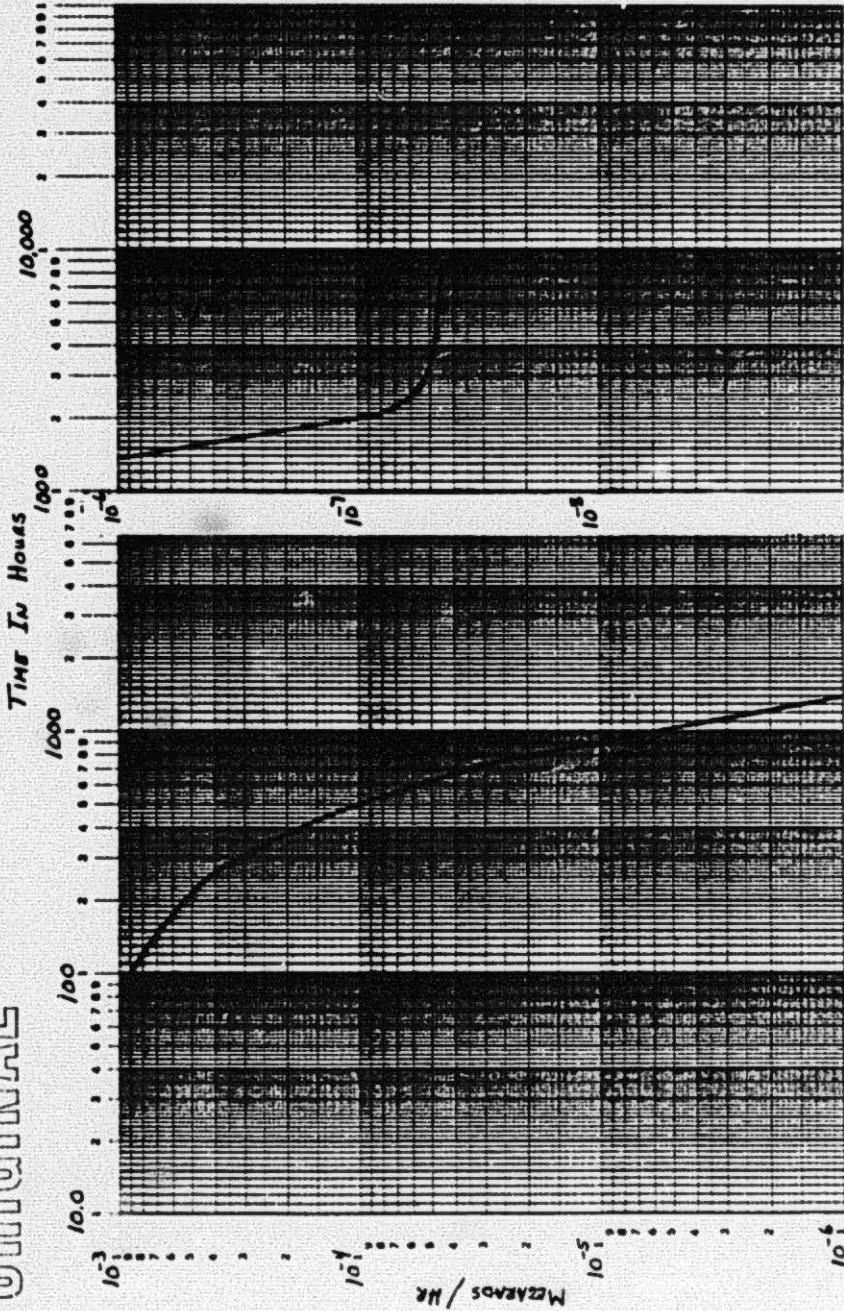
WITH SPRAYS  
SEE 2.2.2.1

181175

POOR ORIGINAL

K&E LOGARITHMIC 3 1/2 CYCLE  
SERVOELECTRIC & CONTROL CO. NEW YORK

46 7522



49% NOBLE GASES  
27% IODINE  
0.05% ALL OTHERS

FIGURE 2-16 b  
MIDIAN BOUND  
AIRBORNE GAMMA DOSES AND DOSE RATES  
UP TO 1 YEAR  
VOLUME BETWEEN EL282 - EL 305

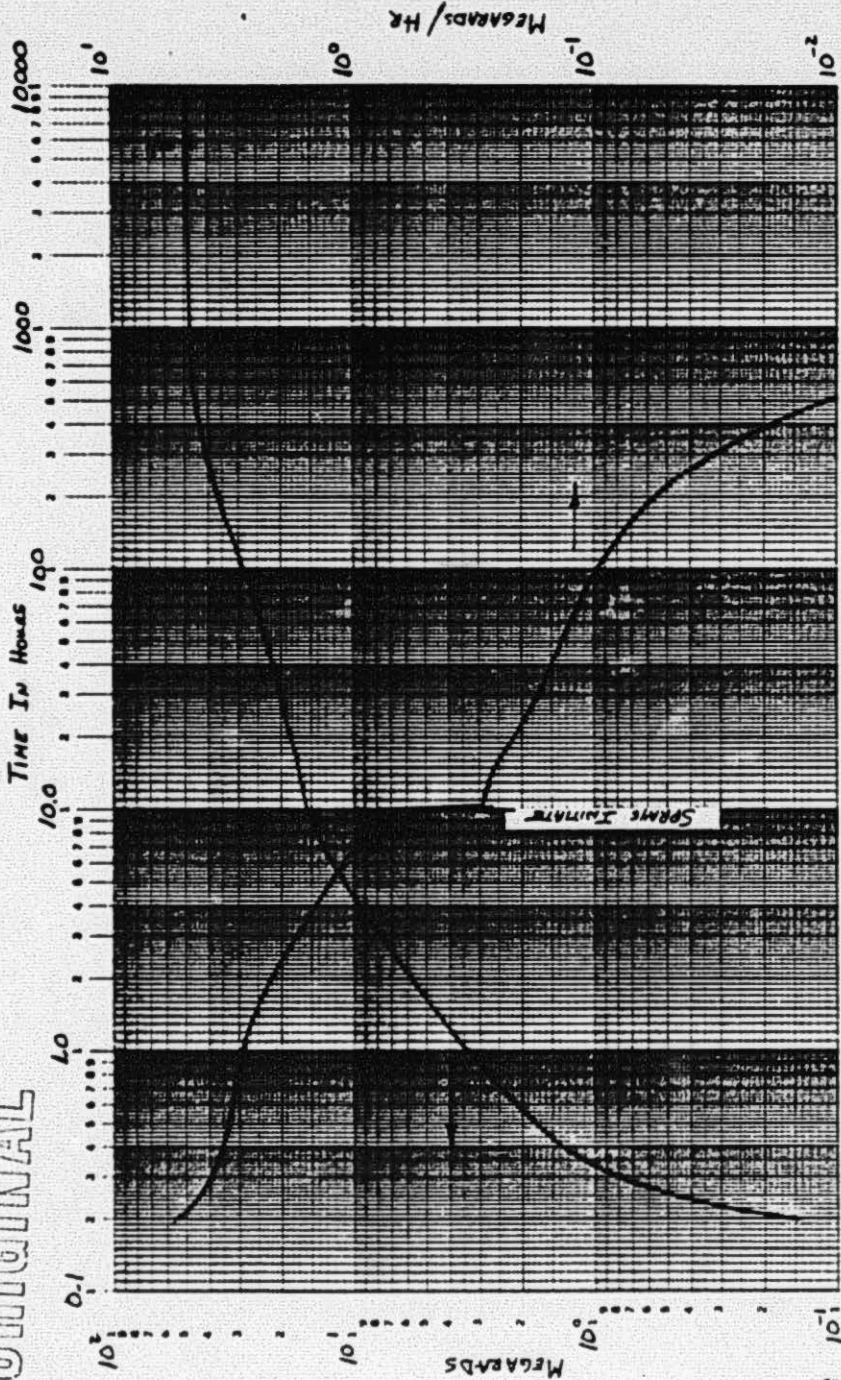
WITH SPRAYS  
SEE 2.2.2.1

281775

POOR ORIGINAL

K-E LOGARITHMIC 3 CYCLES  
DURING 6 HOURS CO. OPERATIONS

46 7522



44% NOBLE GASES  
27% IODINE  
0.05% ALL OTHERS

FIGURE 2-17a  
MEDIAN BOUND  
AIRBORNE BETA DOSES AND DOSE RATES  
UP TO 1 YEAR  
VOLUME BETWEEN EL 2B2 - EL 305

WITH SPRAYS  
SEE 2.2.2.1

817178



POOR

ORIGINAL

KE LOGARITHMIC PLOT FACILITY  
 MODEL & USER LOG

46 7320

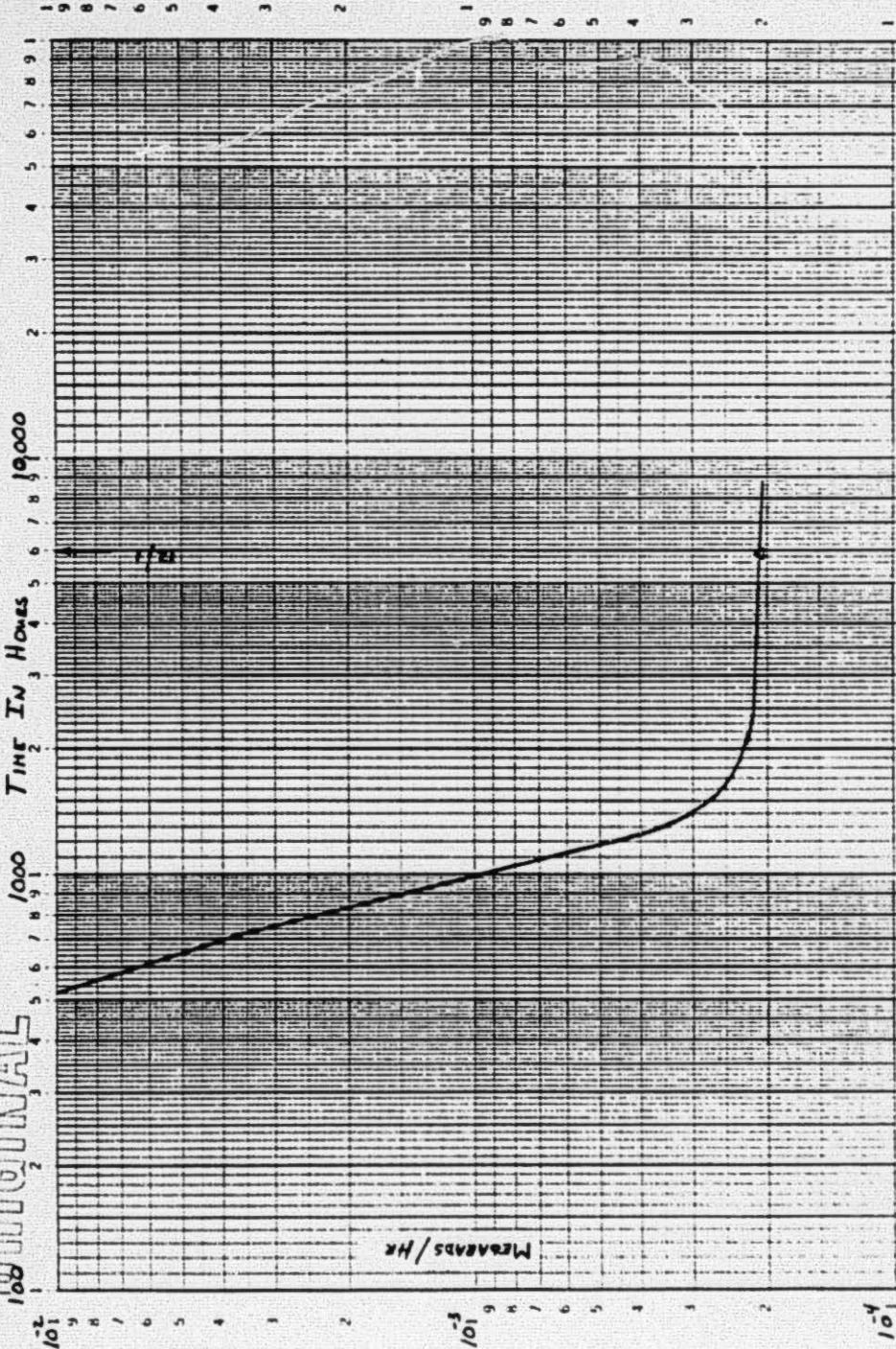


FIGURE 2-17b

WITH SPRAYS  
 SEE 2.2.2.1

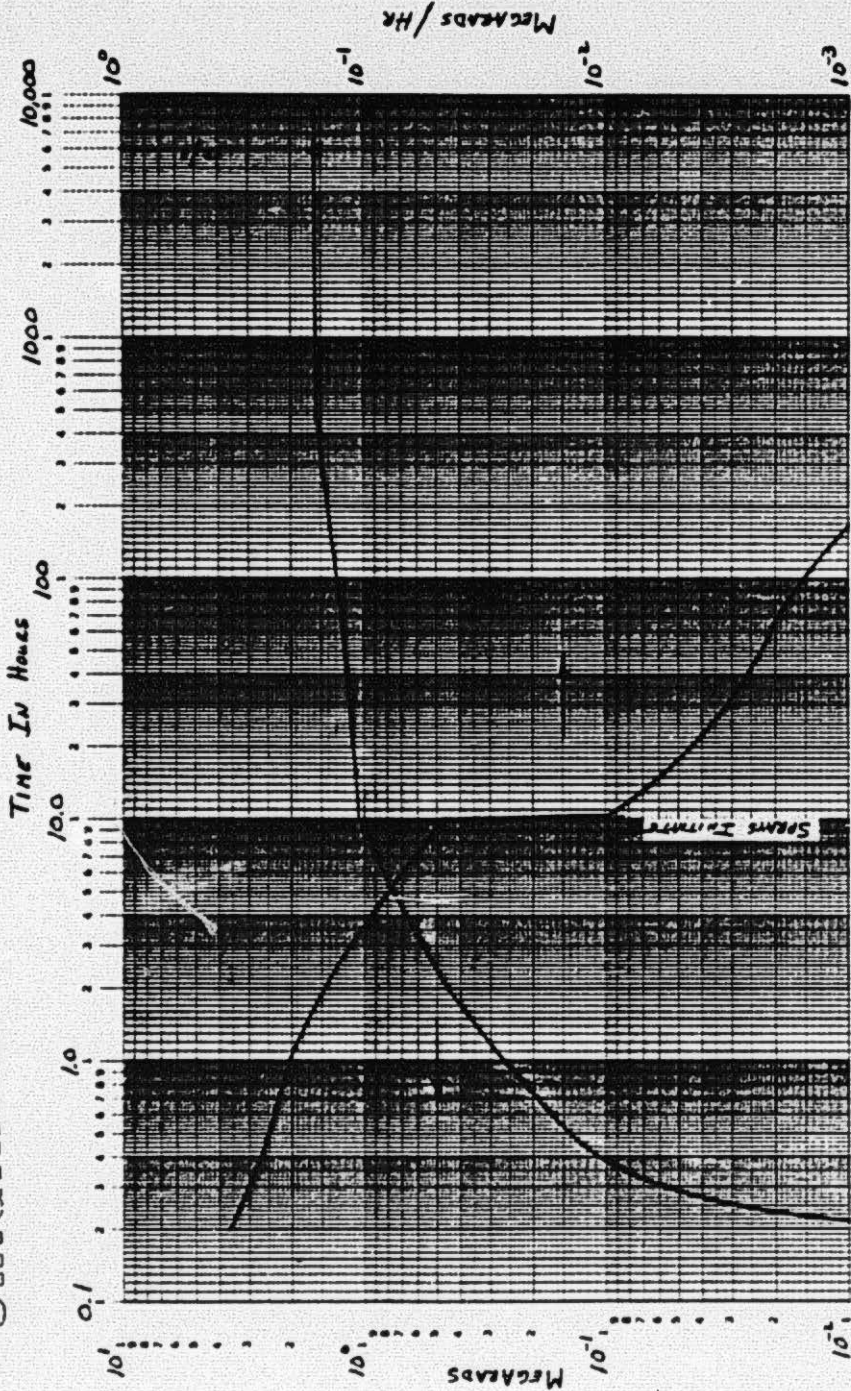
MEDIAN BOUND AIRBORNE BETA DOSE AND DECAY RATES UP TO 1 YR  
 VOLUME BETWEEN EL 282 - EL 305

44% NOBLE GASES  
 27% IODINE  
 0.05% ALL OTHERS

POOR ORIGINAL

KVE LOGARITHMIC 3-0-3 CYCLES  
ADAPTED & REVISED BY KVE

46 7522



44% NOBLE GASES  
27% IODINES  
0.05% ALL OTHERS

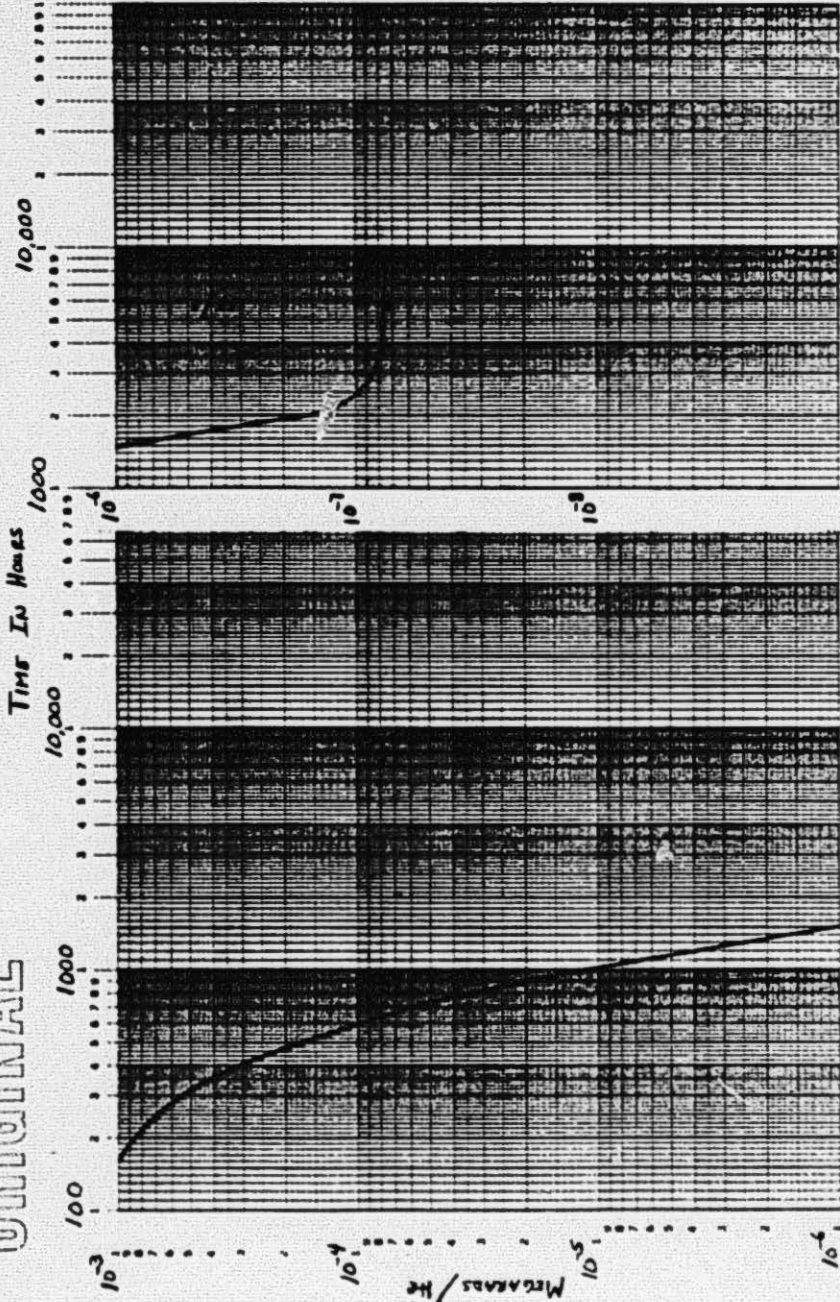
FIGURE 2-18a  
MEDIAN BOUND  
AIRBORNE GAMMA DOSES AND DOSE RATES  
UP TO 1 YEAR  
VOLUME BETWEEN EL 305 - EL 347

WITH SPRAYS  
SEE 2.2.2.2

POOR ORIGINAL

M·E LOGARITHMIC 3-1/2 CYCLES  
 REAPTEL & STONE CO. MADE IN U.S.A.

46 7522



44% Noble Gases  
 27% Iodine  
 0.05% All Others

FIGURE 2-186  
 MEDIAN BOUND  
 AIRBORNE GAMMA DOSES AND DOSE RATES  
 UP TO 1 YEAR  
 VOLUME BETWEEN EL 305 - EL 347

WITH SPRAYS  
 SEE 2.2.2.2

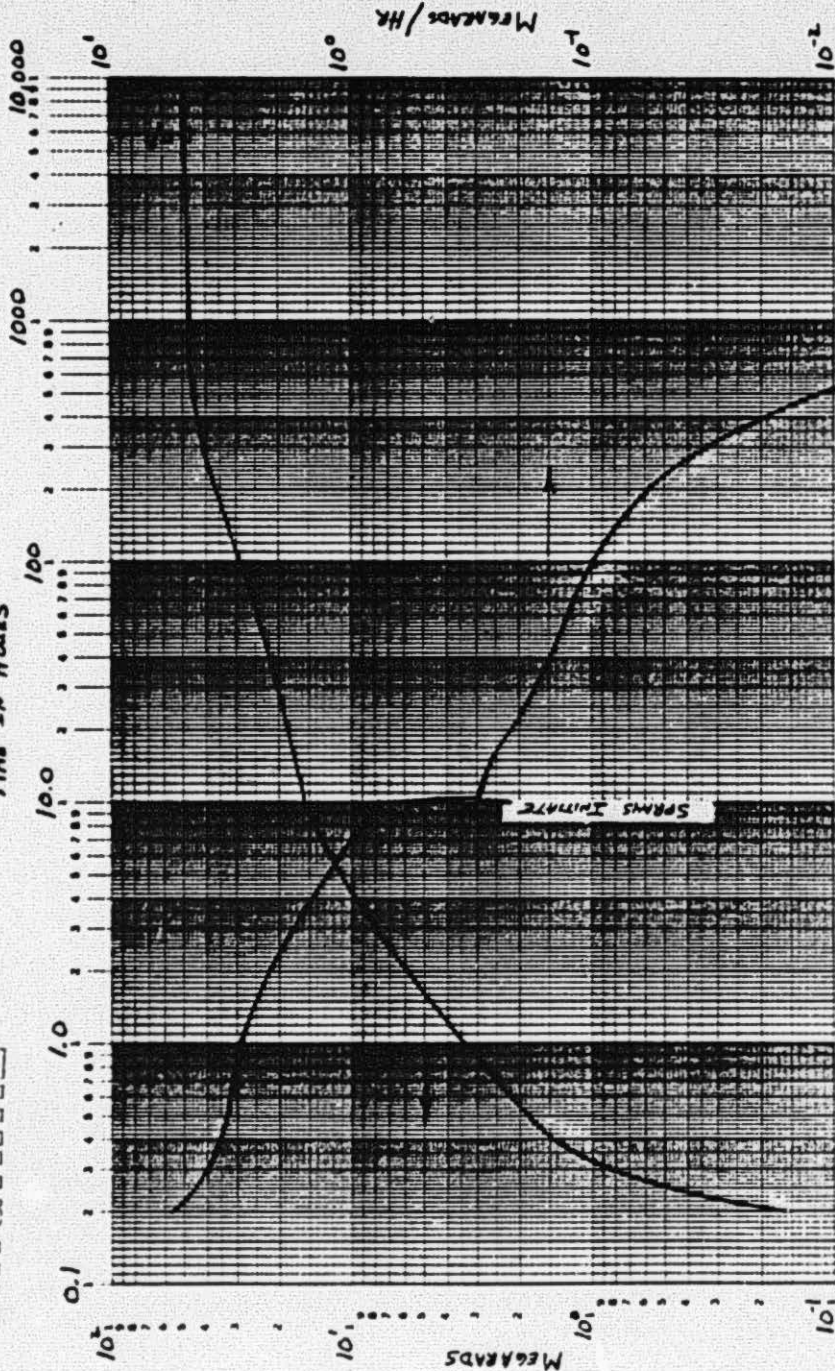
971186

POOR ORIGINAL

KOE LOGANTHATIC 3 x 3 CYCLES  
 MODEL & TABLE CO. COMPANY

46 7522

TIME IN HOURS



44% NOBLE GASES  
 27% IODINES  
 0.05% ALL OTHERS

FIGURE 2-19a  
 MEDIUM BOUND  
 AIRBORNE BETA DOSES AND DOSE RATES  
 UP TO 1 YEAR  
 VOLUME BETWEEN EL305 - EL347

WITH SPRAYS  
 SEE 2.2.2.2

281178

POOR ORIGINAL

SECURITY INFORMATION  
 CONTROL & DISSEMINATION



46 7320

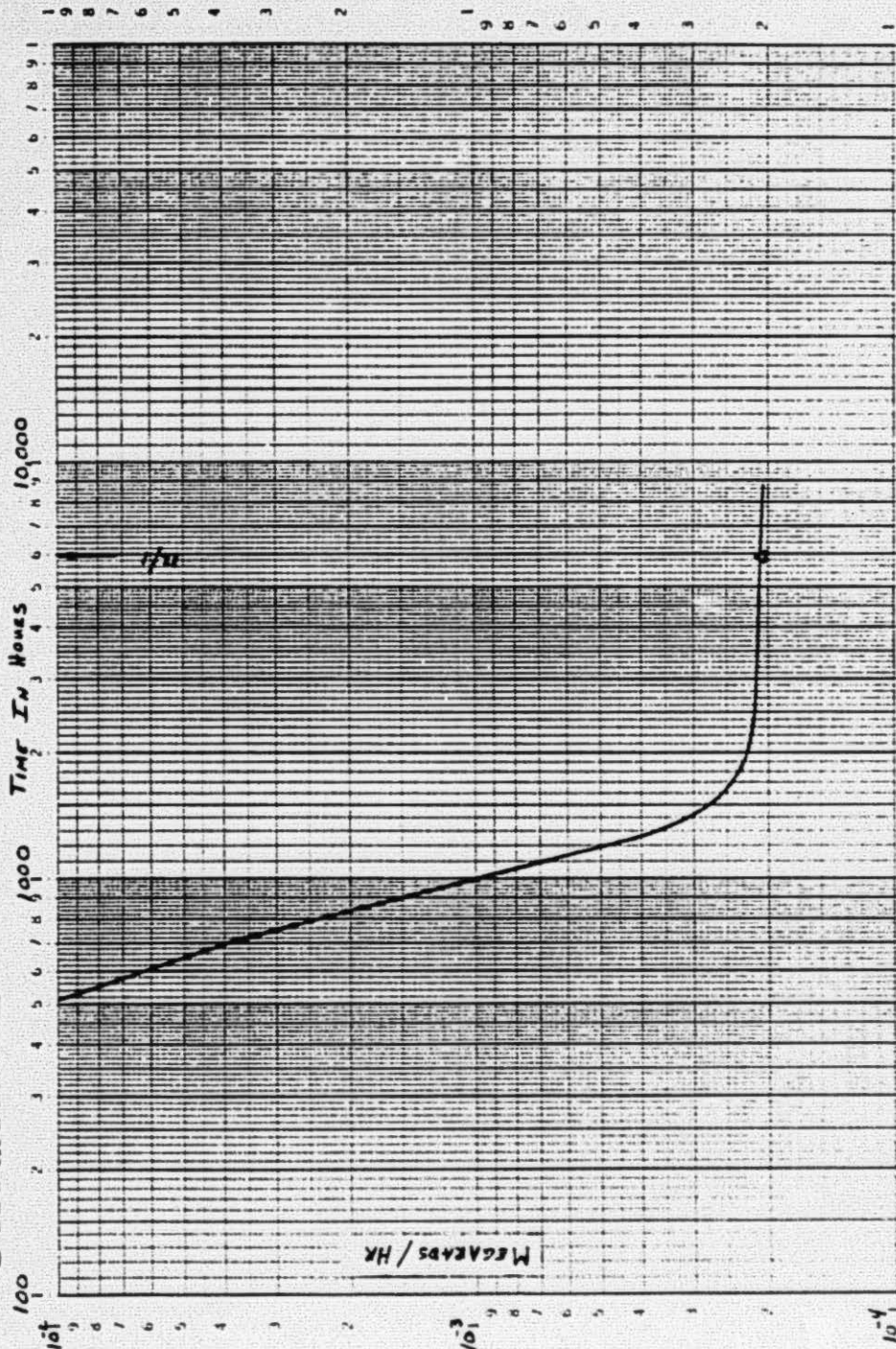


FIGURE 2-19 b

44% NOBLE GASES  
 27% IODINE  
 0.05% ALL OTHERS

MEDIAN BOUND AIRBORNE BETA DOSES AND DOSE RATES UP TO 1 Yr

VOLUME BETWEEN EL 305 - EL 347

WITH SPRAYS  
 SEE 2.2.2.2

021150

POOR ORIGINAL

KOE LOGARITHMIC 3.5 CYCLES  
REPRODUCTION & TAPER CO. 1961

46 7522

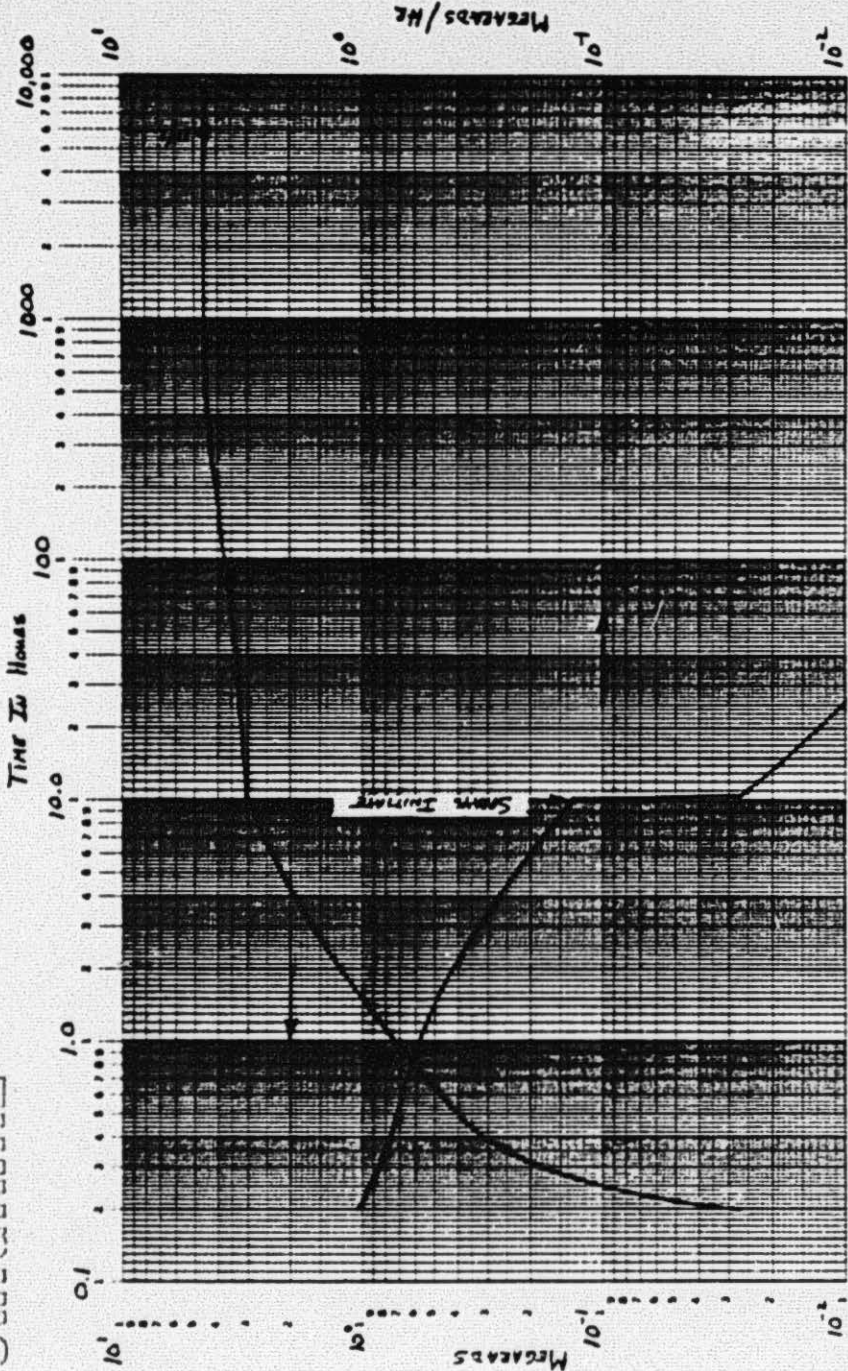


FIGURE 2-20 a  
 MEDIUM BOUND  
 AIRBORNE GAMMA DOSES AND DOSE RATES  
 UP TO 1 YEAR  
 VOLUME ABOVE EL 347

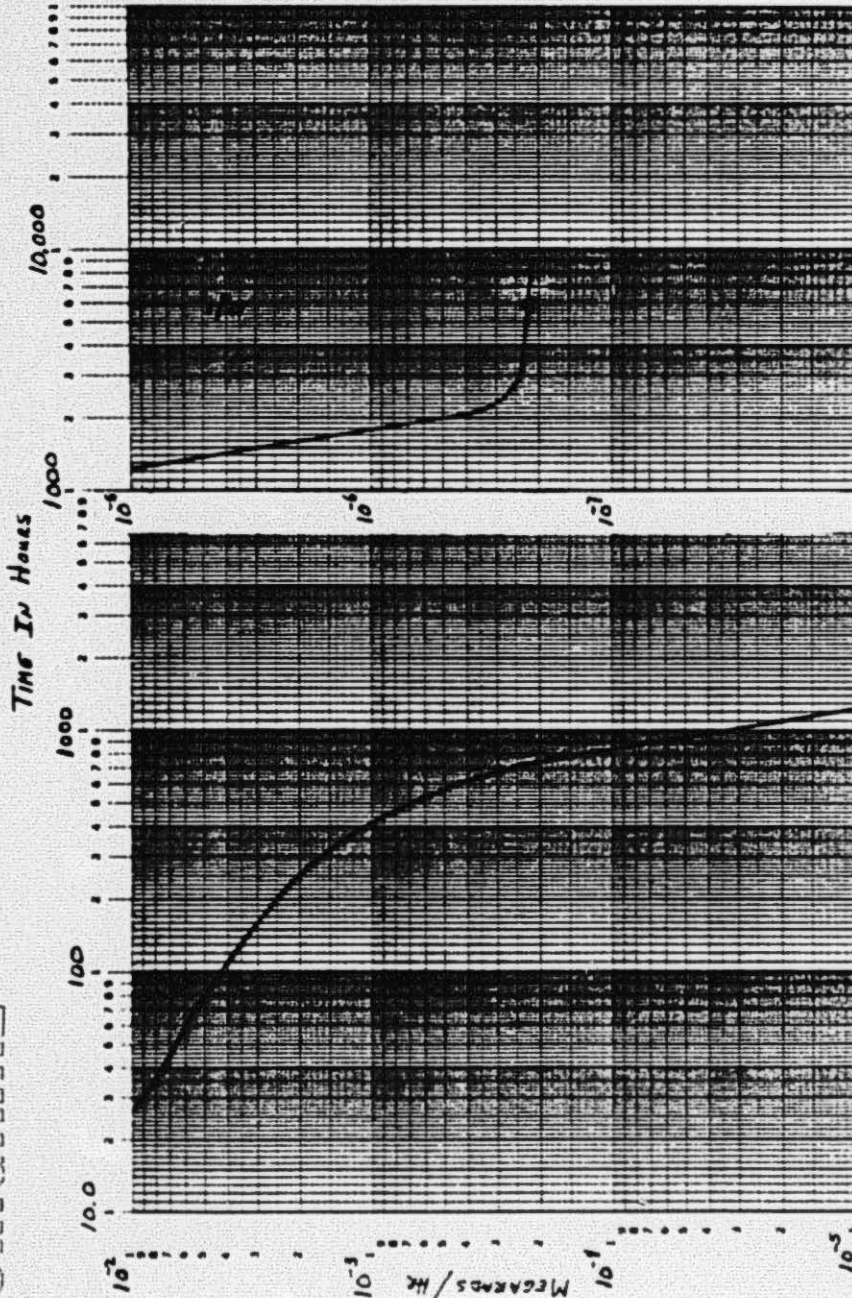
{ 44% NOBLE GASES  
 27% IODINES  
 0.05% ALL OTHERS

WITH SPRAYS  
 SEE 2.2.2.3

POOR ORIGINAL

KOE LOGARITHMIC 2-3 CYCLES  
NEUTRAL B LAMP CO. MADE IN U.S.A.

46 7522



44% NOBLE GASES  
27% IODINES  
0.05% ALL OTHERS

FIGURE 2-20 b  
MEDIAN BOUND  
AIRBORNE GAMMA DOSES AND DOSE RATES UP TO 1 YR  
VOLUME ABOVE EL 347

WITH SPRAYS  
SEE 2.2.2.3





POOR ORIGINAL

KOE LOGARITHMIC & LINEAR MODEL & EXAMPLE

46 7320

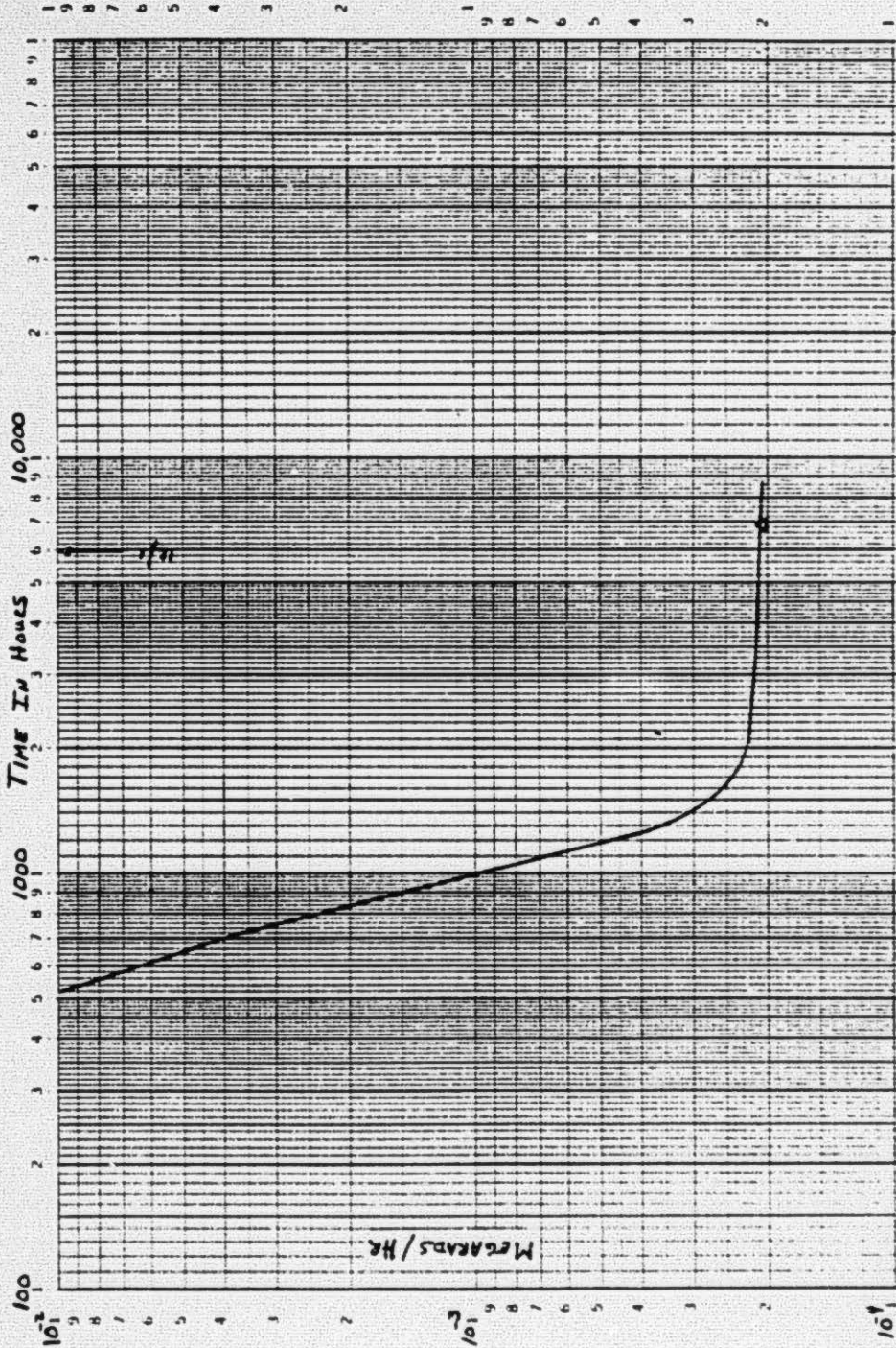


Figure 2-21 b

44% Noble Gases  
27% Iodines  
0.05% ALL OTHERS

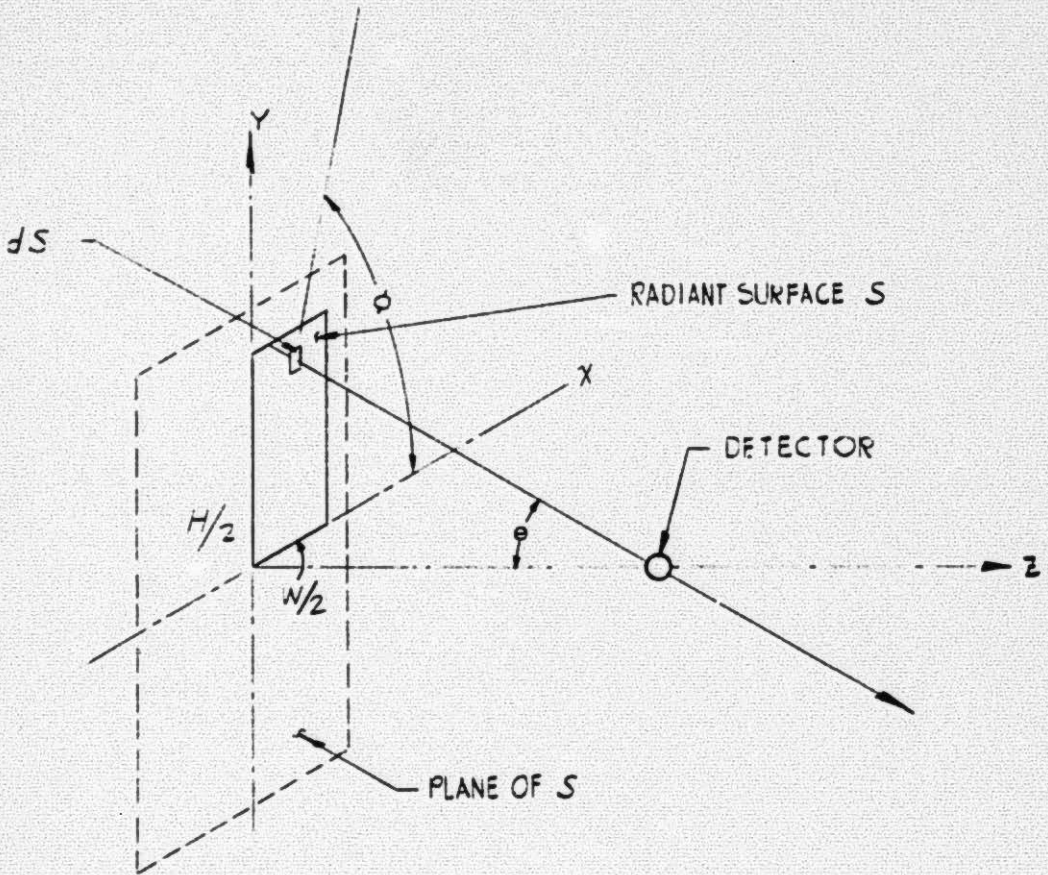
MEDIAN BOUND AIRBORNE BETA DOSER RATES UP TO 1 Yr

VOLUME ABOVE FL 347

WITH SPRAYS

SEE 2.2.2.3

971192



971193

GEOMETRY FOR PLANAR SOURCE

FIG. 2-22

### 3.0 ANTICIPATED PHYSICAL STATUS OF CONTAINMENT STRUCTURE, SYSTEMS AND COMPONENTS (NSSS and BOP)

The accident at TMI Unit 2 on March 28, 1979, and the events that followed have had an effect on the physical status of the containment structure, systems, and components. This section contains an evaluation of the physical condition of the containment structure, systems and components as they may have been affected by the events surrounding the accident.

#### 3.1 Physical Effects of the Elevated Containment Pressure and Temperature on March 28, 1979

##### 3.1.1 Containment Pressure

Containment pressure is continuously monitored and recorded by four containment pressure transmitters and two trend recorders. The transmitters are located outside the containment with two penetrations for four transmitters. The physical location of these penetrations, the point at which containment pressure is monitored, is shown in Figure 3-1 and Table 3-1.

##### 3.1.2 Containment Temperatures

Containment atmospheric temperatures are continuously monitored by sixteen thermocouples and monitored on one trend recorder. The physical location of these thermocouples is shown in Figure 3-1 and their identification is given in Table 3-2.

##### 3.1.3 Conditions Following the Transient

Elevated containment temperature and pressure conditions occurred during the first twelve hours following the initiation of the incident. The pressures and temperatures that resulted are shown in Figures 3-2, 3-3 and 3-4, respectively. Once the reactor coolant system drain tank rupture disk was breached, steam from the drain tank was diverted through a diffuser into an area around the west stairwell (No. 1) on the 282'-6" level. Steam was blown around the 282'-6" level between the secondary shield wall and containment wall and up stairwell No. 1 and the incore instrumentation cable chase to the 305' level and above.

Each time steam was relieved through the pressurizer electromagnetic relief line, the containment ambient temperatures and temperature distribution changed. Temperature sensor AH-TE-5023 (Recorder Point 13) located on the west side of the containment by stairwell No. 1 was the most sensitive to these steam releases.

As shown on Figures 3-2 and 3-3, containment ambient temperatures varied significantly. However, aside from a localized area in the vicinity of the drain tank rupture disk diffuser and stairwell No. 1, containment ambient temperatures remained less than 150° F, an increase of only 30-50° from pre-accident conditions.

S.1134

While venting the pressurizer and during the apparent hydrogen detonation, temperatures in excess of 150° F were detected. These higher temperatures were localized and were of short duration (less than four hours). At no time were temperatures in excess of 190° F observed.

Containment pressure fluctuated during the transient. Pressure increases were directly attributed to steam releases to the containment. The fluctuations in pressure, as shown on Figure 3-4, were consistent with the temperature changes detected by AH-TE-5023 (Recorder Point 13), Figures 3-2 and 3-3. However, unlike containment temperatures, which varied throughout the building, changes in pressure were representative of the entire containment. Although pressure in the area of the drain tank rupture disk deflector would be somewhat higher than that detected by the containment pressure transmitter during steam releases, pressure distribution was nearly uniform.

Excluding the conditions that existed during the hydrogen detonation, the physical effects of elevated containment pressures and temperatures during the March 28, TMI-2 accident on the containment structure, systems and components were probably minimal.

In localized areas, the possibility of some instrumentation damage, hydraulic snubbers leaking, grease fittings/lubricated fittings dripping oil, etc., does exist. The pressure and temperature service conditions that existed, i.e., 4 psig, 150° F, do not appear to be detrimental to the equipment in the containment for the short time period in question.

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### 3.2 Physical Effects of the Hydrogen Detonation on March 28, 1979

Hydrogen gas from the reactor coolant system collected in the pressurizer and was vented through the electromatic relief valve (RC-RV2) to the reactor coolant drain tank. It was probably released to the containment through the drain tank rupture disk (WDL-V26) which had been breached. At approximately 1350:20 on March 28, 1979, the hydrogen concentration reached an explosive mixture somewhere in the building and apparently detonated.

Hydrogen gas from the reactor coolant system was vented to the 282'-6" level in the vicinity of stairwell No. 1. This area would seem to be the most likely location for the hydrogen detonation to occur, however, with the containment ventilation system in operation, hydrogen gas was dispersed throughout the containment. In addition, the behavior of the temperature sensors in the containment appear to be inconclusive in supporting the postulation that the detonation occurred in this area since sensors on the opposite (east) side of the building showed a greater response than those on the west side.

The maximum pressure detected and recorded by the containment pressure transmitters described in Section 3.1 was 28 psig. These transmitters are mounted on the outside of the containment and sense pressure via a small bore tube which penetrates the building wall. This tube would tend to dampen the magnitude of shock waves resulting from the detonation. Also, if the detonation was not in the area of the transducer tubes, a greater deviation between indicated and actual maximum pressures would be expected. Attempts have been made by Bechtel to simulate the detonation as global in nature, with a 28 psig sustained pressure rise resulting from the energy addition. The implication of this simulation is containment atmospheric temperatures in excess of 1000°F, lasting until about one minute after containment spray delivery began. Since no indication of temperatures in excess of 190°F is in evidence, this theory has been rejected, and the event is interpreted as a local detonation with the 28 psig peak recorded pressure resulting from a shock front passing the pressure taps on the wall.

The temperature traces shown in Figure 3-3 show the greatest responses at elevation 330' on the east and west sides of the building (below the 347' elevation and floor). The highest temperatures were also recorded on the temperature sensors located between the 305' and 347' floors. The pressure transducers, which showed a strong response to the detonation, sense building pressure between the 305' and 347' levels. It is possible that an explosive mixture of hydrogen formed under the 347' elevation floor outside the steam generator cavities and detonated.

It is evident from the containment ambient temperature data, plant computer alarm data and the containment pressure data, that hydrogen gas may have burned and then detonated. The pressure pulse from the hydrogen detonation was detected by the building pressure instruments and by in-containment instrumentation (i.e.,

steam generators A and B level instrumentation signal spikes, NI source range instrumentation signal spike, and lower oil pot level alarms on all four reactor coolant pumps). Increases in containment ambient air temperatures were detected on all building air sensors with the exception of those sensors inside the primary shield wall. The result of the burning of hydrogen gas was apparent from the RCP air cooler inlet air temperature alarms (120°F) on reactor coolant pumps 1A and 1B. The available data supports a hydrogen burn and detonation, however, the magnitude of the forces involved and the extent of the building affected cannot be determined conclusively.

The effects of the hydrogen gas detonation on the containment structure, systems and components could be extensive. Considering all possibilities, some or all of the following conditions could exist:

#### Damage Due to Pressure Impulse

1. Ventilation duct work could be collapsed/dented.
2. Cable trays could be damaged/bent.
3. Removable hatches could be displaced/possibly damaged if lifted and then dropped during the detonation, i.e., removable concrete slab at elevation 305' near stairwell No. 2, or gratings and, possibly floor structures displaced at the 305' or 347' elevation.
4. Block walls surrounding the elevator shaft could be damaged.

#### Damage Due to High Temperatures

1. Electrical cabling could be charred or scorched if a sustained hydrogen burn occurred.
2. Coatings on the containment floor and walls could be blistered.

Damage from the hydrogen detonation or from a sustained hydrogen burn should be localized. There could possibly be floor damage immediately above the location where the detonation occurred (to the 305' slab if the detonation occurred between 282' and 305' or to the 347' slab if it occurred between 305' and 347'). A detailed damage assessment will need to be made when the containment is accessible.

3.3 Physical Effects of Containment Spray Actuation  
on March 28, 1979

As a result of the hydrogen detonation described in Section 3.2, high containment pressure actuated the engineered safeguards system. This event started both containment spray pumps (BS-PIA and PIB), opening the containment spray valves (BS-VIA and BA-VIB) and the sodium hydroxide (NaOH) tank isolation valves (DH-V8A and V8B).

The containment spray pumps operated for approximately five minutes and forty seconds before the pumps were stopped by operator action. During this time interval, sodium hydroxide was sprayed along with borated water from the borated water storage tank into the containment. This alkaline solution was distributed throughout the containment shown in the TMI-2 Unit 2 FSAR, Figure 6.2-40 and 6.2-44.

The immediate effect of containment spray was a reduction in building pressure and temperature. Normal spray flow is 1500 gpm per train. Therefore, an estimated 17,500 gallons of water (borated water/sodium hydroxide) was sprayed into the containment. Most of the solution sprayed into the building would have drained to the sump, however, some probably collected in cracks and crevices and some probably evaporated once in contact with the hot RCS and secondary system components.

Spray solution that collects in cracks and crevices will eventually concentrate with chemicals as the water evaporates. Surface corrosion (carbon steel) and corrosion in the areas of concentration may occur. Corrosion can be excessive if humidity conditions change frequently or remain high.

Spray solutions that evaporated on hot RCS and secondary system components would leave chemicals (i.e., boric acid crystals) on the component surfaces. As long as these surfaces remain dry, corrosion would not likely be detectable.

9.1108

### 3.4 Physical Effects of High Radiation Levels and Cumulative Doses

High radiation levels and prolonged exposure to radiation is detrimental to components and equipment. A detailed evaluation is required on a component-by-component basis to determine the total cumulative dose limit and the cumulative exposure received by each component. Several preliminary evaluations have been performed by B&W and others with regard to NSSS instrumentation, reactor coolant pump motor surge capacitors and some critical valve motor operators. The only certain conclusions reached were that the effective remaining lifetime and the reliability of irradiated components were reduced.

Radiation qualification limitations on equipment/components are generally determined based on analytical calculations and/or limited type testing. The resulting limits are strictly limitations on the minimum level of equipment qualification and not necessarily levels at which ultimate equipment failure will occur. Thus, with the uncertainty in determining equipment total cumulative doses, the detailed evaluation may be no more than a conservative assessment with definite recommendations for the anticipated reliability of equipment.

There is a potential effect of high radiation on the epoxy coatings used to seal and protect the containment liner walls, concrete walls and floors and structural steel surfaces. Carboline Phenoline 368 was used on the steel liner plate and structural supports from the containment shell. Structural steel was primed with Keeler and Long Epoxy polyamide 6548 with a surface coat of Epoxy polyamide 7475. The polar crane was primed with Plasite Epoxy phenolic 7155NP with a finish coat of Epoxy polyamide 9009. The poured concrete surfaces were primed with Keeler and Long Epoxy polyamide 6548 with a surface coat of Epoxy polyamide 7475. Design basis accident tests were conducted by Oak Ridge National Laboratory<sup>1</sup> whereby these coatings were irradiated to integrated doses up to  $10^{10}$  rads and then examined for signs of chalking, blistering, cracking, peeling, delamination and flaking. Although combinations of coatings tested were not identical in all respects with those in the TMI-2 containment, the quantitative results indicate a potential for some chalking and blistering for the coatings used in the TMI-2 containment. Specific test results indicated some chalking at  $10^7$  rads and some blistering at  $10^8$  rads. As can be seen from the results presented in Section 2, these values may have been exceeded in the time following the incident on some exposed surfaces, especially floors.

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<sup>1</sup> Tests performed by the Analytical Chemistry Division of Oak Ridge National Laboratory according to Bechtel Corporation Specifications CP-951, 952 and 956.



## 3.5

Physical Effects of Reactor Coolant System  
Thermal-Hydraulic Transient on March 28, 1979

The major components affected by the reactor coolant system thermal-hydraulic transient are those in the reactor coolant system, including:

1. Reactor vessel
2. Reactor vessel head
3. Steam generators
4. RCS hot and cold leg piping
5. Pressurizer
6. Pressurizer surge line
7. Pressurizer spray line
8. Reactor coolant pumps and motors
9. Core flood tanks and associated piping

B&W is presently evaluating the conditions and the events associated with the RCS thermal-hydraulic transient. The evaluation will include a detailed stress analysis for each of the components to determine the effects of this transient on component design life and integrity.

Results of this evaluation will be forwarded by B&W to GPUSC as they become available.

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### 3.6 Physical Effects of Flooding the Containmentment

The containment sump water inventory has continued to increase since March 28, 1979. Large volumes of water were added to the sump during containment spray actuation and during reactor coolant system degasification. Gradually increasing water inventory from system leakage has continued to raise the containment water level.

Flooding of the containment has likely had little effect on the structural integrity of the building. The containmentment was designed for an internal pressure of 60 psig. A structural integrity test (SIT) was conducted prior to unit startup to pressurize the containment to 69 psig, 115% of the design pressure. The SIT test pressure of 69 psig was equivalent to 158 feet of water, considerably higher than the water levels measured in the containmentment.

Equipment and systems on the 282' elevation in the containmentment, both NSSS and balance-of-plant equipment, probably sustained some degradation as a result of flooding the containmentment. Equipment most susceptible to flooding damage were electrical equipment and instrumentation located less than seven feet above the 282'-6" level of the building.

Electrical motors, submerged in containmentment sump water have been meggered and determined to be inoperable. These include the containmentment sump pump motors, reactor coolant drain pump motors, steam generator secondary side drain pump motors and leakage transfer pump motors. Some NSSS equipment/components were also submerged or were partially submerged as a consequence of flooding of the containmentment. A result of increasing containmentment water level was the failure of non-nuclear instrumentation located on instrumentation racks on the 282'-6" elevation (i.e., pressurizer level, steam generator level, RCS pressure instrumentation).

Carbon steel components that are submerged in containmentment sump water will experience some corrosion. Section 11.2 provides additional information on corrosion and corrosion rates.

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3.7 Physical Effects c Extended Operation at Negative Containment Pressure

During the post accident recovery phase, containment pressure was controlled at subatmospheric pressures. Negative pressures around -1.5 psig were not unusual. Operation under these conditions should be of no consequence to either the containment structure or the equipment in it. The containment was designed for an external atmospheric pressure of 2.5 psig greater than internal pressure so that the sealed building could accept changes in outside barometric pressure or changes in internal pressure during cooldown of the reactor coolant system. Negative pressure operation was an acceptable mode of operation for equipment and systems during normal cooldown operation. Extended negative pressure operation should not have been detrimental to in-containment equipment and systems.

9/12/82

TABLE 3-1CONTAINMENT PRESSURE INSTRUMENTATION

<u>Pressure Transmitter</u>	<u>Pressure Recorder</u>	<u>Containment Penetration</u>	<u>Location Figures +</u>	<u>Elevation</u>
BS-PT-1412-1	BS-PR-1412	R-545A	222° 20'	324'
BS-PT-1412-2	BS-PR-1412	R-545A	222° 20'	324'
BS-PT-4388-1	BS-PR-4388	R-554C	197° 40'	319'
BS-PT-4388-2	BS-PR-4388	R-554C	197° 40'	319'

TABLE 3-2

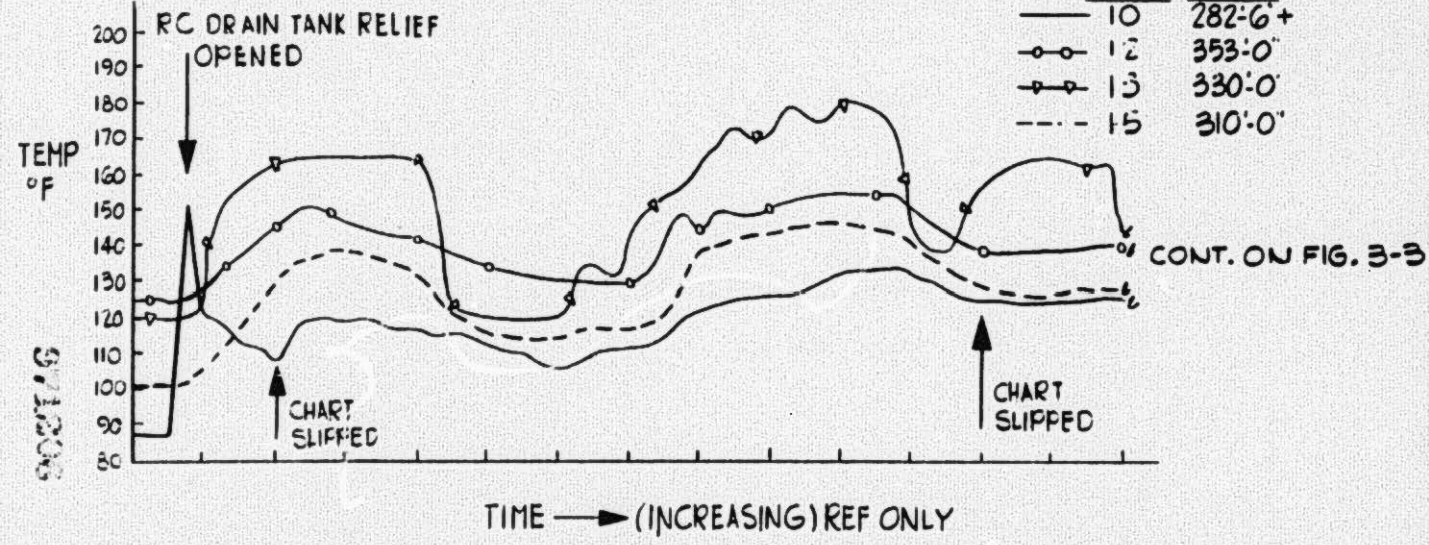
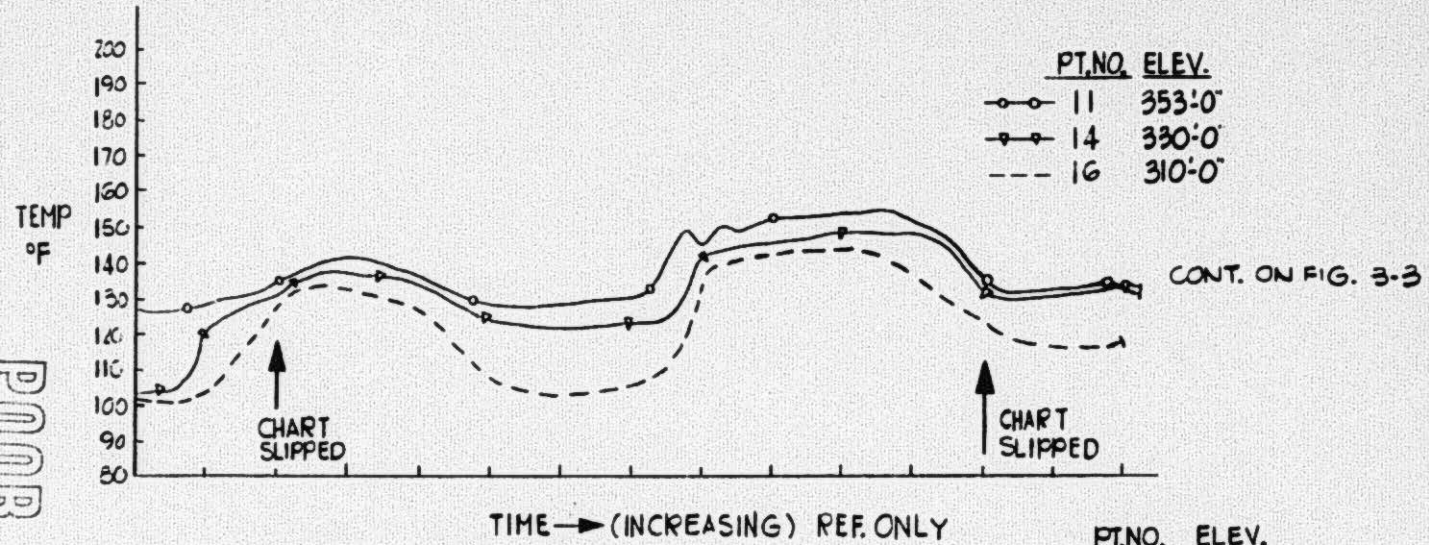
CONTAINMENT TEMPERATURE INSTRUMENTATION

<u>Recorder Point</u>	<u>Identification</u>	<u>Thermocouple</u>	<u>Location</u>
1	1 Primary Shield Temp.	AH-TE-5016	Inside Primary Shield Wall
2	2 Primary Shield Temp.	AH-TE-5017	Inside Primary Shield Wall
3	3 Primary Shield Temp.	AH-TE-5018	Inside Primary Shield Wall
4	4 Primary Shield Temp.	AH-TE-5019	Inside Primary Shield Wall
5	1 RB Air Cooling Unit Outlet Temp.	AH-TE-5015	South East Side RB 305' +
6	2 RB Air Cooling Unit Outlet Temp.	AH-TE-5027	South West Side RB 305' +
7	Impingement Barrier Area Temp.	AH-TE-5013	South Side RB 282'6" +
8	RB Sump Pump Area Temp.	AH-TE-5010	North Side RB 282'6" +
9	Letdown Cooler Area Temp.	AH-TE-5011	North Side RB 282'6" +
10	RC Drain Tank Area Temp.	AH-TE-5012	South West Side RB 282'6" +
11	RB Ambient Air Temp.	AH-TE-5020	On outside of Secondary Shield Wall East Side RB 353'
12	RB Ambient Air Temp.	AH-TE-5021	On Outside of Secondary Shield Wall West Side RB 353'
13	RB Ambient Air Temp.	AH-TE-5023	West Side RB Stairwell 330'
14	RB Ambient Air Temp	AH-TE-5022	East Side RB Elev. 330'
15	RB Ambient Air Temp	AH-TE-5014	West Side RB Stairwell 310'
16	RB Ambient Air Temp	AH-TE-5088	Southeast Side RB - Stairwell 310'



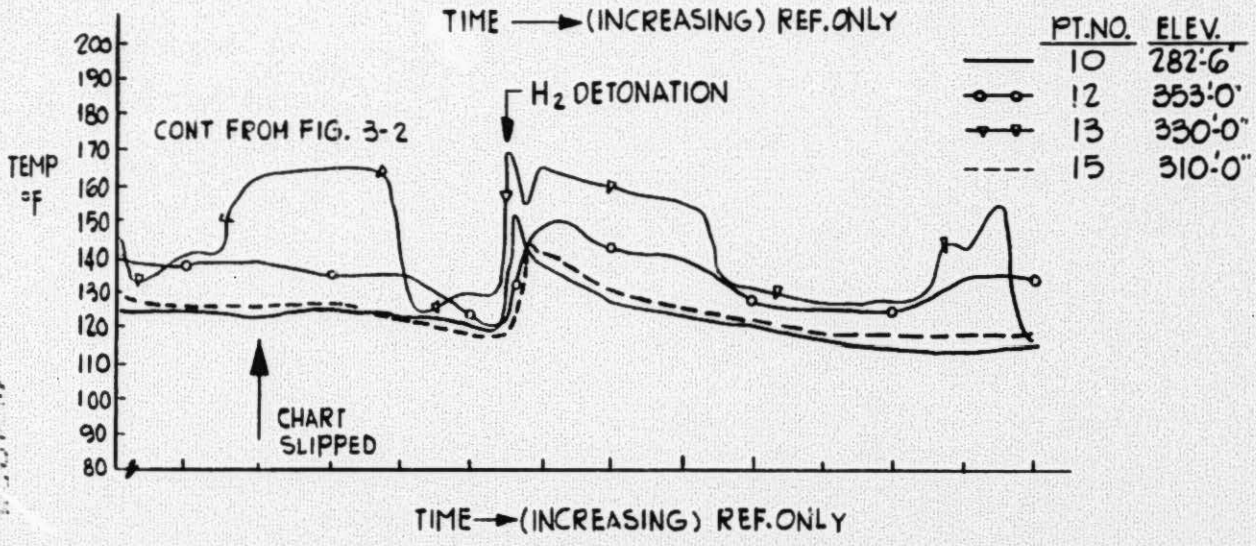
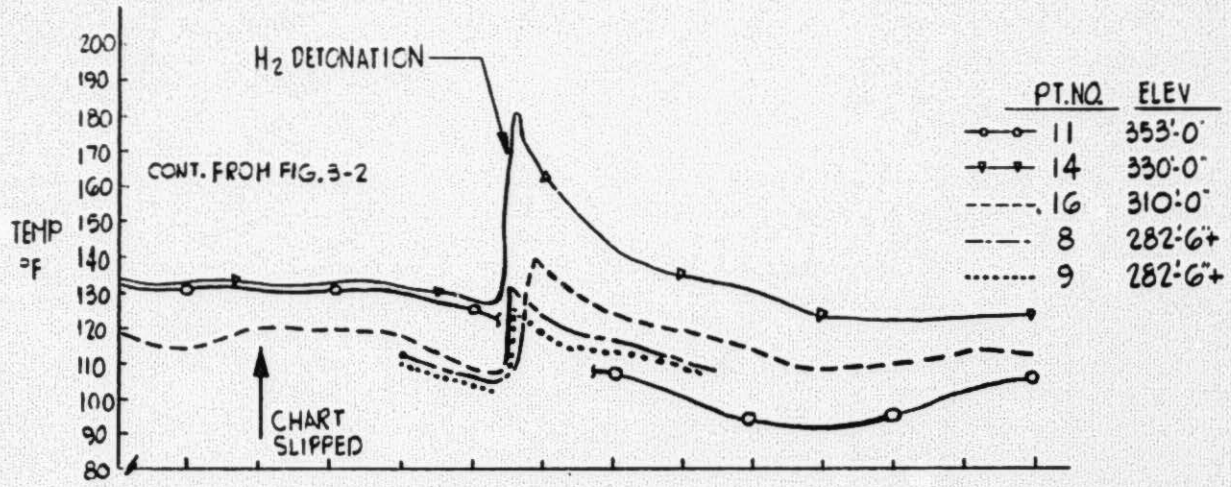
ORIGINAL  
POOR

CONTAINMENT TEMPERATURES  
FIG. 3-2 (REFER TO FIG. 3-1)



TM-2 INITIAL PLANNING STUDY

ORIGINAL CONTAINMENT TEMPERATURES  
 POOR  
 FIG. 3-3 (REFER TO FIG. 3-1)





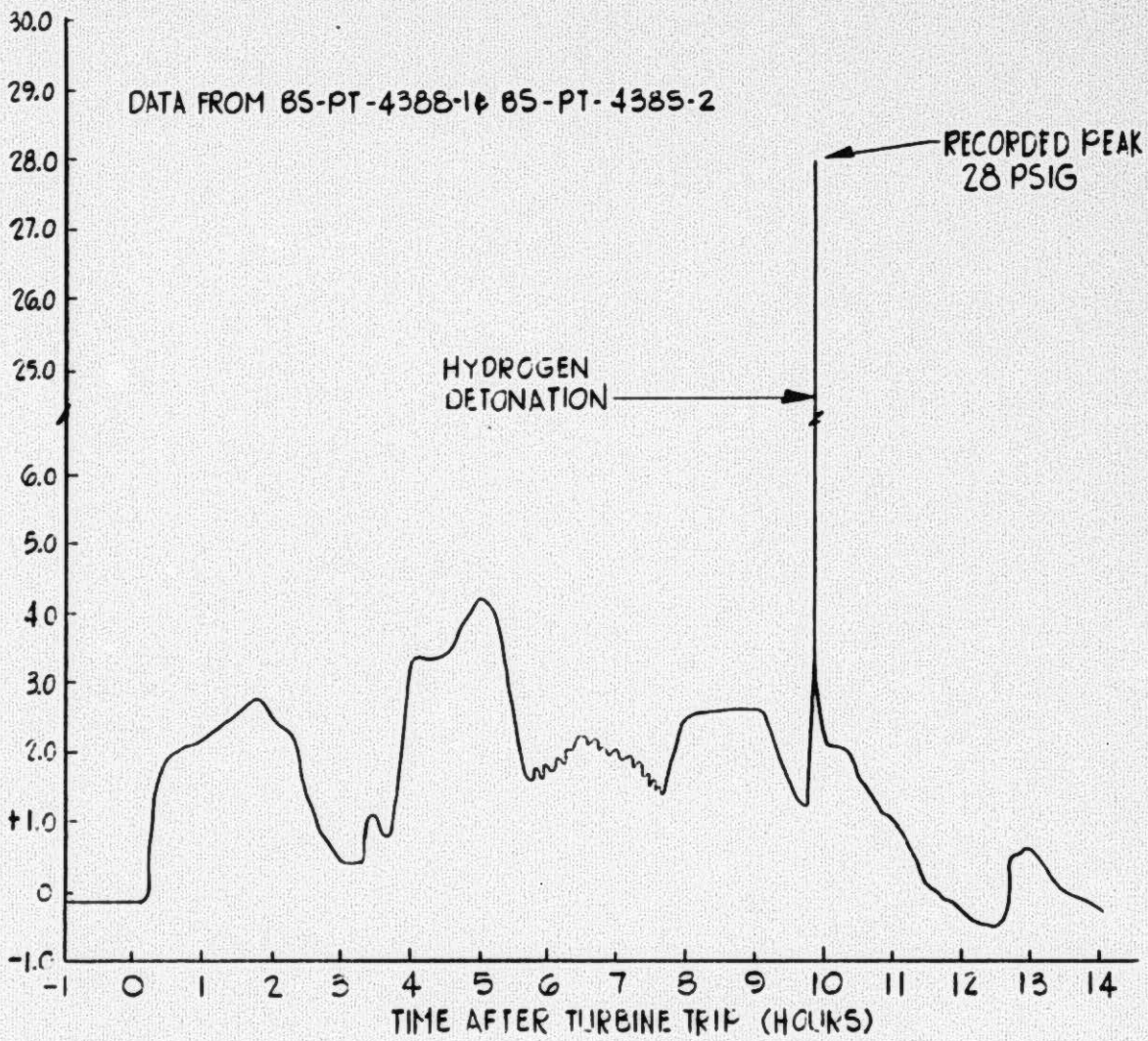
ORIGINAL

POOR

CONTAINMENT PRESSURE  
MARCH 28, 1979  
FIG. 3-4

5/1208

CONT.  
PRESSURE  
(PSIG)



TR-2 INITIAL PLANNING STUDY

#### 4.0 CONTAINMENT SERVICE SYSTEMS AND FACILITIES

#### 4.1 Containment Service Building

##### 4.1.1 Containment Service Building Purpose and Function

During the containment cleanup and decontamination phase, large pieces of equipment and a large number of workers will require access to the containment through the equipment hatch. It is necessary to maintain a contamination control envelope at least throughout the decontamination and reactor coolant system cleanup phases in order to prevent release of radioactive gases or airborne particulate material to the atmosphere. The equipment hatch design does not allow maintaining this control envelope while it is open. A containment service building, shown on Figures 4-1, 4-2 and 4-3 is described in this section to serve the following functions:

- a. Maintain contamination control during containment cleanup.
- b. Provide efficient personnel access to the containment during all phases of the containment decontamination.
- c. Allow passage of large pieces of equipment and the removal of bulk radwaste without opening the containment directly to the atmosphere.
- d. Serve as a staging area to decontaminate and package contaminated equipment removed from the containment.
- e. Serve as a staging area to temporarily store high level radwaste until ready for shipment to an off-site disposal site.
- f. Allow maintaining a hot tool crib in the vicinity of the containment to improve work efficiency and reduce radiation exposure.
- g. Provide space for a contaminated dry cleaning facility.
- h. Provide building space to handle various containment service systems.

##### 4.1.2 Containment Service Building Design Criteria

Each part of the containment service building has a different set of design criteria. In general, the structures described in this study are temporary modifications designed to effect the containment decontamination in a safe and timely manner. As such, it is not intended that normal nuclear power plant design codes, standards and guides should apply. However, it is prudent to make provisions to control unintended releases of radioactive material to the environment by selectively applying codes, standards and guides where appropriate.

It is recognized that some of the temporary structures provided for the containment decontamination may serve a useful purpose after this work is completed. This should be identified early in the detail design phase for any structure or system. For example, the desirability, even need, for a service building surrounding the equipment hatch has previously been identified by plant personnel in connection with a study of refueling activities for Unit 1. It should be understood that this report does not address any permanent plant modifications.

#### 4.1.2.2 Containment Service Area Design Bases

The area on Figure 4-1 shown as the Containment Service Area should be designed with the following bases:

- Seismic separation from the containment structure to assure that the seismic response of the containment is not altered
- Slab floor with drains to radwaste systems to accommodate possible spill of radioactive liquids
- Designed for high winds as defined in the TMI-2 FSAR. Low air leakage, negative pressure building
- Filtered (dust) inlet air
- Filtered (HEPA) exhaust air
- Hose stations for fire protection, fire detection and alarm systems
- Radiation and airborne activity monitors and alarm systems

#### 4.1.2.3 High Level Radwaste Staging Area Design Bases:

- Two-foot thick block walls (for shielding)
- Slab floor with drains to radwaste systems to accommodate possible spill of radioactive liquids
- Portable shield blocks
- Designed for high winds as defined in the TMI-2 FSAR
- Hose stations for fire protection, fire detection and alarm systems
- Radiation and airborne activity monitors and alarm systems

#### 4.1.2.4 Containment Dry Cleaning Area Design Bases

The area on Figure 4-1 shown as the Containment Dry Cleaning Area should be designed with the following bases:

- Ventilation duct to exhaust to a HEPA filter, negative pressure area
- Temporary weather protection
- Hose stations for fire protection, fire detection and alarm systems

#### 4.1.2.5 Personnel Access and Change House

The area on Figure 4-3 shown as the Personnel Change House should be designed with the following bases:

- Temporary design (e.g., metal-sided structure)
- Ventilation exhaust to HEPA filter, negative pressure area
- Hose stations for fire protection, fire detection and alarm systems
- Drain to "warm" radioactive liquid radwaste tanks (for decontamination shower facilities)
- Radiation and airborne activity monitors and alarm systems

#### 4.1.3 General Layout

The Containment Service Building shown on Figures 4-1, 4-2 and 4-3 is composed of the following areas:

- Containment service area
- Personnel access facility and change house
- High level waste staging area
- Contaminated dry cleaning area

In order to serve the functions identified in Section 4.1.1, the space in the vicinity of the TMI-2 equipment hatch is utilized to the maximum practical extent. It is important to mobilize equipment and materials needed to support the in-containment decontamination efforts close to the equipment hatch to maximize productivity of personnel who are working in radiation areas. Since work inside the containment will require a large quantity of materials to be brought into and taken out of the containment, contamination control and minimizing worker radiation exposures are important considerations.

The layout of the containment service building allows the passage of large numbers of workers through the TMI-2 security gates and the new change house. Personnel should change into anti-contamination (i.e., Anti-C) clothing in accordance with health physics procedures in effect at the time and enter the service area where work planning can take place. Personnel then enter the containment through the equipment hatch.

Upon completion of the work assignment, personnel exit the containment through the equipment hatch and various contamination control barriers, discussed in Section 8.3 and proceed to the personnel access facility.

The service building allows the equipment hatch to be removed during the containment cleanup. The equipment hatch and the No. 1 personnel air lock can be stored in the service area during this time or decontaminated and moved to a storage area outside of the building.

The shield door is used in conjunction with a new shield block and swing-away door attached to the shield door to permit personnel access when the shield door is closed. The shield door must be closed whenever the outer truck door is to be open. (Refer to Figure 4-2)

Equipment should be brought into the service area through the outer truck door. The outer truck door must be closed when the shield door is open.

Service systems that are needed in the containment that are not routed through a containment penetration should be run along the top of the northwest quadrant tendon access gallery, through the existing personnel door on the north side of the shield structure, and through the equipment hatch opening into the containment. The HVAC exhaust fans should be located on the containment service building roof. The exhaust duct should be routed along the outside of the south side of the containment to the existing temporary filter train inlet plenum located on the auxiliary building roof.

The containment cleanup and decontamination will result in a large quantity of contaminated materials being brought out of the containment for shipment as radwaste. Some of the packaging can be done inside the containment, but lower radiation levels in the containment service area will allow the decontamination and packaging to be done in low radiation fields and free valuable containment space for construction efforts.

The layout of the containment service building provides an area for a hot tool crib near the equipment hatch, until radiation levels permit moving the tool crib inside the containment.

This report proposes that a contaminated clothing dry cleaning facility be provided for the cleanup and decontamination of the containment. The existing concrete pad which forms the roof of the control building basement housing the auxiliary feedwater pumps should be used for the anti-C dry cleaning and respirator cleaning facility. In addition to being close to the equipment hatch and the personnel access facility, the facility is easily accessible from the No. 2 personnel hatch area and health physics area in the service building through a control building corridor at the 305' elevation.

#### 4.1.4 Design Features and Operating Procedures

##### 4.1.4.1 Containment Service Area

The containment equipment hatch closure and No. 1 personnel lock should be removed during containment cleanup and decontamination. An equipment hatch storage stand is required within the containment service building. The hatch and the personnel lock can be stored outside the service building after decontamination. It is anticipated that the hatch closure will have to be in place when fuel is removed. It is necessary that a hatch handling fixture be provided.

In order to maintain a contamination control barrier after the equipment hatch is removed and when it is necessary to open the outer truck door, a second barrier should be provided. This can be accomplished by modifying the big shield door or by installing hanger-type doors on the outside of the shield structure. For this report it is proposed that the shield door be modified with weather stripping-like provisions to isolate the containment from the atmosphere when the shield is closed and the truck door is open. This feature is provided because of the inherent difficulty in replacing the equipment hatch every time the outer truck door is required to be opened.

When the shield is closed, personnel access would become more difficult and entry would have to be made through the side door in the shield structure (which is intended to be used for containment service system access as discussed in Section 4-2), or through the No. 2 personnel lock. A swing-away personnel door and shield block is provided (Figure 4-2) to be installed on the south side of the shield door to maintain the contamination control envelope and still allow personnel access to the containment.

During periods in the containment when high levels of contamination exist or when recontamination due to airborne activity occurs, it will be desirable to provide an additional barrier of contamination control such as a plastic "tent" on the inside of the containment hatch. Sections 8.2, 8.3 and 8.4 discuss the methods used for contamination control during personnel and equipment entry and egress.

The south portion of the containment service area is used as a staging area for work planning, mobilization of equipment and materials for containment entry. Personnel enter this area from the change house. Egress from the containment is made through the equipment hatch, the swing-away personnel door on the missile shield and a door to the change house in the south side of the service area.

The north portion of the containment service area is used for decontamination of equipment and temporary staging of contaminated materials while they are being packaged and prepared for transfer to the on-site radwaste facilities or for shipment. The area should be at a lower elevation than the area in front of the hatch and should have a stainless steel lined floor to aid in decontamination of the area. Partitions or

splash curtains for sprays or showers employed during decontamination of equipment should be provided along with flexible vent hose connections to the building exhaust in order to control aerosol and particulate activity resulting from decontamination efforts.

A bridge crane was considered for the service area but its cost and the inability to cover all areas led to the conclusion that materials handling by fork lifts or truck-mounted boom cranes would be more desirable.

The containment service building should be exhausted through the temporary auxiliary building and fuel handling building HEPA/charcoal filter train installed on the auxiliary building roof as discussed in Section 4.2.14.

Floor drains should be provided to aid in cleanup of the service building if it should become contaminated. The floor drains should be tied into the plant radwaste system. Drains should also be provided in the north portion of the containment service area for use when decontamination of equipment is to be performed. A radwaste processing and disposal flow chart showing quantities and activities of liquid radwaste and types and forms of processed radwaste from this and other decontamination efforts is shown on Figure 4-4.

Service systems provided in the containment service building:

- a. Steam
- b. Demineralized water
- c. Raw water
- d. Fire water to hose stations
- e. Recycled low activity water
- f. Service air
- g. Lighting and 110/220 VAC power supply
- h. Welding receptacles
- i. Radiation monitoring

It may be desirable to provide interlocks between the outer truck door and the shield door such that both could not be open at the same time. This interlock would be needed as long as airborne activity existed in the containment.

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#### 4.1.4.2 Personnel Access Facility and Change House

The personnel access facility is a temporary facility designed to efficiently allow the entry and egress of a large number of people to work inside containment. The facility includes a health physics office which is used as the control point for processing Radiation Work Permits (RWP). It is reasonable to expect that 100 or more people per shift might be engaged in various activities of decontamination and reconstruction inside the containment.

The change house also includes storage for clean anti-C clothing (coveralls, gloves, boots, etc.), respirators and breathing apparatus, lockers for storage of personal clothing, decontamination sinks and showers, personal hygiene facilities, and radiation monitoring portals. Separate locker and personal hygiene facilities for men and women should be provided. If additional space is needed, the area south of the turbine building railroad door or a second floor to the facility could be employed.

Double sets of doors at the points of entrance to the containment service building will be needed to maintain the proper air flow and control infiltration.

The personnel access and change house will be located in front of the turbine building inlet louvres. The bottom of the louvres is below the top of the access corridor and change house. This will necessitate blocking off the lower portion of the louvres while the temporary facility is in use. Since the turbine will not be in operation, this is not expected to be a problem.

The floors and walls should be sealed and painted to facilitate decontamination of the facility if it becomes contaminated.

Heating, ventilation and air conditioning should be provided as discussed in Section 4.2.14.

#### 4.1.4.3 High Level Radwaste Staging Facility

The high level radwaste staging facility will be needed for temporary storage of high level radwaste which cannot be stored at other on-site facilities. Many large items will have to be removed from the containment which cannot be decontaminated to low levels (examples include sections of the containment air coolers, letdown coolers, etc.). Since shipments cannot be scheduled immediately upon removing high level radwaste from the containment, it is apparent that such a facility will be required.

The high level waste staging facility should be provided with a slab floor and floor drains to the radwaste system. Two foot thick concrete or block walls should be provided for shielding. Additional shielding which may be required should be provided by portable concrete shield panels or temporary lead shielding to reduce radiation levels inside occupied areas and outside the building to within a range of 2.5 - 25 mr/hr. A concrete roof (precast panels) should also be provided.

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Because it is expected that radioactive materials stored in the facility will be in stable form (e.g., contaminated equipment, drummed waste, etc.), the containment service building need not be designed for seismic Class I or aircraft hardened protection.

The north wall has an interface with the emergency modifications made for the auxiliary decay heat removal system, and the proposed waste evaporator system which have not yet been located on the site plan drawings.

#### 4.1.4.4 Dry Cleaning Facility

The dry cleaning facility should be located on the slab between the containment and the turbine building. It is expected that more than 10,000 pounds of contaminated clothing will have to be cleaned each day during the containment decontamination and reconstruction. It is necessary that the cleaning and issuing of anti-C clothing be done with minimum impact on the work performed inside the containment. The location chosen for the dry cleaning facility is centrally located to the change facilities for both the No. 2 personnel lock and the equipment hatch.

Although not addressed specifically in this report, if the dry cleaning facility is established in the near future it can be used to support work in the auxiliary building and the fuel building even prior to containment entry.

The dry cleaning facility is proposed to avoid processing a significant amount of detergent waste water that is contaminated. Dry cleaning systems, available on a contract lease basis, are in use which are self-contained, i.e., do not require plant contaminated waste processing, and are adaptable to this service.

A respirator cleaning and drying rack should also be located in this area.

Trash compactors will be needed for the throw-away anti-C clothing, gloves and boots and should be located in the dry cleaning area.

A portion of the area can be used as a hot tool crib until such time that radiation levels are low enough to put it inside the containment.

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## 4.2                    Containment Decontamination Service Systems

### 4.2.1                    General Purpose and Philosophy

The general purpose and philosophy for containment decontamination service systems is to:

- a. Provide means and equipment to implement proposed remote and hands-on decontamination methods.
- b. Provide services required to support proposed decontamination operations.
- c. Adapt existing plant systems, equipment and facilities for containment decontamination use when this action would present an obvious economic and schedule advantage.
- d. Design systems to be compatible with construction practices that can be performed in a radioactive environment inside containment and will minimize the spreading and dispersion of radioactivity.

### 4.2.2                    Containment Remote Decontamination Spray and Chemical Additive System

#### 4.2.2.1                    Purpose

- a. Provide a means to spray water and detergent or other chemical cleaning solutions into the containment for the remote decontamination operations.
- b. Provide a means for introducing saturated steam into the containment for remote decontamination operations as discussed in Section 4.2.8.

#### 4.2.2.2                    Design Criteria

- a. Provide for sufficient water flow into the existing containment spray system to create the remote decontaminating flushing action discussed in Section 5.0.
- b. Provide for introducing the amounts of detergents or chemical cleaning agents into the containment water stream during remote decontamination operations to satisfy the requirements discussed in Section 5.0. Also provide for pumping the required amount of premixed detergent or chemical cleaning solutions into containment through the containment spray system.

- c. Provide piping and connections to the existing containment spray system and ILRT test connection to supply saturated steam through alternative paths during remote containment decontamination operations.

#### 4.2.2.3 Conceptual System Description

4.2.2.3.1 Flush water for the remote containment decontamination operations should be provided through a tentatively sized 10 inch line from the proposed containment water supply system. This 10 inch line could be connected to the existing 20 inch borated water supply header in the outdoor pipe trench adjacent to the existing borated water storage tank. The proposed 10 inch line and system interconnections are shown schematically in Figures 4-5 and 4-14.

4.2.2.3.2 The existing sodium thiosulfate storage tank BS-T-1 can be used to store the required amount of concentrated liquid detergent or chemical cleaning agent in a single batch for the remote detergent or chemical decontamination operation. A variable speed positive displacement chemical addition pump should be provided and connected to the existing 4 inch capped connections at sodium thiosulfate tank drain valve BS-V139B. This proposed pump should be installed in the containment spray pump compartment on floor elevation 258'-6" in the auxiliary building. This will minimize pipe runs since both of the subject 4" capped connections are located in this compartment. Figure 4-5 shows the proposed pump and system interconnections.

4.2.2.3.3 As an alternate means of providing detergent or chemical solutions, the existing sodium thiosulfate tank and sodium hydroxide storage tank DH-T-2 can also be used to store a complete remote decontamination batch of premixed detergent or chemical cleaning solution. A 4 inch drain connection already exists from the sodium hydroxide tank to the 20 inch borated water supply header which would allow injection of the tank contents into the water stream by gravity and under the influence of the tank static head. Likewise, a 4 inch bypass line can be provided with the proposed chemical addition pump to permit injection of the sodium thiosulfate tank contents into the water stream by gravity.

4.2.2.3.4 A new tentatively sized 3 inch steam line can be connected to the existing 3 inch flanged test connection on the containment spray system "B Loop", or alternatively, to the existing ILRT test connection at valve AH-V7 to supply steam for the remote containment decontamination operations as discussed in Section 4.2.8. A tentatively sized 2 inch instrument air line should also be tied into the 3 inch steam line connected to the containment spray system as shown in Figure 4-5, to permit air purging of the spray headers and nozzles.

#### 4.2.2.4 System Operation

4.2.2.4.1 Since the existing containment spray system "A and B Loops" are identical and redundant, and only the spray nozzles of one loop will be needed to effectively introduce water or steam into the containment for the remote decontamination operations, existing decay heat removal and containment spray system valves should be lined up to ensure that the "A and B Loops" are isolated from each other, from their point of connection, on the 20 inch borated water supply header. Therefore, the "A Loop" piping from the containment sump through the containment spray pump test recirculation drain valve BS-V134 will be available for draining containment sump inventory to the radwaste processing system.

4.2.2.4.2 When initiating water flow to the containment spray headers, it would be desirable to throttle down the existing control valve BS-V1B downstream of the containment spray pump BS-P-1B until the spray headers are completely filled with water to minimize dynamic effects that could occur when the headers are filled too rapidly.

4.2.2.4.3 When injecting concentrated liquid detergent or other chemical cleaning agent from the sodium thiosulfate tank directly into the containment spray system water stream, the additive flow rate should be monitored using the proposed flow indicator and the chemical addition pump speed should be adjusted accordingly to ensure that the correct proportions of chemical or detergent additives and water are maintained throughout the remote containment decontamination spray operation. When injecting premixed detergent or chemical solutions directly from the sodium thiosulfate tank into the containment spray system water stream by gravity, the flow rate adjustments should be made with the proposed bypass throttling valve.

4.2.2.4.4 Operation of the system proposed for introducing steam into the containment for remote steam decontamination and for purging the containment spray headers using instrument air is discussed in Section 5.0.

#### 4.2.3 Containment Ventilation and Filtration System

##### 4.2.3.1 Purpose

- a. Purge and filter the containment atmosphere to reduce the airborne radioactivity to a level that will minimize radiation exposure to members of the decontamination team entering the containment
- b. Provide ventilation to maintain acceptable temperature and humidity levels inside containment while it is occupied.
- c. Control containment pressure to avoid possible uncontrolled release of radioactivity.

4.2.3.2

## Design Criteria

- a. Design criteria for purging and filtering the containment atmosphere prior to entering containment.
  - Capability to satisfy purging and filtration requirements outlined in Section 6.0
  - Expeditious replacing and handling of radioactive filters in the containment ventilation and purge system.
  - Capability to control containment pressures within operating limits.
  - Capability to intermittently cool the containment heat sinks during remote decontamination operations as described in Section 5.0. This requires using the existing containment coolers.
- b. Design criteria for ventilating and filtering the containment atmosphere during manual decontamination operations inside containment.
  - Air flow to be from relatively low radioactive areas to higher radioactive areas.
  - Ventilation and cooling or heating to maintain ambient temperature and humidity within occupational limits.
  - System to maintain slightly negative pressure inside containment to prevent uncontrolled release of radioactivity.

4.2.3.3

## Conceptual System Description

4.2.3.3.1

Purging and filtering containment atmosphere prior to entering containment.

It is expected that the existing containment ventilation and purge system with some possible modifications as described in Section 6.0 will satisfy the system design requirements. The containment ventilation and filtration system is shown in Figure 4-6.

Any additional shielding required to minimize radiation exposure while replacing and handling radioactive filter media, framed modular filters or activated charcoal filter beds shall be arranged in a manner compatible with expeditious filter handling.

To prevent the accumulation of radioactive gases in the capped-off station vent stack when operating the containment purge system, which could result in the uncontrolled release of radioactivity when the lid cover is removed from the stack opening, blank-off plates should be installed in horizontal duct runs downstream of the purge exhaust fan (AH-E-19A and B) recirculation duct connections and upstream of the pneumatic actuated dampers D-5129A and B. Also, to prevent the possible uncontrolled release of radioactive gases past the dampers in the outside air supply ducts, blank-off plates should be installed in horizontal duct runs downstream of pneumatic actuated dampers D-1528C and D and upstream of the recirculation duct connection points.

When operating the hydrogen purge system and releasing noble gases at a rate within maximum permissible concentrations, containment pressure can be adjusted and maintained by employing an ILRT test connection fitted with a valve and particulate filter to allow clean outside air to replace the exhausted purge flow. Since the station vent stack has been capped off, a separate 6 inch pipe vent stack installed and supported on the station vent stack and extending above the dome of the containment would enhance the dilution effects of the released gases. Replacing the hydrogen purge exhaust valve AH-V36 and associated 2-1/2 inch and 3 inch ducting with 6 inch ducting in conjunction with modifying the exhaust fan drive to provide higher fan speeds could cut the purging time to as much as one-fourth that required with 150 cfm operation as discussed in Section 6.4.3.

#### 4.2.3.3.2 Ventilation and filtering of containment atmosphere during manual decontamination operations inside containment.

The existing containment purge and ventilation system with some modifications as described above and illustrated in Figure 4-6, should satisfy the initial manual decontamination operations inside containment.

Purge air enters and leaves the containment through 36 inch diameter air ducts in the northeast quadrant of the containment. Purge air flows from the two vertical supply ducts in this quadrant at elevations 412'-0", 385'-0", 365'-0" and 326'-3". Exhaust air flows from the steam generator cavity in the same quadrant through horizontal ducts at elevation 341'-6". While the purge air is distributed over a wide area vertically as illustrated in Figure 4-7, it may be confined primarily to the eastern half of the containment without containment cooler operation since all the purge supply and exhaust openings are located there. This arrangement will result in a positive air flow through the access-ways and stairwells located in this half of the containment.

As the decontamination team progresses to the elevation 367'-4" operating platform for decontaminating the upper portions of the containment, the downward sweeping purge air flow through the steam generator and reactor compartments can be enhanced by closing the dampers in the vertical supply ducts just above the lowest supply air openings and/or covering the four 36" x 48" supply air registers at elevation 326'-3" with cardboard, plywood or sheet metal. This will force twice the quantity of purge air out of the upper supply air openings.

Also, to prevent the possibility of recontaminating upper areas after they have been decontaminated, temporary tent-type coverings can be placed over the openings at the top of the steam generator cavities as illustrated in Figure 4-7. This will prevent any upward air flow through the openings at the top of the steam generator cavities.

The containment coolers would normally provide ambient cooling inside containment. In the event they have accumulated radioactivity to the extent they are a significant source of radiation exposure or would expel additional airborne radioactivity into occupied areas when operated, they may have to be disassembled and removed. If the containment coolers cannot be used, new smaller capacity cooling units should be installed, connected to the existing flexible normal cooling water system lines and connected to the existing containment cooler supply ducts.

As the decontamination operations move downward in the containment into smaller, more confining areas and compartments, flexible "elephant trunk" type ducting can be attached to the purge air supply registers and cooling unit air supply registers as necessary to provide positive ventilation and cooling flow to these areas. Again, certain supply registers may have to be covered to force cooled air into only those areas occupied and prevent the undesirable dispersion of radioactivity to areas that have already been decontaminated.

The increased hydrogen exhaust fan capacity range to minimize the required purging time, as discussed above, should also ensure that a negative pressure can be maintained inside containment with increased air infiltration through personnel access openings.

#### 4.2.3.4 System Operation

##### 4.2.3.4.1 Purging and filtering containment atmosphere prior to entering containment.

Operation of the existing containment ventilation and purge system in this application is described in Section 6.0.

Radiation levels of the air and hydrogen purge system filter units should be closely monitored so that filter replacement can be scheduled before the filters become too radioactive to handle. It is expected that the filter replacement frequency will be governed initially by radioactivity buildup rather than limiting pressure drop considerations.

##### 4.2.3.4.2 Ventilation and filtering of containment atmosphere during manual decontamination operations inside containment.

Since the intent is to decontaminate the containment from the point of entry upward along an access path to the elevation 367'-4" upper operating platform, and then from the containment dome downward, the ventilation air flow distribution should follow the same route to prevent recontaminating areas already decontaminated with airborne radioactivity carried

by ventilating air from contaminated areas. This can be achieved using the existing containment purge system with some modifications as discussed in Section 4.2.3.3.2, above.

Since the existing supply air ducts connected to either the containment coolers or new cooling units distribute air in a widespread manner to many areas inside containment, dispersion of radioactivity from contaminated areas to cleaned up areas may be a problem. Operation of the cooling units during initial activities inside containment should not affect the radioactivity levels in any one area appreciably while the overall level is still relatively high. When areas are cleaned up and decontaminated, care should be taken to ensure that ventilating air flows only from decontaminated areas to radioactive areas, and not vice versa. This can be achieved by judiciously covering certain purge and cooler supply air registers and attaching flexible "elephant trunk" type ducting to other supply air openings as discussed in Section 4.2.3.3.2.

In cold weather, any heating required for personnel comfort inside containment should be provided by small, portable, electric radiant heating units that can be readily set up in any given working area and moved from area to area as required. Electric power should be provided by the containment temporary lighting and power system described in Section 4.2.4.

#### 4.2.4 Containment Temporary Lighting and Power System

##### 4.2.4.1 Purpose

- a. Provide electric power in the following areas to implement, control and monitor containment decontamination operations:
  - On various floor elevations within the containment
  - In the communication center located in the control building area on the east side of the containment.
  - In the proposed containment service building to be located on the west side of the containment.
- b. Provide illumination in the above designated areas for implementing, controlling and monitoring containment decontamination operations.

##### 4.2.4.2 Design Criteria

- a. Electric power requirements for equipment to be utilized in the decontamination operations can be satisfied by 480 volt, 3 phase, 60 hertz and 120 volt, single phase, 60 hertz power supplies.



- b. Since these power supplies exist in the plant, any existing available spaces for drawout disconnect circuit breakers should be used in applicable unit substations, power distribution panels, receptacle panels and lighting panels.
- c. In the event power is not available from the 230 kv offsite source through Auxiliary Transformers 2A and 2B, one of the two existing emergency diesel generators can temporarily be connected to 4160 volt switchgear buses 2-3 and 2-4 as required.
- d. As soon as the radiation levels inside containment permit, the existing electric power and lighting systems should be checked out for operability and utilized. In the event these systems cannot readily be made operational, power can continue to be supplied through temporary circuits connected to available unit substation buses outside containment.

#### 4.2.4.3 Conceptual System Description

4.2.4.3.1 New receptacle panels connected to 480 volt pressurizer heater unit substation buses 2-34 and 2-44 should be installed in the control building area just outside the containment equipment hatch to provide a point where extension cords can be used to satisfy power requirements during containment entry operations. Substations 2-34 and 2-44 are located in elevation 280'-6" between column lines C63 and C65, and CX and CZ below the containment equipment hatch. Likewise, in the control building area just outside the No. 2 personnel air lock, new receptacle panels connected to the same substation buses should be installed to accommodate initial containment entry power supply requirements. In addition, these power receptacles will be required to provide power to portable lamps and all electric powered decontamination equipment in the event the existing containment power supply and lighting systems are not operational. Figure 4-8a shows the drawout disconnect circuit breaker spaces on unit substation buses 2-34 and 2-44 that should be available and can be used.

In the event spaces are not available in these unit substations, a determination should be made whether or not the existing auxiliary transformers have sufficient capacity to accommodate a new unit substation specifically for containment decontamination power requirements. If no excess auxiliary transformer capacity exists, an economic evaluation should reveal whether another auxiliary transformer or a diesel/gasoline engine powered generator should be provided.

4.2.4.3.2 The following electrical panels already exist in the containment and are located as shown on Figure 4-8b. The existing power supply system in the containment may not be in a condition to energize due to the water level in the 282'-6" elevation. All circuits should be meggered and the circuit and raceway schedules examined to ensure safety prior to energizing any circuit.

## a. Elevation 282'-6" Floor Level

Receptacle Panel	RPR-1A
Lighting Panel	LPR-1A
Lighting Panel	LPR-1B
Lighting Panel	LPR-3D

## b. Elevation 305'-0" Floor Level

Power Distribution Panel	PDP-3A
Power Distribution Panel	PDP-3B
Lighting Panel	LPR-2A
Lighting Panel	LPR-2B

## c. Elevation 347'-6" Floor Level

Receptacle Panel	RPR-3D
Lighting Panel	LPR-3A
Lighting Panel	LPR-3C
Lighting Panel	LPR-4D

Two (2) spare three phase circuit breakers should be available in power distribution panel PDP-3A to accommodate additional power supply requirements for receptacles and/or lighting inside containment. One breaker has a current rating of 70 amps and the other 30 amps. Both are Westinghouse Type HCDP with vapor tight, surface mounted enclosures and have an interrupting rating of 22,000 amps symmetrical.

4.2.4.3.3 Additional electric power for receptacles and lighting in the communication center can be provided from the same new panels proposed for the area just outside the No. 2 personnel air lock.

4.2.4.3.4 Distribution panels to accommodate power supply requirements for the containment service building receptacles and lighting should also be connected to the same unit substation buses 2-34 and 2-44 due to the close proximity of these buses to the proposed location of the new building. In addition, spare spaces should be available on 480 volt motor control center buses 1-12XD and 2-22XD located outdoors and adjacent to the north wall of the proposed new containment service building for new equipment power requirements.

4.2.4.3.5 In the event the existing lighting system is not operational or supplemental lighting is required, portable lamps on free standing support bases should be used for illumination inside containment. It is recommended that 600 watt or 650 watt 110 VAC quartz iodide lamps be used.

4.2.4.3.6 Portable, emergency, battery-operated, self-contained lighting units should also be installed on every occupied floor level inside the containment to provide back up illumination. The emergency lights should be automatically energized whenever power to either the existing lights or portable free standing lamps is interrupted for any reason.

#### 4.2.4.4 System Operation

4.2.4.4.1 During the initial containment entry and early decontamination operations, electric power for portable lamps and other decontaminating equipment should be provided from new power panels located outside the containment as discussed in Section 4.2.4.3, above. This will require the use of extension cords routed through existing spare containment penetrations or temporary penetrations located in the existing personnel door on the north side of the equipment hatch shield structure.

4.2.4.4.2 As soon as each permanent work station is established inside containment, an emergency battery operated lighting unit should be installed to provide back up illumination in the event of a loss of the primary source of light.

4.2.4.4.3 As soon as practicable, the existing containment power receptacle and lighting systems should be utilized to eliminate the need for long extension cords or new circuits routed into the containment from outside power distribution panels.

#### 4.2.5 Containment and Service Building Breathing Air System

##### 4.2.5.1 Containment and Service Building Personnel Breathing Apparatus

###### 4.2.5.1.1 Introduction

The initial entry to the containment will be made with self-contained breathing apparatus (SCBA), preferably the type with a 60 minute purified oxygen supply (e.g., Bio-Pak 60's from Bio-Marine). Personnel wearing the SCBA's will set up the breathing air supply systems. The SCBA will provide personnel with a  $10^4$  protection factor. (All protection factors used in this section are from Regulatory Guide 8.15 as modified by IE Bulletin 78-07).

The breathing air supply for major decontamination operations in the containment and service building will consist of carts with four - 300 standard cubic foot bottles of air. The tanks will be used to supply pressure demand air line masks with a protection factor of  $2 \times 10^3$  and hoods with a protection factor of  $10^3$ . The air line masks will only be used when the airborne radioactivity has been lowered to the point that SCBA's are not required. The hoods can be used for greater comfort and therefore worker efficiency when the protection factor permits their use. The appropriate mask will be used in any airborne radioactivity area with the objective of limiting breathing air to less than MPC. Breathing air exposure should not exceed the equivalent of 40 MPC - hours per week.

The carts with the air tanks will be positioned at the various work locations. Personnel will enter the containment or airborne activity area in the service building, using a small air bottle (protection factor of  $10^4$ ) or a cannister (protection factor of 5) and will connect to the air hose at their work location.

The containment and service building breathing air supply system could use mobile carts since they can more readily be moved from one work location to another as the decontamination progresses. In addition, the hoses attached to the individual masks can be shorter so there will be less difficulty in entangling them. This will provide greater mobility to these personnel.

#### 4.2.5.1.2 Purpose

The purpose of the breathing air system is to provide a convenient and a safe source of uncontaminated air inside the containment. Greater worker efficiency is possible when tanks do not have to be carried on their backs and, in the case of hoods, when the masks do not have to be worn and air cooling inside the suit is available.

#### 4.2.5.1.3 Design Criteria

The system must provide an adequate protection factor and adequate stay times in the containment and service building decontamination area while maximizing worker efficiency. As an operating objective, inhalation concentrations will be limited to MPC. The protection factors assumed for the various masks are those given in Regulatory Guide 8.15 and were provided in Section 4.2.5.1.1.

As administrative limits, a cannister should be worn whenever the loose surface contamination exceeds  $10^5 \frac{\text{dpm}}{100 \text{ cm}^2}$  and an air supplied mask should be worn whenever the loose surface contamination exceeds  $10^6 \text{ dpm}/100 \text{ cm}^2$ .

#### 4.2.5.1.4 Conceptual System Description

The system will consist of four air tanks mounted on a cart. Each tank will have a capacity of 300 standard cubic feet for a total capacity of 1200 standard cubic feet per cart. A mask in the pressure demand mode requires 1.5 SCFM while a hood requires 6 SCFM. Therefore, a cart would last for approximately 13 man hours with personnel wearing masks and 3 man hours with personnel wearing hoods. Therefore the greater worker efficiency using hoods must be balanced with more frequent replenishment of the air supply. The tanks would be taken to the refilling station near the containment equipment hatch and refilled. Pressure gauges on each tank should be provided to indicate the air supply remaining, and an alarm should sound when the tank has been depleted to less than 25%.

#### 4.2.5.1.5 System Operation

Personnel would enter the containment or airborne activity area in the service building on small air flasks or cannisters depending on the airborne and surface activity and would connect air hoses from the cart mounted tanks to their masks and switch over to the tanks. Personnel would exit the containment or service building area by reversing this procedure.

The carts would be moved from one work location to another as work progressed. The tanks would be refilled at the refilling stations inside the containment and service building.

A special breathing air tank refill system would be available in the service building. It would be equipped with air purifying filters downstream of the compressor to remove impurities such as oil, carbon monoxide and dioxide and any hydrocarbon vapors.

#### 4.2.5.2 Containment Breathing Air Tank Refill System

4.2.5.2.1 The purpose of this system is to provide a means for refilling the pressurized breathing air tanks carried in backpacks by the decontamination team members and those that are an integral part of the life support breathing air tank carts as discussed in Section 4.2.5.1, above.

#### 4.2.5.2.2 Design Criteria

- a. The containment breathing air tank refill system should have sufficient capacity to refill each of the 300 SCF breathing air tanks to its filled capacity at 2000 psi in no more than 3 minutes time.
- b. The system shall be capable of supplying Grade E breathing air as defined in the Compressed Gas Association (CGA) "Commodity Specification for Air", G-7-1 - 1966.
- c. The system shall provide a breathing air tank refill station inside containment on floor elevation 305'-0" to recharge the air tanks on carts and a separate refill station in the containment service building to recharge backpack air tanks.
- d. The system shall be designed to satisfy the requirements of the following standards and regulations:
  - NRC Regulatory Guide 8.15 - Acceptable Programs for Respiratory Protection.
  - NRC Manual of Respiratory Protection Against Airborne Radioactive Materials, NUREG-0041, FINAL

#### 4.2.5.2.3 Conceptual System Description

A complete breathing air refill packaged unit including a high pressure storage reservoir, designed and manufactured to the above design criteria, should be provided as the heart of this system. This packaged unit should be located in the containment service building as shown on Figure 4-9, and draw outside air from a radioactive-free area to avoid contaminating the refill breathing air with radioactivity.

The breathing air discharge piping from the packaged unit to the tank refill stations shall be stainless steel rated at 2500 psi. The refill line shall enter the containment through an existing spare penetration or a temporary penetration in the existing personnel door on the north side of the equipment hatch shield structure. The refill stations should be equipped with a needle valve, pressure gauges on both sides of the needle valve, and a high pressure stainless steel sheathed and reinforced flexible hose rated for 2500 psi and fitted with a threaded connector compatible with the threaded connection on the breathing air tanks discussed in Section 4.2.5.1, above.

#### 4.2.5.2.4 System Operation

Exhausted breathing air tanks mounted on carts should be refilled at the proposed refill station inside containment to eliminate the need for decontaminating and taking contaminated carts outside the containment. Since the decontamination team members will be wearing backpack air tanks when entering and leaving the containment, the backpack air tanks should be recharged at the proposed air tank refill station in the containment service building.

When refilling depleted air tanks at the refill stations, the needle valve should be cracked open slightly and the air stream directed onto the exposed air tank connector momentarily to disperse any loose radioactive particles settled there. The needle valve should then be closed tightly before the hose connection is securely mated to the air tank connector. Caution should be exercised to ensure that the valve on the air tank and the refill station needle valve are always tightly closed before disengaging the hose connection from the air tank connector.

#### 4.2.6 Containment Television System

##### 4.2.6.1 Purpose

Since direct visual monitoring of personnel on the cleanup and decontamination team in the containment will not be possible, some remote means of visually monitoring their activities is required to ensure their well being and quickly render assistance in the event of a personnel safety emergency.

The purpose of the containment television system is twofold, namely:

- a. To remotely monitor cleanup and decontamination operations in progress in the containment radioactive environment, and

- b. To record the cleanup and decontamination activities on magnetic tape for future reference and to be used as a personnel training aid.

4.2.6.2

## Design Criteria

The containment television system should be designed to satisfy the following requirements:

4.2.6.2.1  
ing:

## Camera Unit (including mount, stand and supplemental lighting:

- a. Each assembled camera, mount and stand unit shall consist of components sturdy enough to prevent noticeable vibration while in service. The assembled unit shall also be sufficiently compact and light weight to permit easy lifting and moving by two decontamination team members.
- b. The camera mount shall be motorized and designed to permit 270 degree panning movement in a horizontal plane and 135 degree tilting movement in a vertical plane.
- c. The camera shall be capable of collecting and transmitting recognizable images in minimum light conditions. In some cases, it may be necessary to employ supplemental lamps to highlight areas shielded from direct lighting, especially where dark shadows may exist. Supplemental lamps shall be portable, free-standing units sufficiently lightweight to permit easy lifting and moving by two decontamination team members.
- d. The camera shall be compatible with motorized zoom lenses that will permit remotely changing the lense focal length.

4.2.6.2.2

## Video Monitor and Control Unit

- a. Each video monitor and control unit shall be equipped with at least four viewing screens and associated controls to permit simultaneous monitoring of activities being observed by four separate cameras. In addition, the control unit shall be capable of selecting and projecting the video output from other cameras on the video monitor screens.
- b. The control unit shall be provided with controls capable of selecting and remotely operating the motorized mount on each camera unit so that the camera can be panned and tilted through the designated arcs. The control unit shall be capable

of accepting controls to select and remotely operate the motorized zoom lenses on all cameras so equipped.

- c. Communication between the video control unit operator in the communications center and members of the decontamination team inside containment is covered in Section 4.2.12, Containment Communications System.
- d. The video monitor and control unit shall be capable of selecting and conveying both the video and associated audio signals to a conventional video and sound cassette recorder.

#### 4.2.6.2 Conceptual System Description

To ensure system availability and keep system downtime to an absolute minimum, the intent is to utilize conventional proven components and to make the total system as simple and uncomplicated as possible. With this in mind, Figure 4-10 schematically illustrates a typical television monitoring system. This type of system has been successfully used to monitor radioactive decontamination operations in a number of installations throughout the country including the recent activities in the auxiliary building at Three Mile Island Unit 2.

The video display and control unit includes four individual television screens to display the activities being viewed by four different cameras. The control unit has the capability to receive one to four separate video and communication signals from any of ten selected substations (total video signal input capability is 40 separate channels). A ten push-button substation selector permits displaying the video output signal from 40 different cameras. A local four channel video display monitor may be employed at each of the ten substations. The cable length between the main video display/control unit and any substation monitor is limited to 300 feet maximum.

The camera power supply unit is placed in a location so that no more than 500 feet of coaxial cable is run between the camera, power supply unit, and main video display/control unit. Each of the coaxial cables are provided with multiple-pin connectors for ease of installation. Cables are routed through temporary penetrations provided at the containment access control point or through nearby spare containment penetrations sealed with an impermeable mastic material.

The video display and control unit is provided with output signal jacks to permit connecting patch cords to other receivers, including remotely located auxiliary monitors, video and audio cassette recorders, etc.



For the radiation decontamination operations, a standard video camera, i.e., Sony Model AVC-1400 or equal, should give satisfactory results based on successful past experience in similar service. Expensive radiation hardened underwater cameras are normally employed only in extremely high radiation applications, or when water shielding is employed.

The newest standard video cameras are designed to give satisfactory results even under poorly illuminated conditions. Should supplemental lighting be required, portable free-standing 600 watt or 650 watt quartz iodide lamps are recommended, i.e., Omni Light System Model 01-10 by Lowel Light Mfg. Co., New York, or equal. Barndoor fixtures are also available for mounting on the lamps to further concentrate and direct the light beam on a desired area, i.e., Omni Light System Model 01-20 or equal.

All electrically operated components are powered from a standard 110 VAC power supply. A conventional telescopic type photographic tripod should serve as an adequate portable, free-standing camera stand.

4.2.6.4 A central monitoring station, i.e., communication center in the control building area, should be set up in a radioactivity-free location from which all cleanup and decontamination operations can be monitored. Visual monitoring should be accompanied by associated audio communication at the main video display and control unit in this central monitoring station.

It is intended that the portable camera units and any supplemental lamps be moved from one area to another as each is decontaminated. As more areas are involved, additional camera units and associated video channels can be utilized to monitor the activities.

As the work progresses, it is expected that a large number of decontamination workers will require training to replace those that reach their limits of radiation exposure. It may be advantageous to make video and audio cassette recordings of the early decontamination operations and utilize them as a training aid for preparing future decontamination team members.

#### 4.2.7 Containment Vacuum System

##### 4.2.7.1 Purpose

The containment vacuum system will provide a means to pick up loose, wet, and dry material that cannot be manually picked or swept up during the initial cleanup operations.

##### 4.2.7.2 Design Criteria

The vacuum system and operations should be kept as simple and uncomplicated as possible to minimize personnel exposure times. To permit the greatest system flexibility and easy access into tight areas, the system components should satisfy the following design requirements:

- a. Each vacuum cleaner should be an individual, compact, integral unit mounted on wheels or rollers for mobility. It should be capable of easy handling and maneuvering by a single decontamination team member and able to reach a material pickup point 10 feet from the operator in any direction.
- b. The vacuum cleaner should be capable of picking up both wet and dry material, and free-standing liquids. It should be designed with the capability to collect dry vacuumed-up materials in a sealable disposable container.
- c. The vacuum cleaner should employ a filtered exhaust directed upward away from the area being cleaned to avoid any unnecessary dispersion of material to be picked up. The exhaust filter should be readily replaceable, disposable, cartridge type filter.
- d. The units should be powered by electric motors and listed with Underwriters Laboratories.

#### 4.2.7.3

#### Conceptual System Description

The containment vacuum system shall consist of multiple, individual, integral, tank type industrial vacuum cleaners plugged into a common 110 VAC power supply. A typical unit satisfying the design requirements above is illustrated in the sketch, Figure 4-11. Sears Roebuck & Company, Craftsman Home-N-Shop vacuum cleaners have proven to work very well in radioactive material cleanup operations at other installations throughout the U.S. Either the Craftsman Model 1787 (16 gallon tank size measuring 28-1/4 inches high and 22 inches in diameter and weighing approximately 35 pounds) or the Craftsman Model 1793 (32 gallon tank size measuring 34-3.8 inches high and 26-1/4 inches in diameter and weighing approximately 37 pounds), should perform satisfactorily in this service. Laboratory tests performed by Sears revealed that these units are capable of picking up an average of 1600 (5.9 pounds) of 7/8 inch roofing nails in 15 seconds, one-half bushel of fine, dry sawdust in an average of 6.8 seconds, an average of 44 pounds of gravel (3/8 inch average diameter), in 30 seconds, or one gallon of free-standing water in less than one second. The electric motor and vacuum fan assembly, including the vacuum suction and exhaust ports, is an integral part of the removable cover on the debris tank.

Figure 4-11 also illustrates how a plastic bag in conjunction with a disposable weight in the bottom (in the form of a hollow plastic ring) can be used to line the debris tank to catch dry vacuumed-up material, and how the plastic liner can be sealed and removed for disposal of the radioactive debris and exhaust filter cartridges. Should the vacuum cleaner be used to pick up mainly free-standing liquids, a side-mounted drain plug will facilitate emptying the unlined tank into the containment

sump by gravity flow via garden hoses and floor drain piping. Polypropylene plastic (non-porous material) construction should simplify cleaning up and decontaminating the tank to minimize personnel exposure due to residual radioactivity on the tank interior surfaces.

#### 4.2.7.4 System Operation

The vacuum cleaners are hand carried into the containment through the equipment hatch access opening by the decontamination team members. Once the units have been used inside the containment, they are left there until all vacuuming operations are completed and they are no longer needed. At the end of their usefulness, contaminated vacuum cleaners and all associated accessories should be disposed of as radioactive solid waste.

The replacing of exhaust filter cartridges, removing and sealing of plastic liner bags, and any required decontaminating of vacuum cleaner parts shall be performed inside the containment to avoid spreading radioactive contamination to areas outside the containment.

#### 4.2.8 Containment Decontamination Steam Supply System

##### 4.2.8.1 Purpose

- a. Provide saturated steam to the general containment interior for the remote decontamination operations.
- b. Provide saturated steam to local areas inside containment for manual hands-on decontamination operations.

##### 4.2.8.2 Design Criteria

- a. Supply steam for remote decontamination
  - Steam shall be supplied by a means and at a flow rate sufficient to cause a complete coating of the surfaces inside containment with condensation.
  - Wet saturated steam shall be provided to facilitate the condensing and rinsing action discussed in Section 5.0.
- b. Steam supply for hands-on decontamination
  - The system shall have the versatility to supply wet steam to any area inside containment where steam is to be used for hands-on decontamination as discussed in Section 9.3.

- The system shall have the capability of supplying wet 220° F - 250° F steam in a form that completely wets the contaminated surface at which it is directed.
- The system shall be designed so that the application of steam to a local contaminated area requires no more than one decontamination team member's attention and efforts.
- The system shall provide for the adding of detergents and/or other cleaning agents to the steam before it is applied to the contaminated area.

#### 4.2.8.3 Conceptual System Description

##### 4.2.8.3.1 Steam Supply for Remote Decontamination

Steam should be introduced into the containment through the existing containment spray system nozzles. A 3-inch flanged test connection is readily accessible to the "B Loop" spray headers at the intersection of column lines AA and A62 above floor elevation 280'-6" in the auxiliary building. Since piping carrying saturated steam to the existing reactor coolant evaporator (WDL-Z-1) heater bundle is routed in the same general area, new piping should be connected to the evaporator 8 inch steam supply line downstream of existing desuperheater AS-1143 and routed to the 3-inch flanged test connection on the "B Loop" spray headers. This new piping is shown schematically in Figure 4-5.

In the event the containment spray system cannot be used, an alternate (although less effective) means of introducing steam into containment for the remote decontamination operations is shown in Figure 4-5. It involves routing a line from the existing evaporator 8 inch steam supply line through the stairwells up two floors to the containment ILRT test connection at valve AH-V7.

##### 4.2.8.3.2 Steam Supply for Hands-on Decontamination

Due to the diversity and separation of the various areas that may require local steam decontamination, steam for the hands-on decontamination effort should be generated and supplied by portable, mobile, self-contained steam generating units that can be easily wheeled from one area to another, such as those manufactured by Malsbary - Carlisle Co., No. Uniontown, Pennsylvania. Such "steam jennies" have been successfully used in radioactive decontamination operations at various installations throughout the country, including a SNAP reactor test facility. They are mounted on wheels, weigh approximately 1,000 pounds and are completely self-contained requiring external connections to only a power supply and clean water source. These units are equipped with flexible steam hoses and long handles that extend the steam lance nozzle so that up to 300 psi steam can be sprayed on

surfaces some 10 to 15 feet away from the operator. Additional lengths of flexible steam hose will permit the operator to move some 50 feet from the "steam jenny". A container is provided in the "steam jenny" to receive liquid detergents or other cleaning agents to be mixed with the steam and sprayed from the steam lance nozzle.

#### 4.2.8.4 System Operation

4.2.8.4.1 Operation of the system proposed for introducing steam into the containment for remote steam decontamination is discussed in detail in Section 5.0.

4.2.8.4.2 The proposed "steam jenny" can be easily moved and operated by a single decontamination team member. The containment temporary power system discussed in Section 4.2.4 can provide the electrical power and the containment decontamination water supply system discussed in Section 4.2.10 can provide demineralized water through hose connections to the "steam jennies".

#### 4.2.9 Containment Chemical Supply System

##### 4.2.9.1 Purpose

- a. Provide a system that will permit mixing the correct proportions of chemical cleaning agents or detergents with water, and will deliver the desired cleaning solution when:
  - Washing the containment down using the containment spray nozzles during remote decontamination operations.
  - Washing the containment interior surfaces, including the dome, wall, structural steel and equipment surfaces, with the fire protection system hoses during early hands-on decontamination operations.
  - Washing local contaminated areas during hands-on decontamination operations.

##### 4.2.9.2 Design Criteria

- a. The containment chemical supply system shall be capable of mixing chemical cleaning agents or detergents in the correct proportions to achieve desired solution concentrations.

- b. The system shall be designed to deliver the required concentration of chemical or detergent cleaning solutions to the containment spray pumps to achieve remote containment decontamination as discussed in Section 5.0.
- c. The system shall have the capability of delivering the required concentration of chemical or detergent cleaning solutions to the fire protection and demineralized water systems piping inside containment to permit washing down the containment interior surfaces with hoses as discussed in Section 9.8.
- d. The system shall be designed to deliver the required concentration of chemical or detergent cleaning solutions to chemical supply stations inside containment on floor elevations 282'-6" and 305'-0" where individual decontaminating carts used for local decontaminating operations can be refilled.

#### 4.2.9.3

#### Conceptual System Description

To achieve the capability of mixing dry powder or granular chemical agents and detergents in water, a chemical mixing tank equipped with an electric mixer and heater should be provided. The tank capacity should be approximately 500 gallons, small enough in size and height to permit easy access to a 24 inch hinge covered opening on top of the tank for adding dry material packaged in cartons, sacks or drums. The tank should have a funnel bottom to facilitate complete draining of the mixed contents.

To provide for further mixing by recirculation, representative sampling, and pumping to other tanks for storage in preparation of decontamination operations, a small chemical mix pump should be provided under the chemical mix tank. Since the existing sodium thiosulfate and sodium hydroxide storage tanks are available for storing batches of the mixed cleaning solutions, locating the proposed chemical mixing tank and pump adjacent to these tanks would facilitate generating the required volumes of cleaning solutions. Figure 4-13 is a flow diagram of the system showing how the components can be interconnected to achieve mixing, recirculation and storage capabilities.

For the chemical and detergent remote decontamination operations discussed in Section 5.0, a positive displacement metering pump and direct bypass gravity-feed line should be connected to one of the existing 4 inch capped drain connections on the sodium thiosulfate tank as illustrated in Figure 4-5. This arrangement would permit delivering the desired cleaning solution to the containment spray headers by either of the following means:

- a. Pumping the required amount of concentrated chemical cleaning agent or liquid detergent into the water flowing through the containment spray pump suction header, or
- b. Adjusting the bypass valve to allow the desired quantity of premixed chemical cleaning agent or detergent solution to be drawn into the containment spray pump suction stream.

To provide chemical cleaning or detergent solutions for the containment interior surface decontaminating operations discussed in Section 9.8, a line from one of the existing 4 inch capped drain connections on the sodium thiosulfate tank should be connected to the proposed water supply pumps as illustrated in Figures 4-13 and 4-14. This will permit pumping the desired premixed cleaning solution directly into the containment through existing fire protection or demineralized water systems piping.

Chemical and detergent solutions for the local hands-on decontamination operations can be stored in the sodium thiosulfate storage tank. Piping from this tank and the proposed chemical mix pump will permit filling decontaminating carts at the proposed chemical supply stations inside containment. The main chemical supply line should enter the containment through an existing spare penetration or a temporary penetration in the existing personnel door on the north side of the equipment hatch shield structure. A branch line connected to the sodium thiosulfate tank flanged 2 inch connection should provide gravity flow under the influence of the tank static head. When the water level in the tank drops to a point that the static head no longer overcomes the piping losses to the chemical supply station on the 305'-0" floor elevation, another branch line from the discharge of the proposed chemical mix pump can be provided to supply the cleaning solution to the chemical supply stations while recirculation pumping through the tank. Figure 4-13 shows the piping interconnections involved in this proposed design.

#### 4.2.9.4

#### System Operation

Dry chemical cleaning agents and detergents in powder or granular form should be premixed with water in the proposed chemical mix tank to the desired concentration. Liquid cleaning chemicals and detergents can be pumped directly into either the sodium thiosulfate or sodium hydroxide storage tank through one of the existing capped or flanged connections and mixed with water added to the tank. Thorough mixing to the desired concentration can be achieved by recirculation pumping through the tank using the proposed chemical mix pump. A grab-sample connection should be provided at the pump discharge. The piping interconnections shown on Figure 4-13 provide great flexibility for recirculating through the existing and proposed tanks and for pumping from one to another.

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A detailed discussion of the system operation as it relates to remote containment decontamination using the sodium thiosulfate storage tank as a source of chemical or detergent cleaning solution for the containment spray system is covered in Section 5.0.

In anticipation of the containment interior surface decontaminating operations discussed in Section 9.8, a complete batch of the desired concentrated cleaning solution can be premixed and stored in either or both the sodium thiosulfate and sodium hydroxide storage tanks. Contents in the sodium hydroxide tank can be transferred to the sodium thiosulfate tank using the proposed chemical mix pump. One of the two proposed redundant water supply pumps shown on Figure 4-14 should be lined up to take suction on the sodium thiosulfate tank and deliver the cleaning solution into the containment.

Again, as for the containment interior surfaces decontaminating operations, the same cleaning solution premixing and storing provisions are available for the local hands-on decontaminating operations. When using the proposed chemical supply stations and the tank level is too low for gravity flow, the cleaning solution should be recirculated through the storage tank on which the pump is taking suction so that the operator at the chemical supply station can start and stop the refilling process by merely opening and closing the valve inside containment.

Since the remote containment decontamination, interior surface decontamination, and local hands-on decontamination operations are sequential and do not occur simultaneously, the same premixing and storage facilities can be used for the cleaning solutions used in each of the operations. Flushing of the proposed and existing tanks is afforded by the water supply lines connected to each tank and the discharge to waste connection provided at the proposed chemical mix pump discharge.

#### 4.2.10

##### Containment Decontamination Water Supply and Recycle System

#### 4.2.10.1

##### Purpose

- a. Provide sufficient tankage to accommodate all the supply water storage requirements for the containment decontamination operations.
- b. Provide a means to deliver water into containment for interior surface washdown using fire hoses and to accommodate supply water needs for local hands-on decontamination operations.
- c. Provide for recycling portions of the supply water inventory to and from the radwaste processing system and for conveying tankage to disposal.



4.2.10.2

## Design Criteria

- a. The quantity and capacity of water supply storage tanks shall accommodate the entire water contents presently existing and expected to accumulate in the bottom of the containment by the time it is drained to the radwaste processing system. The quantity of tanks shall provide for reasonable operating flexibility with respect to sequentially providing recycled tritiated water and clean demineralized water for the remote decontamination operations.
- b. System materials shall be compatible with demineralized water, adding no appreciable quantity of corrosion products to the water inventory.
- c. The system water supply pumps shall have sufficient capacity to operate all six fire station hoses inside containment simultaneously. The pump discharge head shall be sufficient to force water through the fire hose nozzle on the elevation 367'-4" platform and eject it to the top of the containment dome exerting a water pressure of at least 3 psi on the liner plate. Two full redundant pumps shall be provided to permit continual system operations while performing maintenance on one pump.
- d. The water supply storage tanks and system piping shall have provisions to permit independent recycling of one tank's contents while simultaneously pumping another tank's contents into the containment.
- e. Piping connections shall be provided in the system to accommodate the following additional operations:
  - Recycle the system water inventory through the radwaste processing system.
  - Transfer the contents of any one storage tank to any other tank.
  - Supply water to the proposed chemical mix tank, DS-T1.
  - Reject system water inventory to clean water disposal.
  - Reject system water inventory to tritiated water disposal.

- Receive cleaning solutions consisting of detergents or chemical cleaning agents mixed in water for delivery to the containment fire hose stations.
- Receive demineralized water from the plant demineralized water storage tank and route it to any of the water supply tanks, directly to the containment spray headers or or directly to the existing containment fire hose stations and demineralized water supply connections.

#### 4.2.10.3

#### Conceptual System Description

Since the existing water contents in the bottom of the containment is estimated to be between 600,000 and 700,000 gallons, three of the four proposed storage tanks would accommodate this inventory after it is processed through the radwaste processing system. The proposed fourth identical tank would accommodate the additional 200,000 to 250,000 gallons of water which could accumulate in the containment before the sump is drained.

An economic evaluation between stainless steel and coated carbon steel should be made to determine the optimum system material selection for clean demineralized water/recycled tritiated water service.

Based on the above design criteria, the water supply pumps have been tentatively sized to pump 600 gpm at a total dynamic head of 400 feet. The redundant pumps are connected in parallel to satisfy the simultaneous continual system operation and pump maintenance criteria. A separate recycle pump tentatively sized to pump 100 gpm at a total dynamic head of 100 feet is provided to satisfy the criteria defined in Section 4.2.10.2.

Figure 4-14 is a flow diagram of the proposed system showing piping interconnections to satisfy the above criteria and giving tentative line sizes.

Figure 4-15 shows a possible arrangement of the proposed four 35 foot diameter by 35 foot tall storage tanks and the proposed three system pumps mounted on a curbed concrete pad. Connections to the existing 4" fire water supply and 3" demineralized water supply lines shown in Figure 4-14 can both be made in the same elevation 305'-0" auxiliary building area between column lines AB/AD and A62/A64. A proposed routing of the 4 inch pump discharge line to these connection points could be along the east-west corridor through the center of the control and service building and then north through the "soiled corridor" into the auxiliary building and to the above designated area.

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#### 4.2.10.4 System Operation

The intent is to store recycled tritiated water in the water supply storage tanks as it is pumped from the radwaste processing system for future use in remote decontamination operations as discussed in Section 5.0. Each tank should be filled to capacity to limit the number of tanks used for radioactively contaminated water and the remaining tanks reserved for clean demineralized water for hands-on decontamination operations as discussed in Section 9.0.

Although the system has the capability and operational flexibility to supply water storage tank inventory to the containment for either remote or hands-on decontamination and simultaneously either recycle directly or through the radwaste processing system from another tank to a third tank, caution should be exercised to ensure proper valve line up to avoid inadvertent mixing of tritiated and non-tritiated water.

A grab sample point downstream of the recycle pump should be used to obtain samples while recirculating tank contents.

As a result of making the proposed water supply pump discharge line connection to the existing 3 inch demineralized water line, the existing 4 inch valve DW-V262 should be closed to prevent water from this proposed system flowing throughout the existing demineralized water system. This valve is located 4'-6" above floor elevation 305'-0" near the intersection of column lines AN and A62 in the auxiliary building. Closing this valve will limit the flowing of this proposed system inventory into only that portion of the existing demineralized water system downstream of DWV262 as shown on Burns & Roe Drawing 2007, Sheet 2.

Likewise, with respect to the proposed water supply pump discharge line connection to the existing 4 inch fire water system supply line, the existing 4 inch valve FS-V651 should be closed to prevent water from this proposed system flowing beyond the existing 4 inch containment fire water supply header into the main 12 inch fire water system supply header. The FS-V651 valve is located about 11 feet above the top of the partial horizontal slab at elevation 289'-0" between column lines AB/AD and A63/A64 in the auxiliary building.

#### 4.2.11 Equipment Decontamination Provisions in Containment Service Building

##### 4.2.11.1 Purpose

- a. Establish an area outside the containment where decontamination of equipment removed from the containment can be carried out under controlled conditions to prevent the spreading and uncontrolled release of radioactivity to the environment.
- b. Provide facilities and services in the designated area to carry out the required equipment decontamination operations.

4.2.11.2

## Design Criteria

- a. The area designated for decontamination of equipment shall be located within the containment service building and provided with means to minimize the spreading of radioactivity beyond its boundaries.
- b. The area shall be designated to collect and drain off the cleaning solutions used to decontaminate the equipment and shall be readily decontaminable itself after removal of the decontaminated equipment to minimize radiation exposure to personnel.
- c. A means to collect and remove radioactive and toxic gases and vapors that may be given off during the decontamination operations should be provided.
- d. Services to be provided in the area for the decontamination operations include 110 volts A.C. electrical power receptacles, demineralized water supply hose connections, a means to spray wet steam, and a means to spray water with and without detergents or other chemical cleaning agents.

4.2.11.3

## Conceptual Description and Operating Considerations

The area designated for equipment decontamination could be located in the northern half of the containment service area. The proposed designated area is shown in Figure 4-1, Containment Service Building plan. Moveable shower type curtains supported on floor stands should be provided to surround the equipment to be decontaminated.

A flat stainless steel liner should be provided on the floor in the designated area which should be depressed by 6 inches below the floor elevation in the southern portion of the building to prevent water spillage outside the decontamination area. It should slope toward floor drains which will gravity drain to a covered sump in the northeast corner of the designated area. A sump pump can pump the drains to the rad-waste processing system. The floor and liner in the designated area should have no vertical protrusions to make possible the handling and moving of equipment to be decontaminated by fork-lift trucks and other load-carrying vehicles.

A moveable exhaust hood should be installed over the designated area to collect and convey any radioactive and toxic gases and vapors to the containment service building ventilation exhaust plenum.

The 110 VAC power receptacles proposed for the area will provide electrical power to operate portable steam spraying units such as the "steam jenny" discussed in Section 4.2.8, portable water/chemical spraying units and mechanical decontaminating devices discussed in Section 9.3. The demineralized water hose connections will provide water for the "steam jenny", the portable water/chemical spraying units, and for general flushing and rinsing operations.

#### 4.2.12                    Containment Communications System

##### 4.2.12.1                Purpose

The purpose of the containment communications system is to provide audio communication between a central monitoring location and members of the cleanup and decontamination team in the containment. This system will serve to supplement the visual monitoring capability provided by the television system covered in Section 4.2.6.

##### 4.2.12.2                Design Criteria

The containment communication system should be designed to satisfy the following requirements:

- a. The system should be a two-way voice communication system. The system should be compatible with the television system covered in Section 4.2.6 so that the audio signal from this system can be combined with the corresponding video signal from the television system. The system should be capable of allowing any of the decontamination team members to verbally communicate with the central control unit operation at will.
- b. The central control unit should be equipped with at least one integral earphone and microphone headset in addition to a speaker. The central control unit operator should have the capability to verbally contact any of the decontamination team members at will.
- c. The audio receiver/transmitter unit worn by the decontamination team members should be self-contained and compact to permit free, unrestricted movement. The headset worn by the decontamination team members should be an integral earphone and microphone unit compatible with anti-contamination headaddress and air masks. The microphone worn by the decontamination team members should be voice actuated or actuated by a means which does not involve the deliberate use of their hands.

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#### 4.2.12.3 Conceptual System Description

Since the communication system is to be used integrally with the television system to closely monitor personnel activities inside containment, this system should also be as simple and uncomplicated as possible, utilizing conventional proven components, to ensure system availability and keep the system downtime to an absolute minimum. Many different type communication systems are available. For this service, a completely untethered battery operated radio system has been proven to afford the greatest flexibility and freedom of movement, especially when movement throughout a large area including a number of different floor elevations is involved.

For this application, a single frequency radio communication system such as the General Electric UHF Personnel Radio System, or equal, should give satisfactory service. This system is a simplex system which transmits and receives on the same frequency. Since they are all tuned to the same frequency, any one individual may talk and all others will hear his conversation. The central control unit available as a desk console should be located near the video display and control unit in the communication center. Also, it is provided with a speaker and a mobile microphone with the capability to use a headset. This unit is operated by a rechargeable nickel-cadmium battery and has its own 110 VAC powered recharger.

A single coaxial cable routed through a spare containment penetration or temporary penetration provided at the containment access control point carries the signal between the central control unit and a LOSSI line type antennae located inside containment. Figure 4-17 illustrates a typical communication system arrangement.

Each decontamination team member carries a 25 ounce radio pack on his belt which is cable connected to the earphone/microphone headset. The radio pack includes a 700 milliampere-hour rechargeable battery good for 8 hours of continuous service. A recharging unit capable of charging multiple batteries simultaneously is provided with the system.

In similar applications, voice-actuated microphones proved to be too sensitive for this service, and therefore, either a balanced-pressure type microphone or pressure tape actuators fastened to the thighs and elbows should be used in conjunction with the headset microphones. The balanced-pressure type microphones, which actuate on voice levels above background noise, are favored since they involve no deliberate action by the operator.

#### 4.2.12.4 System Operation

Voice communication with the decontamination team members in containment should originate from the communication center, and be integrated with the visual monitoring of their activities using the television system as discussed in Section 4.2.6.

As the containment is decontaminated to a point that the paging system can be checked out for serviceability, it is possible that it can also be used, if still operational, to get the attention of any of the decontamination team members inside containment or to sound a general evacuation alarm. Also, the existing maintenance telephone system inside containment may be put into service in certain instances if this system is or can be made operational. Earphone/microphone headsets can be plugged into telephone jacks provided at various equipment maintenance stations.

The existing page system in the containment should be disconnected from the plant page system and dedicated to decontamination operations.

#### 4.2.13 Containment Radiation and Radioactivity Monitoring Program

##### 4.2.13.1 Introduction

The containment radiation and radioactivity monitoring program shall include the fixed, mobile and portable equipment necessary to measure general area gamma radiation levels, airborne radioactivity, surface contamination levels, and neutron multiplication or rapid increases in gamma flux to warn of possible criticality.

##### 4.2.13.2 Purpose

The purpose of the containment radiation and radioactivity monitoring program is to warn of possible criticality, protect personnel inside the containment and monitor possible releases of radioactivity to the environment.

##### 4.2.13.3 Design Criteria

There is a need to detect a rapid approach to criticality that might possibly occur. Due to the possibility that the neutron source range type monitors can give spurious alarms from RF generated by electric tools and the possibility that there can be substantial changes in gamma radiation levels due to cleanup operations without any criticality problem, both neutron and gamma detectors should be used in coincidence, so that increases in both neutron and gamma detectors would have to occur simultaneously.

There is also a need to detect neutron multiplication and alarm if it becomes significant, independent of the gamma radiation in order to detect a slow approach to criticality with the ever-present high gamma radiation level expected to be roughly uniform in the reactor cavity.

Mobile airborne continuous radioactivity monitoring for particulate and iodine radioactivity will be required for all work locations. Whenever any of the NSSS piping systems are opened, noble gas monitoring will also be necessary. The particulate and iodine filter cartridges should be fixed filters so that they can be removed and isotopically analyzed in the laboratory.

Airborne particulate and iodine samples should be taken to verify the proper operation of the continuous monitors and to determine general area airborne radioactivity in the containment. These filters would be taken to the laboratory to be isotopically analyzed.

Gamma radiation surveys should be performed frequently during the hands-on decontamination process. Generally, portable high range meters with extension probes such as Teletectors should be used especially in the initial stages. The beta and gamma radiation levels should be measured before and after each decontamination step to determine gross DF's. Smear surveys should also be taken before and after each hands-on decontamination to verify the loose surface DF's.

Temporary area gamma radiation monitors should be installed in locations where considerable personnel traffic or extended stay times are expected.

#### 4.2.13.4 Monitor Locations

The neutron detectors both for the coincidence circuit for a rapid criticality and the multiplication circuit should be BF<sub>3</sub> tube proportional counters similar to the present source range excore detectors. At present, one of the original source range detectors has failed. Consideration is being given to rewiring the intermediate and/or power range ion chambers for use in the source range. However, these detectors may also fail soon since they have essentially reached the environmental qualification limit, so it is preferable that new detectors be installed.

The placing of these new detectors will be difficult however. The reactor cavity area can be expected to have an extremely high radiation level precluding personnel access. The neutron shield tank is installed above the annular gap between the reactor vessel and the primary shield. Therefore, the detectors cannot easily be inserted into the annulus from the missile shield/service platform. Unless holes can be made in the neutron shield tank very rapidly (to prevent overexposures) and the detectors inserted through the holes in the tank and into the cavity, the detectors will not be very sensitive and it might be necessary to rely on the continued operation of the present excore detectors with possible rewiring of the intermediate and power range detectors. Another possibility is to lay the detectors on the refueling canal floor immediately adjacent to the air gap around the bottom of the neutron shield tank.

The gamma radiation detectors should be ion chambers to provide wide range and no saturation by high fluxes.

The neutron multiplication counters, and the neutron and gamma coincidence detectors should be redundant and on opposite sides of the reactor if possible.



The mobile continuous airborne radioactivity monitors should be mounted on carts. They should be located in a relatively clean area immediately outside the tented area where work is being performed. Tygon tubing can be used as a sample line through the plastic tent to the work area. The length of the tubing should be minimized to reduce the effects of plateout. The wheels of the cart can be taped to minimize their contamination.

High volume particulate and iodine samples should be taken in the working areas to confirm airborne concentrations registered by the continuous monitors. Electrical outlets outside of the work area should be used since the electrical equipment in the area being sprayed will be deenergized. Care should be taken to ensure that the extension cords do not lie in pools of water on the floor.

Permanent general area gamma radiation survey points should be established so that sequential surveys can be readily compared. Hot spots should be added to the list of survey points as they are located since they will have the highest dose rates. These survey points should be located near the instrument racks, sump pumps, leakage transfer pumps, steam generator wet layup recirculation pump, chemical addition tank, reactor coolant drain pump, incore instrument service area, elevator, stairwells, reactor coolant pump seals, steam generator manways, and handholes, air coolers, reactor head studs, missile shield/service platform, pressurizer heaters, pressurizer relief and spray valves, and any other areas with high traffic or high maintenance that might have a high dose rate.

Smear surveys should concentrate on the floors in heavy traffic areas but should also cover walls, ceilings, equipment, and areas where radioactive liquid leakage is likely to collect or concentrate.

A block diagram of the radiation/radioactivity monitoring system is shown on Figure 4-18.

#### 4.2.14 Containment Service Building Heating and Ventilating System

##### 4.2.14.1 Purpose

The heating and ventilating system should provide the following functions for the proposed containment service building:

- a. Maintain a positive purge air flow through all potentially radioactive areas to minimize radiation exposure from airborne radioactivity and through areas which contain exposed toxic or inflammable cleaning agents to reduce their hazard.

- b. Control pressure of areas within the containment service building to avoid the uncontrolled release of radioactivity.
- c. Maintain acceptable temperature levels.

4.2.14.2

## Design Criteria

The containment service building heating and ventilating system should be designed to satisfy the following specific design requirements:

- a. Air flow to be from radioactive-free and relatively low radioactive areas to higher radioactive areas.
- b. Toxic fumes and inflammable vapors to be kept below hazardous levels and occupational limits.
- c. Higher radioactive areas to be maintained at a slightly negative pressure to prevent airborne radioactivity being released to radioactive-free areas.
- c. Ventilation cooling and heating to maintain occupied area temperatures within occupational limits.

4.2.14.3

The heating and ventilating system should provide fresh filtered and tempered ventilating air to the following areas within the containment service building complex:

- a. High level waste storage area.
- b. Containment decontamination staging area.
- c. Dry cleaning facility.
- d. Personnel change facility.

Supply air should be provided to each of these areas in sufficient quantity, resulting in at least two air changes per hour and to limit the temperature to a maximum of 5 degrees above ambient. During the winter season, the supply air should be heated as required to maintain the indoor temperatures at 70° F minimum.

4.2.14.4

Figure 4-20 is a block diagram of the proposed system forced and induced air paths to and from the various areas within the containment service building complex. This diagram also shows the expected air movements between the various areas by infiltration.

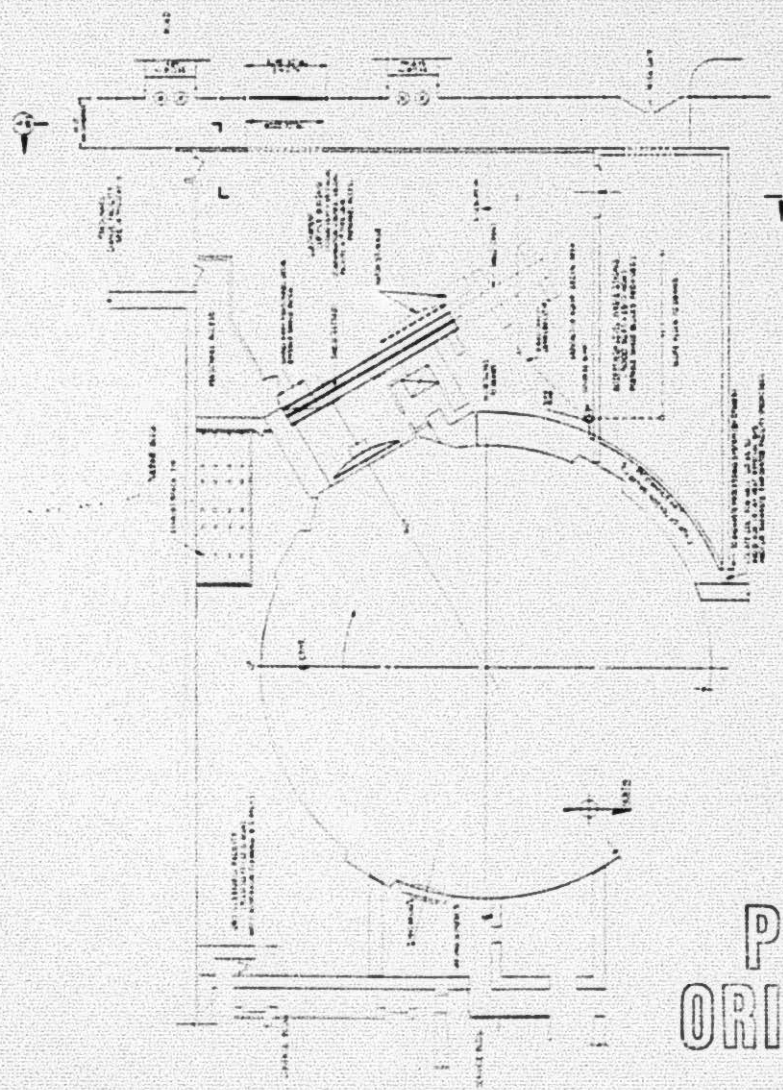
4.2.14.4        The system should provide a means for filtering the exhaust air before discharging it to the atmosphere so that radiation releases are maintained within allowable limits. It is expected that this can be achieved by utilizing the existing temporary filter banks and exhaust fans located on the auxiliary building roof and shown on Burns & Roe Flow Diagram Drawing M 016.

4.2.14.6        A moveable air exhaust hood should be provided in the equipment decontamination area to capture and remove radioactive gases and cleaning agent vapors that may be released during decontamination operations.

NOTE: ALL DIMENSIONS GIVEN IN THIS PLAN ARE IN FEET AND INCHES. ALL DIMENSIONS ARE TO FACE UNLESS OTHERWISE NOTED.

**TIA-2 INITIAL PLANNING STUDY**

<b>BECHTEL</b> BECHTEL CORPORATION 1700 BROADWAY OAKLAND, CALIF. 94612	
PROJECT: GREEN VALLEY WATER TREATMENT PLANT DRAWING NO.: TIA-2-001 SHEET NO.: 1 OF 1	
DATE: 10/15/77 DRAWN BY: J. J. [unreadable] CHECKED BY: [unreadable]	

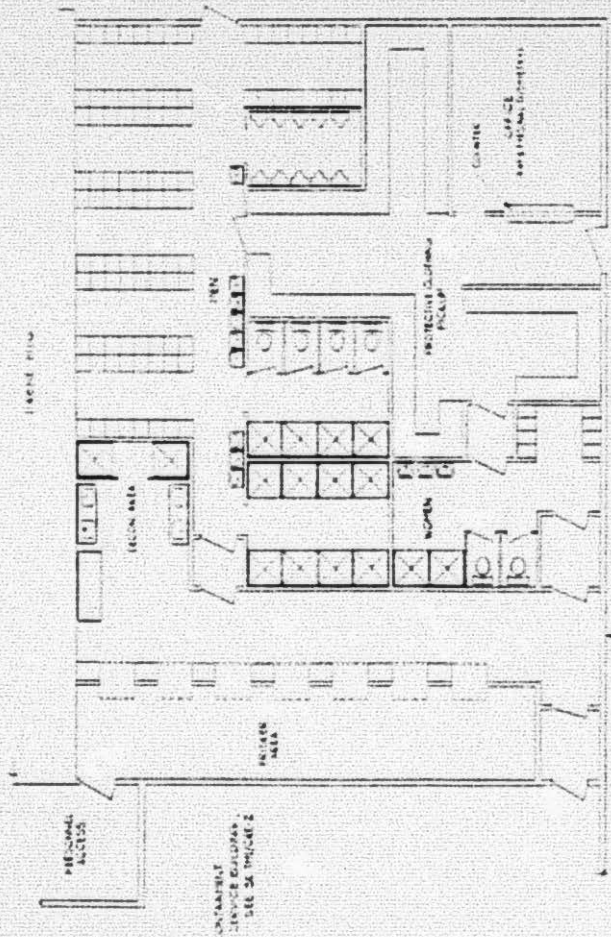


DATE: 10/15/77  
 DRAWN BY: J. J. [unreadable]  
 CHECKED BY: [unreadable]

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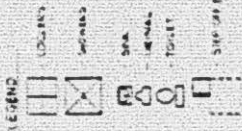


DDP



PLAN  
PERSONNEL ACCESS FACILITY & CONTROL ROOMS  
SCALE

SEE DRAWING FOR  
SCREENING AREA



TOP 2 INITIAL PLANNING STUDY

DATE	1/15/67
BY	W. J. H. / J. H. / J. H. / J. H.
PROJECT NO.	100-100-100-100-100
SCALE	1/4" = 1'-0"

**BECHTEL**  
CORPORATION  
3000 CENTRE EXPLORATION DRIVE  
SAN RAMON, CALIF. 94583

CONTAINMENT  
PERSONNEL ACCESS FACILITY  
FIG. 4-5

DATE	1/15/67
BY	W. J. H. / J. H. / J. H. / J. H.
PROJECT NO.	100-100-100-100-100
SCALE	1/4" = 1'-0"

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TR-2 INITIAL PLANNING STUDY

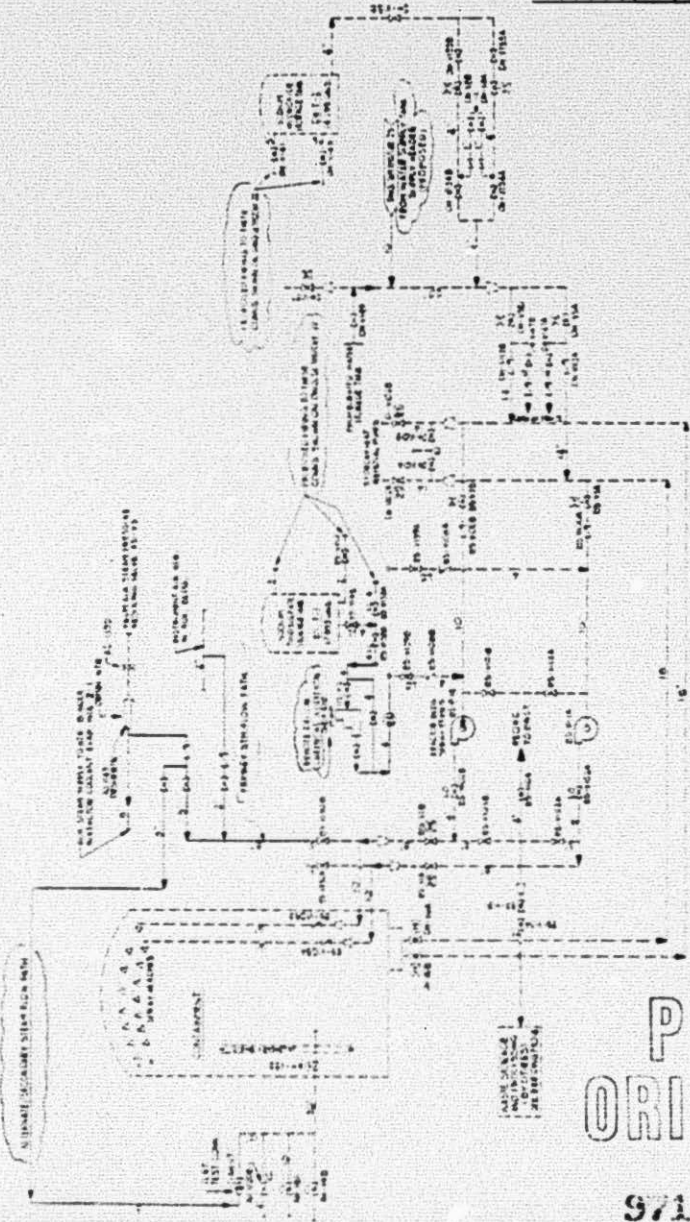
DATE	11/1/57
BY	W. J. ...
PROJECT NO.	...
SCALE	1" = 100'

BECHTEL

GENERAL PUBLIC UTILITIES CORP.  
 SAN FRANCISCO OFFICE  
 100 CALIFORNIA STREET  
 SAN FRANCISCO 4, CALIF.

FLOW DIAGRAM - CHINA POINT FERRITE SCAL  
 SPIN AND CHEMICAL UNIT SYSTEM  
 P.G. 4-5

PROJECT NO.	971235
DATE	11/1/57
BY	W. J. ...
SCALE	1" = 100'
PROJECT NO.	971235
DATE	11/1/57
BY	W. J. ...
SCALE	1" = 100'



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971235

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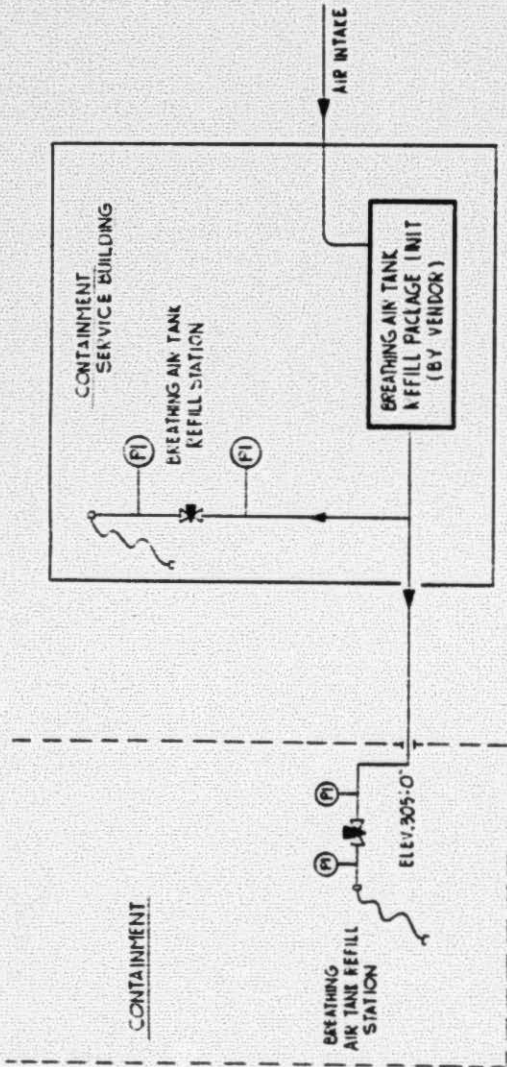


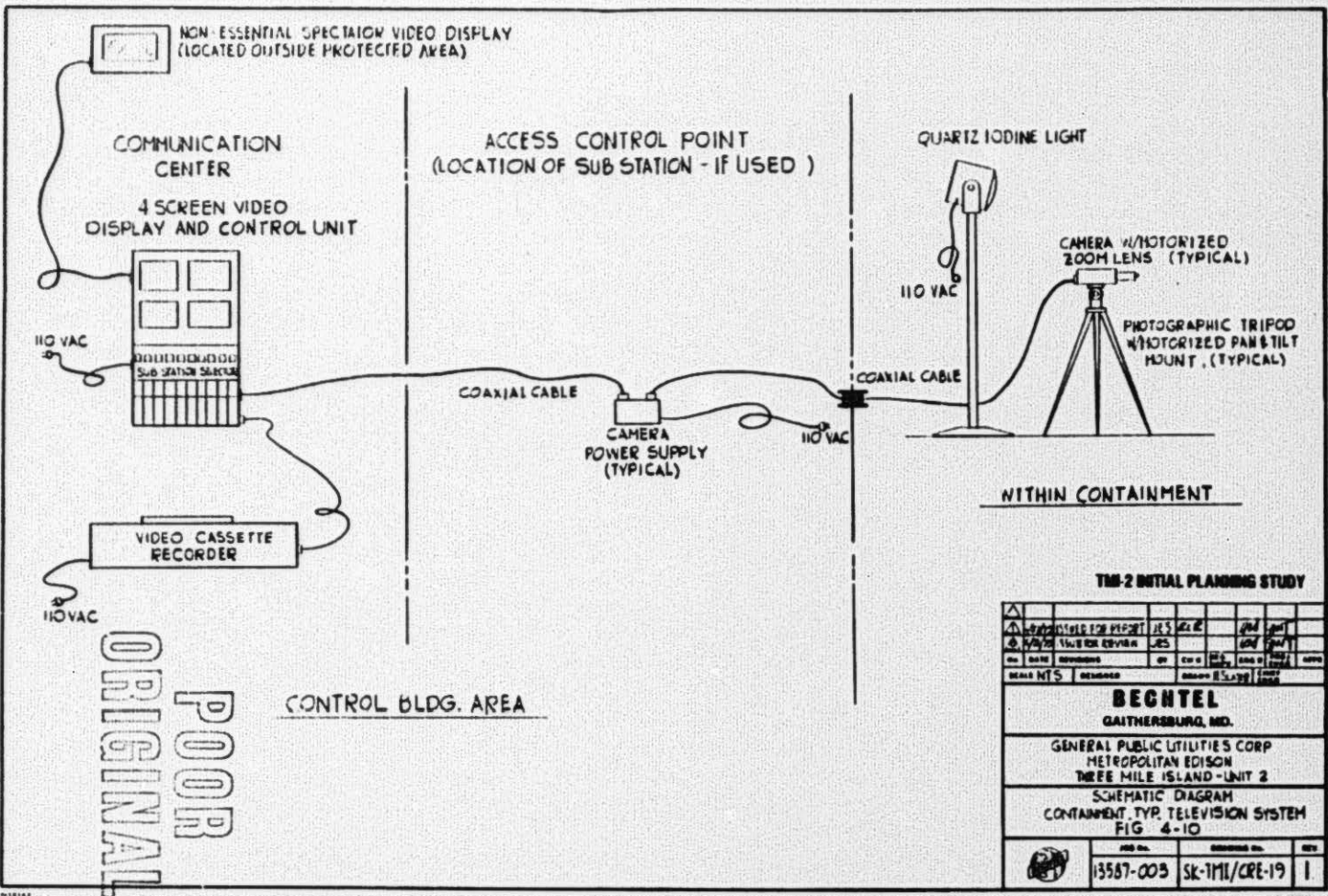
FIG. 2 INITIAL PLANNING STUDY

DATE	DESIGNED BY	REV.	BY	CHKD.
10/1/58	JES	01	JES	JES
BY	INCHES	BY	DATE	BY
JES	1/8"	JES	10/1/58	JES
SCALE	REVISIONS	DATE	BY	CHKD.
<b>BECHTEL</b>				
GAITHERSBURG, MD.				
GENERAL PUBLIC UTILITIES CORP.				
MITCHELLTAN EDISON				
TRIPP MILE ISLAND - UNIT 2				
FLOW DIAGRAM - CONTAINMENT				
BREATHING AIR TANK REFILL SYSTEM				
FIG. 4-9				
JOB No.		Submitted to		
13587-005		SK-1111/4E-10		
SHEET No.		REV.		
1		1		

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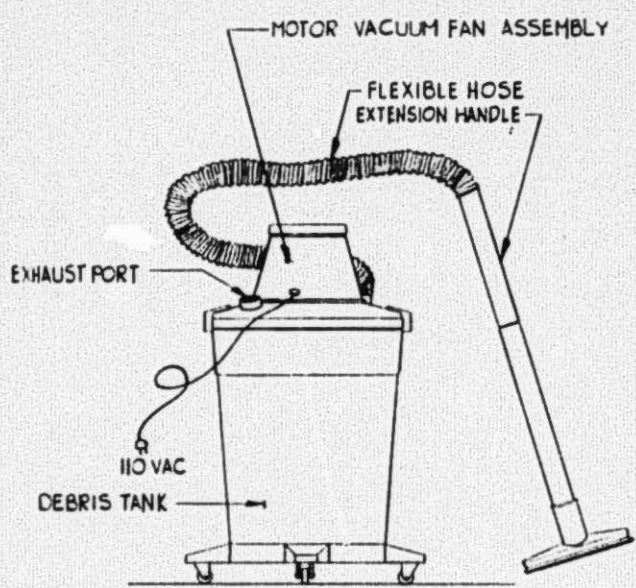
**TMI-2 INITIAL PLANNING STUDY**

NO.	DATE	REVISION	BY	CHK'D	APP'D	REV
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2						
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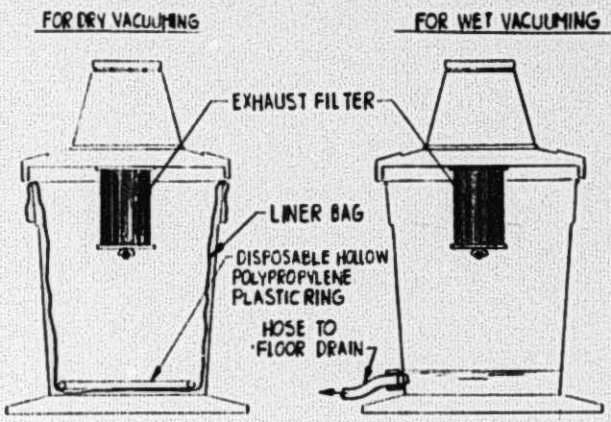
<b>BECHTEL</b>			
GAITHERSBURG, MD.			
GENERAL PUBLIC UTILITIES CORP METROPOLITAN EDISON THREE MILE ISLAND-UNIT 2			
SCHEMATIC DIAGRAM CONTAINMENT TVR TELEVISION SYSTEM FIG 4-10			
	JOB No. 13587-003	DRAWING No. SK-7M1/CRE-19	REV 1

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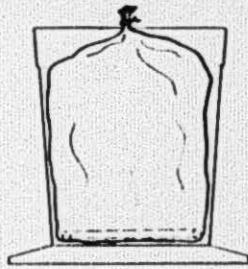


VACUUM CLEANER UNIT



CUT AWAY VIEW

CUT AWAY VIEW



CUT AWAY VIEW  
 SHOWING SEALED PLASTIC LINER BAG  
 AFTER TANK COVER HAS BEEN REMOVED

**TMI-2 INITIAL PLANNING STUDY**

APPROVED FOR REPORT	JES	ELR	AK	AMT
APPROVED FOR DESIGN	JES	AK	AMT	
DATE	REVISED	BY	CHK'D	DATE
SCALE	NTS	DESIGNED	DRAWN	CHK'D

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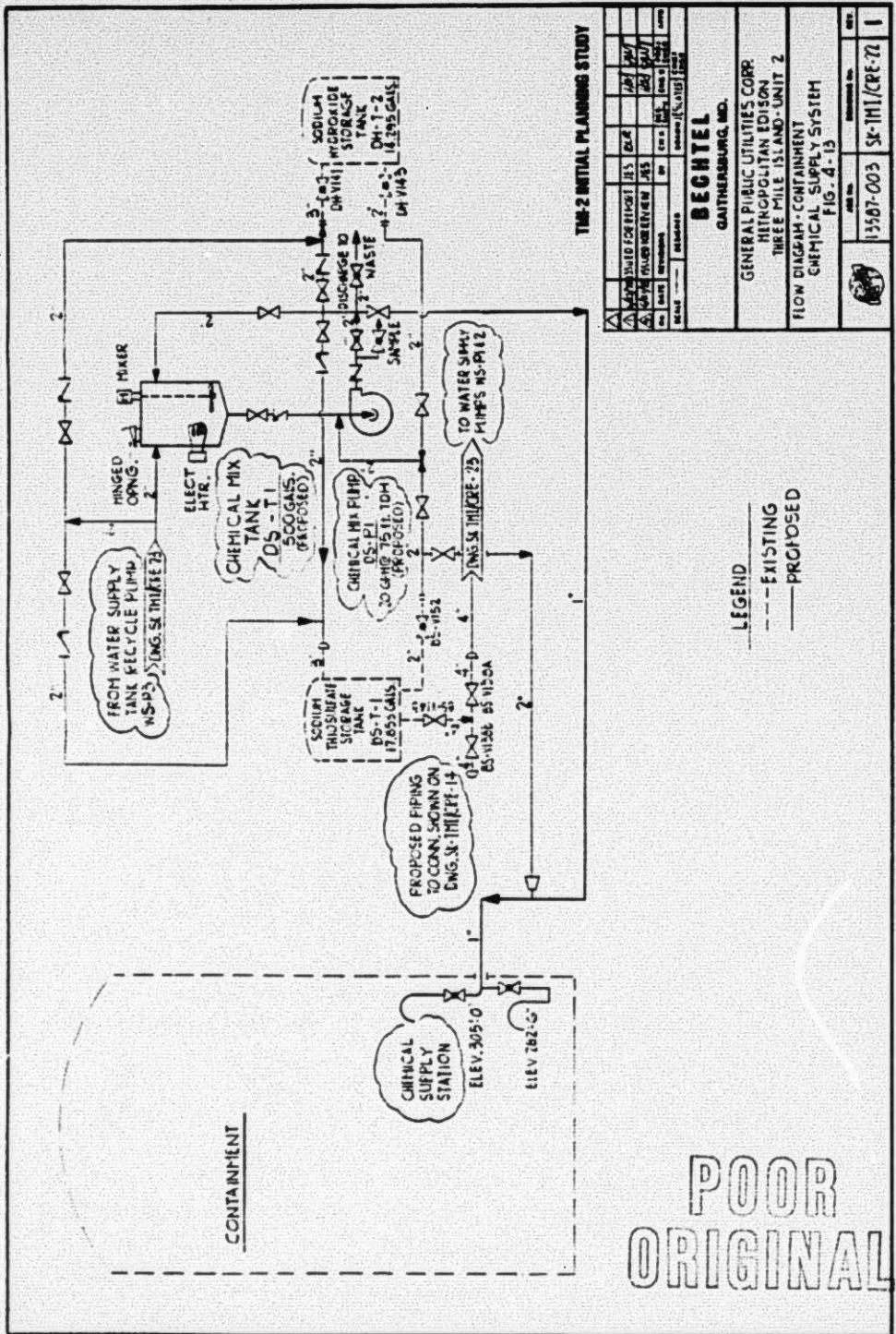
GENERAL PUBLIC UTILITIES CORP  
 METROPOLITAN EDISON  
 THREE MILE ISLAND - UNIT 2

SKETCH  
 WET/DRY VACUUM CLEANER  
 FIG 4-11

JOB No.	DRAWING No.	REV
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097003



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10/14/71	JAS	JAS	JH
DATE	BY	CHKD	APP'D
10/14/71	JAS	JAS	JH
DATE	BY	CHKD	APP'D
10/14/71	JAS	JAS	JH

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GENERAL PUBLIC UTILITIES CORP.  
METROPOLITAN EDISON  
THREE MILE ISLAND-UNIT 2

FLOW DIAGRAM - CONTAINMENT  
CHEMICAL SUPPLY SYSTEM  
FIG. 4-13

JOB No. 13507-003  
DRAWING No. SK-TH/CRE-72  
SHEET 1

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\_\_\_ PROPOSED

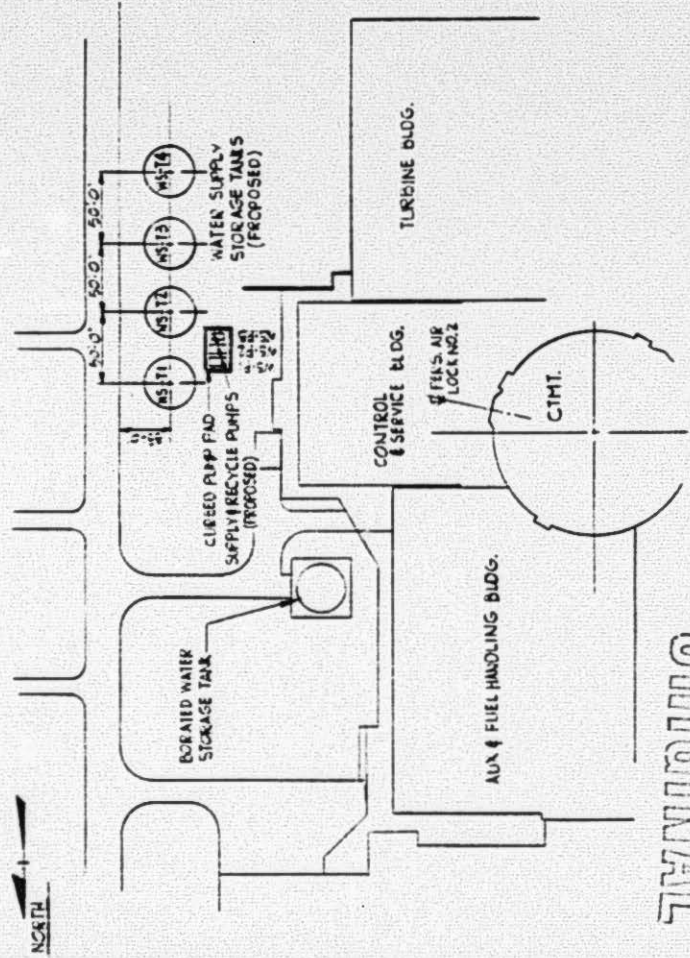
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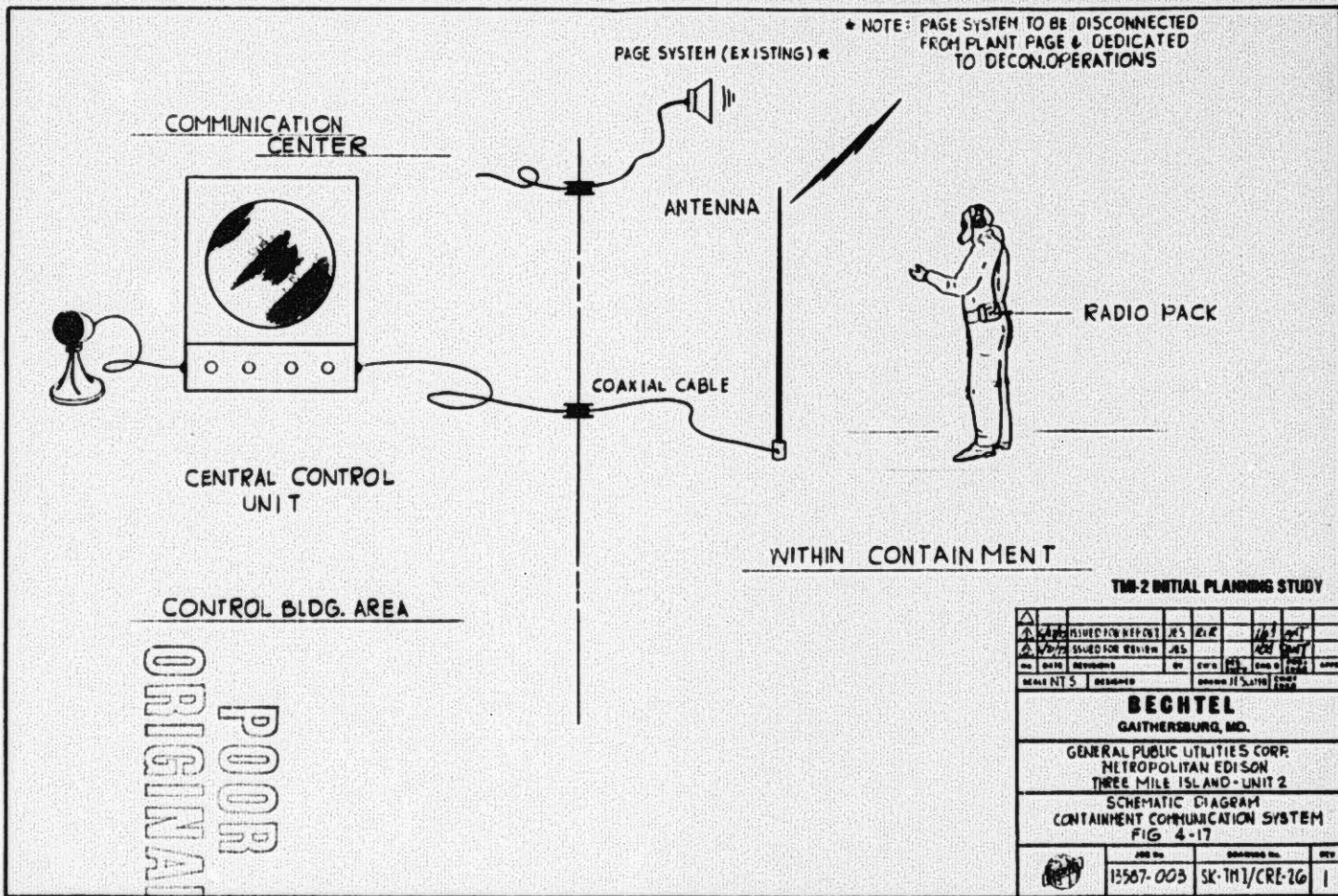
DATE	REVISION	BY	REASON FOR CHANGE
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10/15/67	3	SK	ISSUED FOR PERMIT
10/15/67	4	SK	ISSUED FOR PERMIT
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10/15/67	6	SK	ISSUED FOR PERMIT
10/15/67	7	SK	ISSUED FOR PERMIT
10/15/67	8	SK	ISSUED FOR PERMIT
10/15/67	9	SK	ISSUED FOR PERMIT
10/15/67	10	SK	ISSUED FOR PERMIT

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 GENERAL PUBLIC UTILITIES CORP.  
 METROPOLITAN EDISON  
 THE BEEMLE ISLAND-LAUIT 2  
 POSSIBLE ARRANGEMENT  
 OF WATER SUPPLY STORAGE TANKS AND PUMPS  
 FIG. 4-15

DATE: 10/15/67  
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 CHECKED BY: SK  
 PROJECT NO.: 14587-005  
 SHEET NO.: SK-TM1/CRF-24  
 OF: 1

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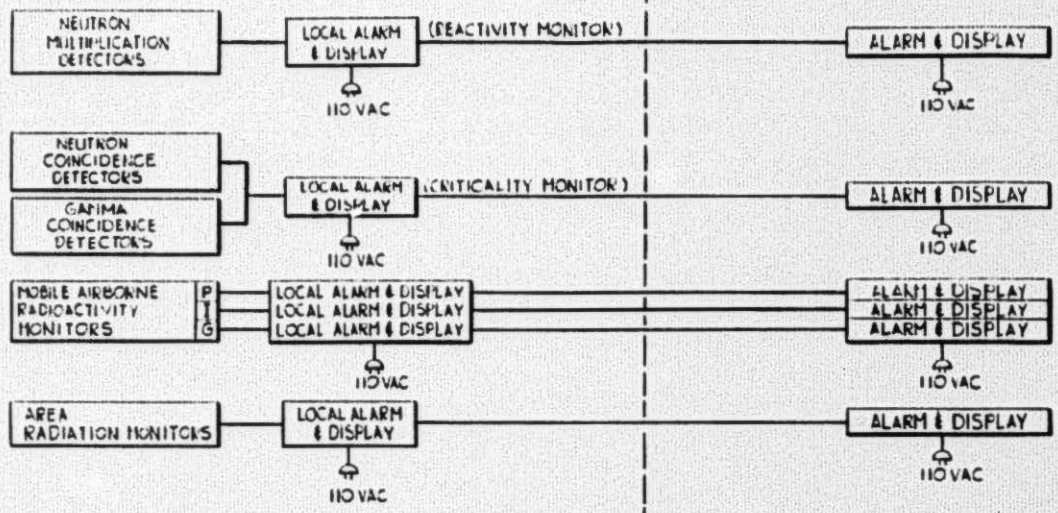


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TMI-2 INITIAL PLANNING STUDY									
REV	DATE	DESCRIPTION	BY	CHKD	APPD				
1	10/78	ISSUED FOR REVIEW	JES	JES					
2	11/78	DESIGNED	JES	JES					
<b>BECHTEL</b> GAITHERSBURG, MD. GENERAL PUBLIC UTILITIES CORP. METROPOLITAN EDISON THREE MILE ISLAND - UNIT 2 SCHEMATIC DIAGRAM CONTAINMENT COMMUNICATION SYSTEM FIG 4-17									
JOB No.		DRAWING No.		REV					
13567-003		SK-TM1/CRE-26		1					

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**LEGEND**  
 P - PARTICULATE  
 I - IODINE  
 G - NOBLE GAS

**TMI-2 INITIAL PLANNING STUDY**

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APPROVED FOR RELEASE	YES	NO	DATE	BY
DATE	REVISIONS	BY	CHKD	DATE
SCALE	DESIGNED	DRAWN (SCALE) DATE		

**BECHTEL**  
 GAITHERSBURG, MD.

GENERAL PUBLIC UTILITIES CORP.  
 METROPOLITAN EDISON  
 THREE MILE ISLAND-UNIT 2

BLOCK DIAGRAM - CONTAINMENT  
 RADIATION/RADIOACTIVITY MONITORING SYSTEM  
 FIG. 4-15

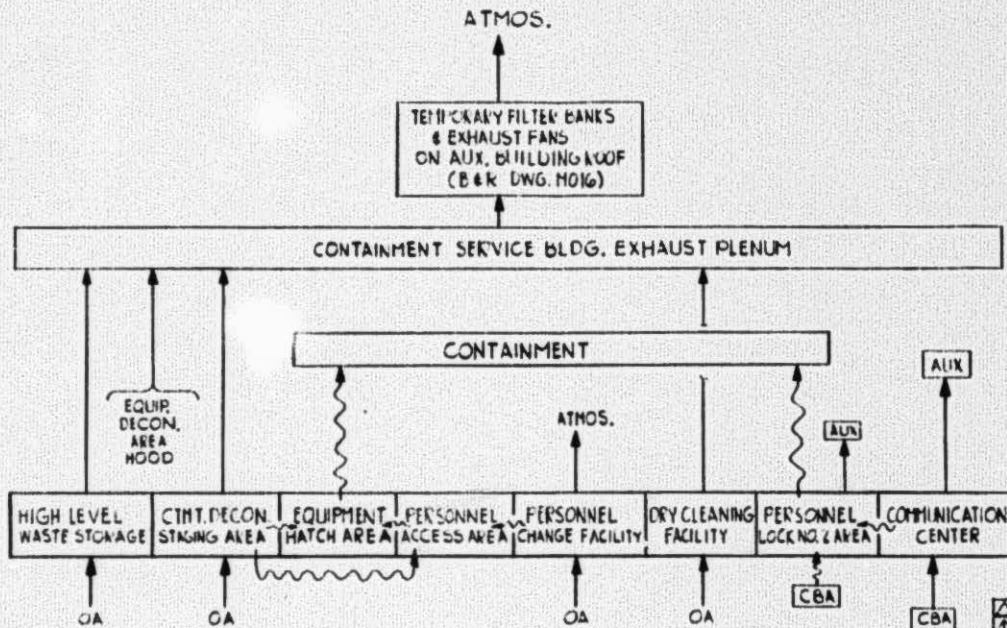
JOB No.	DRAWING No.	REV
13587-003	SK-TMI/CRE-27	1

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5/1/78

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**LEGEND**

- FORCED & INDUCED AIR
- ~ FILTRATION AIR FLOW
- ATMOS - EXHAUST TO ATMOSPHERE
- OA - OUTSIDE AIR SUPPLY
- CBA - CONTROL BLDG. AREA
- AUX - AUX. BLDG. DISCHARGE TO FILTERS

**TMI-2 INITIAL PLANNING STUDY**

△	ISSUED FOR PERMIT	YES	NO	DATE	BY		
⊕	ISSUED FOR REVIEW	YES	NO	DATE	BY		
NO.	DATE	REVISIONS	BY	CHK'D	DATE	APP'D	DATE
SCALE	DESIGNED	BY	DATE	DATE	DATE	DATE	DATE

**BECHTEL**  
GAITHERSBURG, MD.

GENERAL PUBLIC UTILITIES CORP  
METROPOLITAN EDISON  
THREE MILE ISLAND - UNIT 2

BLOCK DIAGRAM - CONTAINMENT  
SERVICE BLDG. AIR FLOW PATHS  
FIG. 4-20

JOB NO.	DRAWING NO.	REV
15587-005	SK-TMI/CRE-29	1

5.0

REMOTE CONTAINMENT DECONTAMINATION

Due to the high contamination levels expected inside the containment, it appears prudent to use remote methods to reduce levels of easily transportable contamination to as low a level as reasonably achievable prior to hands-on decontamination. This should help reduce the likelihood of significant contamination of personnel and areas outside of the containment and reduce general radiation fields in the containment to allow longer personnel stay times. A secondary objective is to attempt to reduce contamination levels in the dome, on the polar crane, and on the containment walls and surface areas, to aid in the initial refurbishment of the polar crane trolley and reduce later decontamination efforts in the dome area. This should also reduce the probability of recontamination of the areas at the 347' elevation during the "hands-on" decontamination phase.

The following four concepts for remote decontamination were identified by the Containment Engineering Group, all involving delivery of fluids through the containment spray system:

- a. Deionized water flush
- b. Detergent solution flush
- c. Steam/condensation cycles
- d. Chemical solution flush

In evaluating the sequencing and delivery volumes for these procedures, the following criteria, which are presented in random order, were set up:

1. The remote decontamination procedures should attempt to maximize decontamination effectiveness.
2. The procedures should attempt to minimize off-normal radwaste processing chemistry problems, and, in particular, not create high specific activity wastes coincident with off-normal radwaste processing chemistry problems.
3. Flush volumes should be of sufficient magnitude to move most or all dislodged or dissolved contamination to the containment sump to avoid increasing contamination levels at the 305' elevation by washing contamination from the 347' elevation and not moving it all the way to the sump.
4. The procedures chosen should attempt to minimize corrosive action on containment components and structures.

5. The procedures should provide some measure of decontamination for all surfaces in the containment.
6. Radwaste volumes should be minimized.

Clearly, a sequencing procedure and volume selection could not be developed which satisfied all the criteria simultaneously. The following logic was therefore invoked:

- o Studies presented in Section 2 show that the 347' elevation may be in a highly contaminated state, predominately cesium, which will result in high radwaste specific activities on the initial flush, due to the high solubility of most cesium compounds, regardless of the concept chosen. Criterion 2 was deemed to dominate the considerations from the standpoint of facilitating waste processing, therefore a deionized water flush was recommended for the initial flush, since a detergent flush would present high specific activity combined with abnormal chemistry.
- o Studies of an extremely empirical nature resulted in a required flush volume of about 250,000 gallons to meet Criterion 3.
- o Criterion 5 resulted in the selection of multiple steam/condensation cycles to attempt to decontaminate surfaces which cannot be sprayed or flooded by liquid sprays. Criterion 3 was then involved, resulting in a recommendation for a deionized water flush following the multiple steam/condensation cycles to move the activity to the sump.
- o Criterion 1 resulted in the selection of detergent solution flushes if the deionized water flushes and steam cycles prove insufficient in decontaminating the containment.
- o Criteria 4 and 2 relegated chemical flushes to the position of "last resort".

- o Criterion 6 could only be satisfied by a recommendation that further remote decontamination procedures not be initiated if they are no longer effective or if the goals set up for the remote decontamination effort have been met.

The overall sequence for remote decontamination through the building sprays can thus be described as follows:

1. High-volume (250,000 gallons) deionized water flush (Section 5.1).
2. Maintain containment humidity at 100% by a small steam flow through the containment sprays until the containment sump is drained (to prevent precipitation of desolved chemicals in flush water adhering to surfaces).
3. Multiple steam/condense cycles to remove contamination from walls, ceilings, and unsprayable/unfloodable surfaces. (Section 5.2)
4. Evaluate effectiveness of Steps 1, 2, and 3. If Step 1 was effective, repeat Step 1. If not, proceed to Step 5.
5. High-volume (250,000 gallons) detergent solution flush. (Section 5.3)
6. High-volume (250,000 gallons) deionized water flush.(Section 5.1)
7. Evaluate effectiveness of Steps 5 and 6 and repeat or proceed to Step 8.
8. Chemical decontamination, beginning with least deleterious reagent and proceeding to more deleterious reagents as necessary. Then flush according to Step 1. (Section 5.4)
9. Whenever it is determined that the radiation fields are sufficiently low for entry, (the end point must be a deionized water flush), proceed to Step 10.



10. High-volume (200,000 gallons) flush with water containing corrosion inhibitors, to minimize airborne tritium and provide shielding for solids deposited at 282'6" elevation. This water would not be drained from the sump but remain in place for the initial hands-on decontamination activities. (Section 5.5)

Figure 5-1 presents an example of a schedule and sequence which might be required to implement the above procedures.

The first and subsequent recycle water flushes will require large volumes of water, at least 250,000 gallons and possibly up to 1,000,000 gallons. This also will require extended spray pump operation without interruption to assure that large quantities of the loose (gross activity) contamination will be effectively flushed from all sprayed or otherwise flooded surface areas to the containment sump. Each recycle water flush should be followed by a steam-condensate flush cycle or cycles to aid in moving any gross activity collected on the vertical and/or the underside surface areas not contacted during the recycle water flush to the floors where it can then be flushed to the sump.

In addition, to assess and evaluate the effectiveness of the recycle water flush and detergent solution flush, the containment dome monitor HP-R-214 should be monitored continuously throughout the entire flushing sequence (See Section 2.2.1.2.3). It is expected that the deionized water/steam cycle/detergent solution/deionized water decontamination sequence could result in an overall DF of between 800 and 80,000 for those coated surfaces which are sprayed or flooded in the water flushes. The decontamination factors estimated for remote decontamination are based on the results of decontamination tests, using mixed fission products, performed by the Analytical Chemistry Division of ORNL according to Bechtel Specification CP-952. The tests were performed on coatings identical to those used in the TMI-2 containment.

The first attempt at remote decontamination should not be done until the water presently in the containment sump is drained to storage or processed. This water has a very high specific activity (Section 2) and is tritiated. Additional water added to the sump while it contains such contaminants will also become tritiated, and will increase the volume of highly contaminated (e.g.  $> 200 \mu\text{Ci/ml}$ ) water which must be processed. Once the tritiated water is processed, it can then be used for recycle for the remote decontamination methods discussed in this Section, but clean water additions to this recycled water should be minimized.

It is anticipated the first deionized water flush will be the most effective in removing gross activity from the building surfaces, and could result in waterborne activity levels as high as 30  $\mu\text{Ci/ml}$ . Since this activity level is perhaps an order of magnitude higher than any which will result from subsequent remote decontamination operations, it is advisable that this water be drained from the building for batch processing before further remote operations proceed.

## 5.1 Deionized Water Flush

### 5.1.1 Objective

The objective of the deionized water flush cycle is to flush loose contamination, detergent solutions and/or chemical decontamination reagents from containment structures and equipment to the containment sump. In addition, it is expected that the use of recycle water will minimize and control the water inventory in the containment sump and on-site tankage. It is anticipated that the initial deionized water flush will result in a DF of between 10 and 100 for all coated surfaces sprayed or flooded by the containment sprays.

### 5.1.2 Prerequisites

- a. Containment sump drained (for the initial flush)
- b. Primary coolant system cooling in the decay heat removal mode, if possible, since DHR cooling requires the fewest in-containment systems and instruments.
- c. Containment HVAC recirculation fans off.
- d. Loop "A" of the containment spray system valved out, control power breakers racked out and locked out.
- e. Containment cooling system off, but available for service, if required.
- f. Containment atmosphere temperature controlled at a minimum value consistent with other plant operating requirements.
- g. Containment atmosphere pressure controlled at a maximum value consistent with minimum temperature and other plant operating requirements. Prerequisites "f" and "g" are designed to minimize magnitude of negative pressure transient induced by spraying cold water into the containment atmosphere.
- h. Recycle or demineralized water available (250,000 gallons) from the recycle water storage tanks or the demineralized water tank (See Figure 4-14).

1. Verify that the radwaste storage and processing system is operable and available to process the contaminated containment building sump water.
- j. Verify that the containment dome monitor HP-R-214 and other supplemental radiation monitors, if operable, are activated.

### 5.1.3

#### Method

In the initial remote decontamination phase, the reactor containment building spray system should be utilized to spray and flush down the containment building walls and floors and also to spray all of the exposed surface areas of its associated equipment. The flushing water can be taken from the recycle water storage tanks or the demineralized water tank. The deionized flush water should be pumped into the containment through the "B" loop of the containment spray system. Maximum decontamination effectiveness should be achieved by operating the containment spray pump at its full capacity (1,500 gpm) until 250,000 gallons of recycle water has been pumped into the containment. The decontamination flush water should be allowed to drain down into the reactor building sump for at least two hours, after which sump and containment air samples will be taken and radiation surveys will be made at the preselected areas to determine the decontamination effectiveness (DF factors) of the water sprayed into the containment through the containment spray system.

### 5.1.4

#### General Procedure

1. Verify that the containment spray system valves have been lined up to take suction from a recycle water storage tank or the demineralized water tank. (See Figure 4-14).
2. Start containment spray pump BS-P-1B and with throttle valve BS-V-1B adjust the containment spray flow rate to its full pumping capacity (approximately 1,500 gpm).
3. Closely monitor the containment spray system flow rate until approximately 250,000 gallons of water has been pumped into the containment.
4. Closely monitor the containment dome monitor (HP-R-214) and other installed radiation monitoring equipment, during the flushing procedure and record data at ten minute intervals.

5. Stop containment spray pump BS-P-1B and close throttle valve BS-V-1B.
6. After Step 5 above, allow at least two hours for drain down time, then sample the reactor containment building sump to determine the decontamination effectiveness of the water spray flush.
7. Complete a radiation survey of the pre-selected areas and record the data.
8. Obtain an air sample of the containment atmosphere.
9. Initiate the radwaste processing system and process the contaminated flush water in the containment.
10. Maintain a small steam flow through the building sprays using the procedures described in Section 5.2 to keep surfaces wetted and prevent precipitation of chemicals from the flush water which will remain on building surfaces.

## 5.2 Steam-Condensation Method

### 5.2.1 General

The second step of the remote decontamination program should be initiated immediately after the first large volume deionized water flush has been completed (See Section 5.1). The steam-condensation method is to be performed in conjunction with and should complement step 1 in effectively removing gross contamination from the containment walls, and undersides of floor slabs and from the exposed and unexposed (underside) surface areas of its associated equipment. The containment spray system (See Figure 4-5) should be utilized to admit saturated steam through the spray nozzles into the containment. In case the containment spray system is unavailable, an alternate path through the integrated leak rate test (ILRT) penetration can be used (See Figure 4-5).

The expected results of this phase are to significantly reduce radiation fields and levels of contamination on the containment dome, on the polar crane, and on the containment walls and undersides of floor slabs and move the contamination to floor surfaces where it can be flushed to the sump. It is also expected that this decontamination phase will reduce the possibility of recontamination of the areas at the 347' elevation during the "hands-on" decontamination phase.

Although the steam-condensate method is somewhat limited as to vigorous flushing action, its coverage of all containment surface areas should be more uniform and, with a minimum of about eight steam cycles, it should be effective in the decontamination of those surface areas not contacted during the deionized water flushing procedure. It is expected that an overall decontamination factor of at least 4 may be achieved using the steam-condensation method for those surfaces which have not been previously flooded in the water flushes.

### 5.2.2 Objective

The objective of the steam condensation procedure is to condense steam on floors, walls, and ceilings of the containment which cannot be reached by water sprays. It is anticipated that the steam condensate will move contamination from ceilings and walls to the floors where it can be more effectively flushed with water. Also, the steam method will aid in minimizing the water inventory in the containment building and thus prevent the overloading of the radwaste processing system and its storage tanks.

### 5.2.3 Prerequisites

- a. Containment sump drained or at an acceptable level to receive additional water inventory.
- b. Containment cooling system off but available for service when required.
- c. Loop "A" of the containment spray system valved out, control power breakers racked out and locked out.

- d. Containment HVAC recirculation fans off.
- e. Primary coolant system in the decay heat removal mode, if possible.
- f. Containment temperature controlled at a minimum value consistent with other plant operating requirements.
- g. Containment pressure controlled at a minimum value consistent with minimum temperature and other plant operating requirements.
- h. All temporary piping connections and valves identified and connected for the saturated steam purge (See Figure 4-5).
- i. Saturated steam source available with pressure, temperature, and flow control.
- j. Verify that the radwaste storage and processing system is operable and available to process the contaminated containment sump effluent.
- k. Safety valves have been installed as required and are operable.
- 1. Verify that the containment dome monitor HP-R-214 and other installed monitors, if operable, are activated.

#### 5.2.4 Method

Saturated process steam will be admitted at a predetermined flow rate into the containment through the existing containment spray system. The containment temperatures and pressures should be strictly controlled at an optimum value to induce maximum condensation on all containment surfaces and associated equipment surfaces (See Figure 4-5).

#### 5.2.5 General Procedure

- 1. Purge the containment spray system piping with air or steam to remove any residual spray water from the spray system riser, or drain the riser if possible (ref. Figure 4-5).
- 2. Crack open the steam addition control valve for approximately thirty (30) minutes and pre-heat the containment spray system piping.
- 3. With the steam flow control valve adjust the steam flow rate to maximum capacity (~ 20,000 lbs/hr.).

4. Purge steam into the containment until the containment atmosphere pressure increases to the highest value permitted by operating conditions (see note below item 5), (approximately thirty minutes), then close the steam flow control valve.
5. Closely monitor the containment temperature and pressure during the above step.

NOTE 1: Stop steam addition if the containment pressure increases to  $-0.1$  psig (to avoid containment atmosphere outleakage) unless the building has been purged.

2: If the containment has been purged, the pressure may be increased to a higher value ( $\sim 3-4$  psig).

6. If operable, closely monitor the containment dome radiation monitor (HP-R-214) and other installed radiation detection instrumentation during Step 4.
7. After securing from Step 4, start the containment building cooling system and return the pressure and temperature to their initial conditions (See Section 5.2.3).
8. Allow two hours drain time after Step 4, then sample the containment building sump.
9. Perform a radiation survey at the pre-selected areas and record data. A Ge(Li) spectrum taken through the equipment hatch should give a good indication of the effectiveness of this method since only the steam condensate can reach the inside surface of the hatch.
10. Obtain a containment air sample.

NOTE: It is not necessary to hold up the flushing sequence for the sample results. Proceed to Step 11 when the containment has been returned to its initial conditions and the sump is available to receive another steam cycle.

11. Repeat Steps 1 through 10 at least eight times or until it has been established that the remote steam condensation decontamination effort is no longer effective.
12. Proceed immediately to a deionized water flush as described in Section 5.1.



### 5.3 Detergent Solution Flush Cycle

#### 5.3.1 General

In the third step of the remote decontamination procedure, the containment spray system should be utilized to flush down the containment walls, exposed surfaces, and equipment with a mild strength, low suds detergent solution. (Radiac wash, or other acceptable and approved detergent).

The expected results of this step are to significantly reduce the radiation fields and the levels of contamination on the containment dome, on the polar crane, and on the containment walls to aid in the initial refurbishment of the polar crane trolleys. It is expected that this decontamination step will reduce the possibility of recontamination of the areas at the 347' elevation during the "hands-on" decontamination phase.

Although the containment spray system is somewhat limited in its coverage of the containment surface area, (approximately 60%), it is expected that the first detergent solution flush will be effective (particularly for cesium removal) and should result in an overall decontamination factor between 10 and 100 on all coated surface areas contacted by the detergent decontamination solution.

#### 5.3.2 Objective

The objective of the remote detergent flush is to remotely decontaminate the containment and its associated equipment with a detergent which will degrease wetted surfaces and loosen adhering dirt and contamination.

#### 5.3.3 Prerequisites

- a. Containment sump drained to allow addition of 250,000 gallons of detergent solution and 250,000 gallons of rinse water.
- b. Containment HVAC recirculation fans off.
- c. Loop "A" of the containment spray system valved out and breakers for the unused spray pump and control valves racked out, locked and tagged out.
- d. Containment temperature controlled at a minimum value consistent with other plant operating requirements.
- e. Containment pressure controlled at a maximum value consistent with minimum temperature and other plant operating requirements. Prerequisites "d" and "e" are designed to minimize the magnitude of negative pressure transient induced by spraying cold water into the containment atmosphere.

- f. Detergent or Radiac wash concentrate (concentration to be determined later) made up and pumped to the sodium thio-sulfate tank (BS-T-1) using the chemical supply system (See Figure 4-5 and 4-14).
- g. Verify that the containment dome monitor HP-R-214 and other supplemental radiation monitors, if operable, are activated.
- h. Primary coolant system in the decay heat removal mode, if possible.
- i. 500,000 gallons of deionized water available in the demineralized water storage tank or from the recycle water storage tanks.
- j. Containment cooling system off but available for service, if required.
- k. Verify that the radwaste system is operable and available to process the contaminated detergent solution effluent.

#### 5.3.4 Method

The containment spray system will be utilized to spray an acceptable and approved detergent or Radiac wash solution on the containment walls and to all of the exposed surface areas of its associated equipment. The detergent or Radiac wash solution will be prepared in the mix tank, then pumped to the sodium thiosulfate tank, heated to approximately 150° F, and recirculated back through the mix tank until it has been thoroughly mixed before adding it to the containment spray stream. The mixing and concentration of the detergent decontamination solution can be achieved by adding it at a controlled flow rate into the "B" loop of the containment spray system during the flushing operation. Maximum decontamination effectiveness should be achieved by operating the containment spray pump at full capacity (1,500 gpm) for a total solution delivery of 250,000 gallons/cycle. The detergent flush should be allowed to drain to the containment sump for approximately thirty minutes and then be followed by a high volume deionized water flush as described in Section 5.1. The rinse water should be allowed to drain down into the containment sump for at least one full hour; the sump will then be sampled and radiation surveys at pre-selected areas (including the containment dome monitor HP-R-214, if operable, will be made to determine the decontamination effectiveness of the detergent solution and the rinse water flush.

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5.3.5

## General Procedure

1. Verify that the containment spray system valves ("B" loop) have been lined up to take suction either from a recycle water storage tank (See Figure 4-14) or the demineralized water storage tank.
2. Verify that the containment spray system valves have also been lined up to take suction from the sodium thiosulfate tank BS-T1, and that the flow control valve is in the closed position. (See Figure 4-5)
3. Start containment spray pump P-1B and with throttle valve V-1B adjust the containment spray system flow rate to its full pumping capacity (approximately 1500 gpm). (See Figure 4-5)
4. Crack open the sodium thiosulfate tank outlet flow control valve (See Figure 4-5) and adjust the rate to achieve the pre-determined detergent and/or Radiac wash solution concentration.
5. Closely monitor the spray system flow rate, including detergent addition flow, until approximately 250,000 gallons of detergent solution has been pumped into the containment, then stop pump BS-P-1B and close throttle valve BS-V-1B.
6. Close the sodium thiosulfate tank outlet flow control valve. (See Figure 4-5)
7. Proceed immediately to a high volume de-ionized water flush as described in Section 5.1.

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## 5.4 Chemical Decontamination

### 5.4.1 Chemicals

Strong chemical decontamination methods should only be used as a last resort if the other methods, including use of a detergent, fail to provide a sufficient DF to allow containment entry. Before any strong chemical solution is to be sprayed from the containment spray header into the containment, evaluations should be performed for each proposed chemical as to its detrimental effects on NSSS equipment. (See also Section 10.3)

The chemicals listed are provided in the order of preference for use in the containment. In general, the chemicals listed first are weaker and are expected to have less of a deleterious effect but will probably result in lower DF's as well. All chemical treatments would be applied in  $2.5 \times 10^5$  gallon flushes dissolved in recycle or demineralized water followed by  $2.5 \times 10^5$  gallon flushes with recycle or demineralized water.

#### Chemicals:

Morpholine - (tetrahydro - 1,4 - oxazine; diethylenimine oxide)  $\text{OCH}_2\text{CH}_2\text{NHCH}_2\text{CH}_2$  mild basic chemical used in all volatile treatment for steam generator secondary side corrosion control.

Concentration - same as in all volatile treatment

Disodium phosphate and trisodium phosphate - ( $\text{Na}_2\text{HPO}_4$  and  $\text{Na}_3\text{PO}_4$ ) basic chemicals formerly used in "U" tube steam generator secondary sides for corrosion control.

Concentration - same as secondary side  
(300 ppm  $\text{PO}_4$ , pH=10)

Sodium Hydroxide  
(NaOH) base used in containment sprays

Concentration - pH=10

Boric Acid -  $\text{H}_3\text{BO}_3$   
acid used in primary system and containment sprays.

Concentration - near saturation

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Hydrogen peroxide -  $H_2O_2$   
mild, non-crystalline oxidizer.

Concentration - 3% (6% if 3% not effective)

Peracetic Acid -  $CH_3COOOH$   
mild acid oxidizer

Oxalic acid and ammonium citrate  
ethanedioic acid -  $COOHCOOH \cdot 2H_2O$   
ammonium 2 - hydroxy - 1, 2, 3 - propanetricarboxylate  
 $(COOH)CH_2C(OH)(COOH)CH_2COONH_4$   
mild acid complexer and rust remover

Concentration - near saturation

Ammonium hydroxide  $NH_4OH$   
base, complexer

Concentration - pH=10

Sulfamic acid  $NH_2SO_3H$   
acid, complexer

Concentration - pH=5

The results from each chemical addition step would be evaluated before proceeding to the next step. The procedure to add chemicals through the containment sprays will be essentially the same procedures as those used for detergent addition in Section 5.3.

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## 5.5 Final Flush Procedure

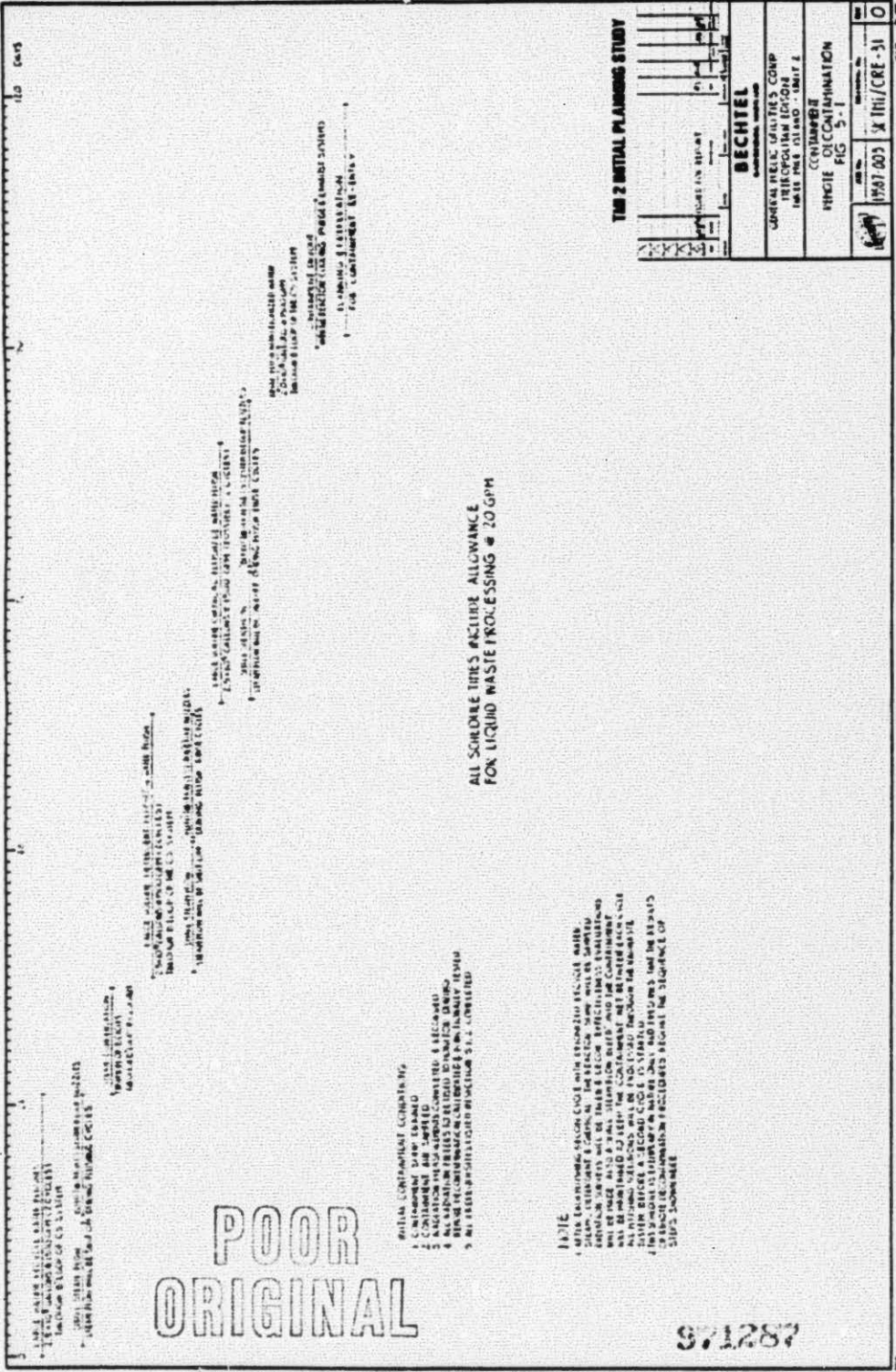
### 5.5.1 Objective

The objective of the final flush procedure is to flood the sump with an inhibited water volume to minimize component corrosion and provide radiation shielding for solid radionuclides remaining on the floor of the containment. This procedure also provides steps to "condition" the containment atmosphere to minimize airborne tritium.

### 5.5.2 General Procedure

1. Verify that the sodium thiosulfate tank (BS-T1) contains disodium and trisodium phosphate solution sufficient to adjust demineralized water (approximately 200,000 gallons) to pH of 7.5 - 8.0 (approximately 50 ppm).
2. Verify that the containment spray system valves have been lined up to take suction from the demineralized water storage tank. (See Figure 4-14)
3. Verify that the metering pump valves have been lined up to take suction from the sodium thiosulfate tank BS-T1. (See Figure 4-5)
4. Start containment spray pump BS-P-1B and with throttle valve BS-V-1B adjust the flow rate to full capacity (1500 gpm).
5. Start the disodium and trisodium phosphate metering pump and adjust the flow rate to obtain a pH of 7.5 - 8.0. (See Figure 4-5)
6. Continue operation of the containment spray system until approximately 200,000 gallons of demineralized water has been added into the containment (approximately 2 to 3 feet above the containment building floor) to provide radiation shielding during initial containment entry.
7. Stop containment spray pump BS-P-1B and close throttle valve BS-V-1B.
8. Stop disodium and trisodium phosphate metering pump and close the flow control valve.

9. Initiate building filtration system in recycle mode.
10. Start the containment building cooling system and adjust the containment temperature to dry out the containment before initial entry (to minimize airborne tritium).



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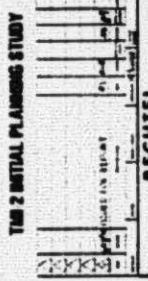
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- BECHTEL CONTINGENT CONTRACTING
1. CONTINGENT DRAWING BOARD
  2. CONTINGENT AIR SUPPORT
  3. CONTINGENT ELECTRICAL ENGINEER
  4. CONTINGENT MECHANICAL ENGINEER
  5. CONTINGENT CHEMICAL ENGINEER

ALL SCHEDULE TIMES INCLUDE ALLOWANCE FOR LIQUID WASTE PROCESSING @ 20 GPM

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BECHTEL

GENERAL ELECTRIC UNITED STATES CORP  
 1000 WEST 101ST AVENUE  
 DENVER, COLORADO 80202

CONTINGENT  
 ENGINEER  
 FIG. 2-1

DATE: 1987-003  
 X TH/CRE-31  
 O

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## 6.0 CONTAINMENT ATMOSPHERIC FILTRATION AND PURGING

### 6.1 Existing Situation and Design Objectives

#### 6.1.1 Containment Atmosphere Conditions

The release of large quantities of reactor coolant to the containment coincident with significant fuel failure has led to extremely high airborne levels within the containment. These levels must be reduced as much as possible to minimize operator exposures during containment decontamination activities. Table 6-1 presents a summary of results from numerous containment air samples and the MPC which is allowed in the air in controlled spaces to indicate the magnitude of the problem. The primary contaminants are miscellaneous fission products, noble gases, iodine, cesium, and tritium, all of which must be treated and/or released in a controlled manner to assure the minimum impact on the public health and safety.

It is apparent from analysis of Table 6-1 that the actual value of the specific activity of each of the primary contaminants is not accurately known. A reasonable consistency in the order of magnitude of the primary radioisotopes does exist and this information was considered sufficient for preliminary planning. More accurate and precise knowledge of the containment atmosphere will be essential prior to the start of and during cleanup operations so that an accurate evaluation of the impact of these releases can be made.

Although the bulk of the containment atmosphere radioactivity should be removed prior to containment entry there will still be levels of airborne contamination inside the containment throughout the decontamination activities. This additional airborne activity is expected from resuspension of radionuclides which had plated out and from the dislodging of radioactivity during remote and manual decontamination activities.

#### 6.1.2 Design Objectives

To evaluate and compare various system designs and operating alternatives for cleanup of the containment atmosphere, it is first necessary to establish objectives. The following objectives are considered appropriate for this aspect of the containment decontamination:

- o To minimize the impact on public health and safety from containment atmosphere cleanup
- o To assure that operator exposures are ALARA
- o To comply with the established release technical specifications
- o To minimize the impact of containment atmosphere cleanup operations on the decontamination schedule

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## 6.2 Alternatives Considered and Selection of Filtration and Purge Alternative

### 6.2.1 Alternatives Considered

Even after filtration through both HEPA and charcoal filters, there will still remain a significant concentration of noble gases and tritium in the containment atmosphere. These gases can then be either concentrated and stored for decay or discharged to the environment in a controlled manner.

The alternative approaches to concentrating and storing the waste gases include high pressure compression and storage, differential diffusion through charcoal beds at either ambient, refrigerated, or cryogenic temperatures, or cryogenic distillation and storage.

The alternatives available in a purge mode of containment air cleanup are limited to the purge start date, variations in purge rate, and the specification of meteorological conditions during which purging would be terminated.

### 6.2.2 Selection of Filtration and Purge

Filtration and purge can be used to meet any non-zero release rate or off-site dose objective. It is simply a matter of reducing the purge rate to comply with the objective, given the meteorology. Obviously, as the release rates or dose objectives get smaller, the time required to purge increases.

In an attempt to determine the feasibility of filtration and purging for cleanup of the TMI-2 containment atmosphere, the May 5, 1979 containment air sample and the existing TMI-2 effluent release technical specifications were used to determine how long it would take to reach MPC for Kr-85 in the containment assuming compliance with the technical specifications. This analysis indicated that the filtration, purge, and dilution mode of containment atmosphere cleanup would take about 51 days using existing systems. Although 51 days is a relatively long time for this activity, it is not so long as to make the filtration, purge and dilution mode infeasible.

Concentrating the noble gases and storing them in a pressure vessel could further reduce the release of radioactive gases to the environment, but there are significant risks associated with concentrating and storing gaseous wastes. Failure of a storage tank containing thousands of curies of Kr-85 could result in an uncontrolled release causing far higher doses at the site boundary than the dose resulting from a controlled purge. A large tank of Kr-85 under pressure could probably not be transported from the site and could not be buried at any of the existing commercial low level waste burial grounds. Since Kr-85 has a half-life of 10.76 years, such a tank would have to be maintained on the site long after the plant had ceased to generate power or the contents would have to be released in a controlled manner to the environment.

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Considering all of these factors, it is recommended that the existing containment ventilation and purge system be used to clean up the containment atmosphere. The system can be used to meet all the design objectives with the fewest undesirable consequences, such as increased operator exposure and increased accident risks.

### 6.3 Filtration/Purge Schedule

#### 6.3.1 TMI-2 Technical Specification Release Limits

The TMI-2 operating Technical Specifications were written as interim technical specifications to be superseded by technical specifications implementing Appendix I to 10 CFR 50. A footnote in the interim Technical Specifications states that their use is not expected to result in releases in excess of those that would be permitted by Appendix I to 10 CFR 50.

#### 6.3.2 Timing of Purge in Relation to Other Activities

July 2, 1979, is 96 days following the incident, and the short-lived isotopes have already decayed to relative insignificance. Initiation of a purge could therefore begin at any time depending only upon the required completion date. Based only on Kr-85 in the May 5 air sample and assuming the use of existing systems with no modifications, purging containment would require about 51 days to remain within the gaseous release specification. Therefore, the purge should be started approximately two months prior to the date by which the containment atmosphere must be purified.

It is suggested that the containment purge be initiated so that it is complete prior to entering containment. This would assure that all significant releases from the containment were both controlled and monitored.

After the initial purge to rid the containment of the gross noble gas activity, additional purification and purge will be necessary to remove airborne activity generated by remote decontamination activities. Purification and purge will also be required immediately prior to containment entry as part of the operator ALARA exposure program. The purpose of these subsequent purification and purge operations is primarily to remove particulates, iodine, cesium, tritium, and trace amounts of the noble gases which will be made airborne by the decontamination operations. The particulates, iodine, and cesium should be removed by the HEPA and charcoal filters during purification. Tritium and trace amounts of the noble gases can then be purged at rather high capacities because of the high MPC for the former and the low quantities of the latter. These operations, performed at 25,000 cfm, should take less than about 12 hours for a complete purification and purge cycle, depending on the initial concentrations.

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## 6.4 System Configuration and Operating Modes

### 6.4.1 Existing Systems and Capabilities

The existing containment ventilation and purge system is briefly described in Section 4. In summary, there are three subsystems performing different functions, all of which should be employed during the initial purification and purge operation.

The heat removal subsystem, consisting of the air cooling units, should be used during the purification and purge operation to continually recirculate the containment atmosphere, thereby assuring a reasonably homogeneous low humidity air mass for the purification and purge operation.

The purge and purification subsystem consists of two trains of ducting, filters, dampers, and a fan to provide a high volumetric capacity system, 25,000 cfm per train, for containment atmosphere purification and recirculation or purging. When operating in the purge mode, separate supply air fans provide clean air, heated if necessary, to the containment.

Finally, the hydrogen control subsystem provides for the controlled discharge of filtered air from the containment at a rate variable from 4 to 150 cfm. When discharging at this relatively low rate, supply air may be made up through test connections which exist outside of containment.

### 6.4.2 Proposed Modes of Operation for Kr-85 Purge

Kr-85 will be the limiting radionuclide for containment purge considerations because it is already the most prevalent and has the longest half-life. However, in order to purge Kr-85 as quickly as possible under the existing specifications, it is first necessary to remove I-131 and Cs-137 so that the specification limiting the release of I-131 and particulates with half-lives longer than eight days is not violated. To accomplish this cleanup, a single train of the 25,000 cfm purification and purge subsystem could be run in the recirculation mode to remove I-131 and Cs-137 from the containment atmosphere, depositing them on the charcoal and HEPA filters.

Based on the May 26 sample analyzed by SAI, and assuming DF's of 1000 in the combined HEPA filters for Cs and 10 in the charcoal filter for I, it is estimated that the concentrations of I and Cs in the containment atmosphere could be reduced to less than MPC for controlled areas in slightly less than 16 hours. This would load about 4 1/2 curies of Cs-134 and Cs-137 on the HEPA filters and about 3 curies of I-131 on the charcoal filters, assuming decay to July 6, 1979. This quantity of I-131 distributed over 60 charcoal cells will lead to a radiation field of approximately 100 mr/hr at one foot from each charcoal cell. The Cs-134 and Cs-137 distributed over 20 HEPA filters will result in a radiation field of approximately 1200 mr/hr at one foot from each HEPA cell.

Following the reduction of the I and Cs, the Kr-85 and remaining Xe isotopes should be purged from containment via the hydrogen control subsystem. Use of this system will provide the variable, low flow rate necessary initially to meet the instantaneous release limits on gross gaseous activity.

Air must be supplied to the containment during this purge. Although it is possible to supply air through several of the 1/2" test connections, the 2" return line from the hydrogen recombiner, and possibly the radiation detection and sampling system, a plant modification to provide a single, filtered air supply equal to the hydrogen control system capacity is recommended. A single air supply, besides being more convenient, should assure faster isolation of the containment should it be required.

Purging K-85 from the containment through the hydrogen control subsystem should continue until the Kr-85 concentrations are low enough to permit use of the higher capacity purification and purge system. When this higher capacity system is used, the containment purge air supply system must be used to make up air to the containment.

It is recommended that one train of the purification and purge system be dedicated to I and Cs removal and recirculation and that the other train be used for recirculation, after the gross amounts of I and Cs have been removed, and high capacity purge. The purification and purge train dedicated to I and Cs removal would be operated first. After the containment atmosphere has been cleaned of I and Cs sufficient to allow initiation of the Kr-85 purge through the hydrogen control subsystem, the purification and purge train dedicated to I and Cs removal should be shut down. The other train should then be started in the recirculation mode to assure a reasonably homogeneous air mass inside the containment during the Kr-85 purge. The contaminated HEPA and charcoal filters in the idle train should be replaced during this period.

#### 6.4.3 Possible System Modifications

There are a few plant modifications which, if incorporated, would facilitate the containment purge operation:

First, a low capacity air supply will be needed during the initial Kr-85 purge via the hydrogen control subsystem. This air supply should have a capacity which will match the hydrogen control subsystem capacity. The hydrogen control subsystem capacity is presently 150 cfm maximum but a few modifications could increase its capacity to about 1000 cfm, which in turn would decrease the time required to purge the containment. This air supply can be connected to the recirculation return portion of either train of the purification and purge subsystem, preferably between the last isolation valve outside containment and the containment itself. The air supply should contain an isolation valve capable of automatic closure.

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Second, the hydrogen control subsystem discharges to the plant stack, which is presently capped to route all HVAC air flow through the supplemental filters on the auxiliary building roof. This results in essentially a ground level release. Both for the protection of personnel on site and to reduce off-site doses, an elevated release of noble gases is desirable. Since the bulk of the Kr-85 release will be via the hydrogen control subsystem at low flow rates, a 6" pipe supported by the plant stack, but extending to 2 or 3 meters beyond the top of the containment, would be of substantial benefit.

Third, the hydrogen control subsystem presently has a variable capacity from 4 to 150 cfm. If the upper limit of this variable capacity were raised, containment purge could be executed in a correspondingly shorter time. The filters in the hydrogen control subsystem are rated for 1000 cfm, so the limiting component appears to be the hydrogen control exhaust fan. If the fan is replaced with a unit capable of variable capacity up to the filter capacity, a reduction in the time required to purge the containment will be achieved.

The previously stated system modifications are those which could rather easily be accomplished and which would facilitate the initial containment purge. Other modifications might be considered which would benefit either the initial containment purge or limit airborne releases during containment decontamination.

The addition of a microprocessor or mini-computer to use real time meteorological data and containment air activity data to set release rates would allow the fastest possible purge in compliance with established technical specifications with a minimum of operator attention. Although completely feasible, this concept has not yet been licensed at any commercial power reactor facility. No estimate of the cost of such a modification has been made.

Rather significant modifications to air flow patterns inside containment will be desirable following reentry during the decontamination phase. Containment cooling and atmosphere control to provide a comfortable working environment and air flow control to minimize airborne recontamination of cleaned areas may sometimes create conflicting priorities which can only be resolved by the use of temporary systems. Tenting will be required around clean areas until the decontamination has progressed to the point that a few local areas of high contamination can be effectively sealed and the resuspension of additional airborne contamination from these areas can be prevented or controlled. Proposed system modifications are discussed in Section 4.2.3.

For operator protection and to control offsite releases, several changes to the existing containment air sampling system are proposed. Airborne particulate monitors, gross gaseous activity monitors, and monitors for determining tritium levels in the atmosphere may be necessary. The existing monitors at the release points may be sufficient for the final effluent release, although their capacity and adequacy must be checked if modifications are made to hydrogen control system capacity. Airborne particulate monitors should be provided

in each tented area where decontamination operations are ongoing to assure sufficient and timely information to workers in the area. Refer to Section 4.2.13 for additional discussions of this topic.



## 6.5 Assessment of Resultant Containment Airborne Activity

Depending on the duration and volumetric flow rates of the containment purge, airborne activity levels inside containment due to the initial purge could asymptotically approach zero. The activity levels can be brought below the MPC's for controlled areas within about two months, with Kr-85 being the limiting isotope. The level of noble gases in the containment should remain low until the reactor vessel head is lifted from the vessel, at which time some off-gassing should be expected. The noble gas activity off-gassed when the RCS is opened should be easily controlled by containment purge.

A containment purge will be necessary following the last use of tritiated recycle water during remote containment decontamination. This will be needed irrespective of noble gas or particulate activity to lower the tritium concentration below MPC inside the containment.

The containment purification system, running in the recirculation mode in conjunction with the iodine and particulate activity removal due to operation of the containment spray system during remote decontamination, should lead to very low initial levels of airborne iodines or particulates. However, resuspension of plateout is expected to cause a significant airborne contamination problem throughout all phases of the containment decontamination. Very large quantities of radioactive plateout are likely to remain in the containment, even after remote decontamination efforts. Therefore, even though the reported range of resuspension factors is very broad, being rather low for wetted surfaces having little or no traffic and being rather high for dry surfaces experiencing heavy traffic, the resuspension phenomena is likely to generate substantial amounts of airborne activity, at least until nearly all surfaces have been decontaminated and resealed.

6.6 Offsite Dose Consequences

As was stated earlier in Section 6.3.1, compliance with the existing plant technical specifications should result in offsite doses no greater than those determined to be "As Low As Reasonably Achievable" in Appendix I of 10 CFR 50. A very preliminary analysis of the offsite doses due to purge of Kr-85 over a 51 day period resulted in a gamma dose to the whole body of .14 mrem and a beta dose to the skin of 14.8 mrem. This is a very preliminary analysis based only on Kr-85 as determined in the May 5 air sample and the annual average X/Q. Obviously a more rigorous analysis, based upon a containment air sample which is known to accurately reflect actual containment atmosphere concentrations will be required. However, this initial analysis establishes that containment atmospheric cleanup can be accomplished by a filtration and purge operation in keeping with the numerical guidelines which were determined to be "As Low as Reasonably Achievable".

6.7 Additional Containment Atmosphere Control Requirements

Additional containment atmosphere requirements are discussed in Section 4.2.3.

TABLE 6-1

SUMMARY OF CONTAINMENT ATMOSPHERE SAMPLES

	Kr-85	I-131	Xe-131m	Xe-133	Xe-133m	Cs-137	Other
<u>MPC</u>	$1 \times 10^{-5}$	$9 \times 10^{-9} \mu\text{Ci/ml}$	$2 \times 10^{-5} \mu\text{Ci/ml}$	$2 \times 10^{-5} \mu\text{Ci/ml}$	$1 \times 10^{-5} \mu\text{Ci/ml}$	$6 \times 10^{-8} \mu\text{Ci/ml}$	
<u>Half-life</u>	10.76 yr.	8.05d	12d	5.27d	2.3d	30y	

Sample Date

3/31/79	-	6.4E-2	-	6.82E+2	1.59E+1		Xe-135 8.18E0
4/02/79	-	1.1E-1 9.7E-3		1.70E+1 6.50E+1	5.86 2.70E-1	3.96E-2 < 5.4E-3	1.59E-1 6.20E-1
5/05/79	6.29E-1	2.78E-3	6.88E-2	9.89	-	-	-
5/11/79	-	3.33E-5	9.71E-3	5.50E-3	-	-	-
5/14/79	6.62E-1	1.29E-3		8.1E-3	3.09E-1	-	K-40 6.9E-4
5/26/79	5.5E-1	1.39E-3	2.15E-1	3.5E-1	-	4.8E-5	Cs-134 2.55E-5
5/31/79	9.82E-1	1.04E-3	3.24E-1	4.84E-1	-	-	-
6/21/79	7.94E-1	1.22E-4	8.46E-2	2.37E-2	-	MDA	-

9/12/79

TM-2 INITIAL PLANNING STUDY

TABLE 6-2

GASEOUS EFFLUENT RADIOACTIVE DISCHARGE  
TECHNICAL SPECIFICATIONS

- a. The instantaneous release rate of gross gaseous activity except for halogens and particulates with half-lives longer than eight days shall not exceed:

$$\frac{Q_1}{(\text{MPC})_1} \leq 1.5 \times 10^5 \text{ m}^3/\text{sec.}$$

- b. The instantaneous release rate of I-131 and particulates with half-lives longer than eight days, released to the environs as part of airborne effluents, shall not exceed:

$$0.3 \mu\text{Ci}/\text{sec.}$$

- c. The release rate of gross gaseous activity shall not exceed:

$$\frac{Q_1}{(\text{MPC})_1} \leq 2.4 \times 10^4 \text{ m}^3/\text{sec.}$$

when averaged over any calendar quarter.

- d. The release rate of I-131 and particulates with half-lives greater than eight days shall not exceed:

$$0.24 \mu\text{Ci}/\text{sec.}$$

when averaged over any calendar quarter.

## 7.0 INITIAL ENTRY, RADIATION FIELD MAPPING AND DAMAGE ASSESSMENT

### 7.1 Prerequisites for Entry

#### 7.1.1 General

The initial entry into the containment should not be made until proper precautions are taken and conditions exist inside the containment that will not pose an undue hazard to personnel. As noted in Section 2, a preliminary evaluation of radiation data indicates prohibitive radiation levels may exist to make a containment entry for the purposes of extended radiation surveys and data acquisition tasks not feasible at this time. Additional radiation dose rate data are needed in order to better define the preparations required for entry, or to determine the feasibility of containment entry prior to remote decontamination.

The scenario for reentry presented in this report is not intended to preempt studies currently underway for which future data or evaluations might demonstrate acceptable alternate conditions for reentry. However, many of the thoughts and ideas presented here are applicable for other scenarios such as early entry, entry through the No. 1 personnel lock, etc., provided that proper precautions are taken and safety assessments are performed.

#### 7.1.2 Data Evaluation Prior to Entry

An assessment is presented in Section 2 of the prediction of radiation dose rates inside the containment. Prior to opening of the containment personnel lock inner door, a complete survey of the radiation fields on the inside of the personnel lock should be taken by opening the outer door and entering the air lock. This has not been done at this time, but is presumed to have been done prior to initiating the reentry task. These data will be required to make a final reconciliation of all previous predictions of radiation levels.

It must be realized that radiation levels are subject to a wide variance, as discussed in Section 2. Once entry has been made it is imperative that a continuous survey be made by the reentry team and subsequent teams who follow until such time as detailed radiation mapping has been performed.

#### 7.1.3 Prerequisites to Initial Reentry

Prior to containment entry, preparations should be made to ensure worker safety and to avoid the release of airborne activity or contamination to the control and service building. The initial entry can be made through either personnel lock. Because the No. 2 personnel lock is located in the control building, and it is not anticipated that the containment service building, discussed in Section 4.1, will be completed when the initial reentry is made, it is assumed that the initial entry will be made through the No. 2 personnel lock.

A temporary contamination control envelope should be constructed as shown on Figure 7-1. This can be constructed using sheet plastic and fire-resistant treated wood. The intent is to close off the area around the entry point with two or more barriers and to vent each control zone to the temporary filter train installed on the auxiliary building roof. Doors would be provided in the plastic "tents" to permit personnel entry and egress.

A communications system should be provided as discussed in Section 4.1.12 and thoroughly checked out prior to reentry.

It should be assumed that some, if not all, of the containment lights are not working. The initial reentry team should wear hardhats with miner's lamps and take a beam flashlight with them.

A reentry procedure should be developed to identify radiation limits, the specific tasks to be accomplished, and emergency plans. Complete training and briefing of the reentry crews and their backups should be conducted. The training should include a thorough briefing on expected radiation levels, contingency plans if radiation levels are higher or lower than expected, step-by-step data acquisition plans, and emergency procedures.

The reentry team should be composed of two or three members with another standing by in the airlock. Personnel safety considerations dictate that at least two persons perform the initial survey in order to allow one to provide assistance to the other if an accident (e.g., slip or fall) should occur. On the other hand, high radiation levels dictate that the surveys be performed with as few people as is efficient to reduce man-rem exposure. It is assumed in this report that physical and radiological conditions in the containment following remote decontamination will permit the acquisition of radiation field, visual damage assessment and contamination smear sample data on the initial entry, and therefore a crew of three was selected. While the reentry team is in the containment, three or more persons should be properly suited out with breathing apparatus and prepared to make an immediate emergency entry if needed. See Section 7.4 for the functions of each person on the team.

#### 7.1.4

#### Systems and Containment Conditions for Reentry

Plant systems and containment conditions should be established which are favorable to personnel reentry. In order to reduce radiation levels to as low a level as possible, the remote decontamination methods outlined in Section 5 should be performed prior to entry. It is expected that the 282' elevation will be greatly contaminated at levels which will result in very high radiation dose rates. After the sump is drained and remote decontamination has been completed, severe contamination of the 282' elevation will remain. Much of this contamination will have settled out on the floor. Effective shielding and marked reduction of resuspension of airborne activity can be obtained by reflooding the 282'

elevation of the containment during occupancy of the containment. As noted in Section 5, two to three feet will be effective and should be maintained until later in the decontamination efforts when the 282' elevations will be cleaned.

The containment should be purged of the initial airborne activity as discussed in Section 6. The purge should be maintained during the reentry to maintain the containment at a negative pressure. This will minimize the risk of contamination release to the control building through the No. 2 personnel lock.

It is desirable from a personnel comfort standpoint and to improve worker efficiency to have the containment coolers in operation and maintain the containment temperature between 65 and 85° F.

The hydrogen concentration inside the containment should be analyzed. If the concentration is above 1%, personnel entry should be restricted until the purge or the recombiner is used to reduce the hydrogen concentration. See Section 7.4 for hydrogen sampling procedures during the initial entry.

#### 7.1.5 Specific Criteria for Reentry

In addition to the prerequisites noted above it is suggested that a specific set of criteria be established as part of the prerequisites to serve as a check list for last minute assessment of containment conditions. This list would serve to flag conditions or a range of conditions which if exceeded would indicate conditions outside the limits of the procedural assumptions. If excess conditions were found, special evaluation would be required before containment entry is permitted.

The criteria would be established for the major indicators of conditions inside of the containment. This would include the following parameters:

- Sample of sump water
- Sample of containment air
- Sample of reactor coolant system water
- Radiation levels at the inner door of the No. 2 personnel lock
- Containment dome radiation monitor HP-R-214 (if operable)
- Containment pressure
- Hydrogen concentrations
- Oxygen sufficiency

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## 7.2 Procedural Outline for Containment Entry

### 7.2.1 Data Acquisition Planning

The initial containment reentry should be made with a precise plan for data acquisition. The radiation levels will dictate the duration of stay time inside of the containment and therefore will be the controlling factor in the amount of data that can be acquired during the initial entry. Priorities should be established in order to make efficient use of the time of the reentry team, while attempting to maximize the data acquisition. General radiation levels (Section 2.2) and hot spot sources (Section 2.3) have been predicted and should be used as a guide to planning the initial reentry.

The radiation levels will dictate the plans for data acquisition after the initial entry and therefore become the highest priority for the initial entry as discussed in Section 7.5. Simultaneous with the radiation survey, a visual account of the status of the containment is important. Thirdly, as time and conditions permit, smear samples of contamination of the surfaces within the containment should be obtained.

Later entries for data acquisition will have the objectives of detailed radiation and contamination surveys (Section 7.5); installation of remote monitoring such as television and lighting, radiation monitors, etc. (Section 7.2.2); materials samples; and containment status assessment (Section 7.6).

Many requests for data will be made by many organizations regarding the status of the containment. In order to effectively use manpower, maintain low worker dose, and minimize the impact on the containment cleanup schedule, it is recommended that central coordination and pre-planning for data acquisition be instituted by GPUSC and Met Ed. An individual or a central group should be assigned for this coordination and planning. Each request for data should have the following information clearly defined:

- Sponsor and requesting organization
- Objectives of the data acquisition
- Justifications for obtaining the data
- An assigned responsible individual within the GPUSC TMI Recovery Organization
- Data acquisition plan and schedule
- Safety assessment
- Proper funding or cost reimbursement (if request external to owner's organization)
- Approvals required
- An assigned priority by the GPUSC TMI Recovery Organization management

An example of a log for coordination of the data acquisition phase is shown on Figure 7-2. A typical format for recording summary information for data acquisition requests is shown on Figure 7-3.

7.2.2

## Initial Reentry Plan

The timing of the initial reentry is subject to many considerations. A large uncertainty exists at this time as to the status of the containment and it is important to reenter the containment as soon as practical, but not until worker safety can be assured. The plan presented herein is intended to reflect only one approach regarding the timing and prerequisites of the reentry. It is not intended to impact other efforts underway to assess the containment status. Data acquired by such efforts could allow entry sooner or under different conditions than presented in this report.

The reentry procedure is summarized in the following outline:

- a. Prerequisites completed (Section 7.1.3)
- b. System/Facility conditions prepared for reentry (Section 7.1.4)
- c. Final data evaluation within reentry criteria (Section 7.1.5)
- d. Data acquisition tasks and priorities reviewed
- e. Communications and lighting systems prepared for entry
- f. As noted in Section 7.1.3, three persons are assumed to form the reentry team for the purposes of this study (two of which are health physicists and one familiar with plant layout), one person standing by in the airlock, and three persons acting as the emergency backups, all persons suited up.
- g. Open the outer hatch door of the No. 2 personnel lock
- h. Take radiation survey at the inner bulkhead of the personnel lock and take other surveys described in Section 7.4
- i. Close the outer hatch door
- j. Open the inner hatch door and immediately make a radiation survey inside of the containment as described in Section 7.4

**CAUTION:** If radiation levels at this point exceed the maximum specified in the procedure, personnel shall withdraw and close the inner hatch door for procedure reevaluation.

**NOTE:** Although entry may be permitted at higher levels, a general gamma field of 10 rem/hour just inside the inner air lock door is suggested as a maximum level for reevaluation of the entry procedure to reassess data acquisition priorities.

- k. Take smear samples inside the personnel lock inner door

- l. Make radiation surveys (Section 7.5)
- m. Make visual observations of the status of the containment
- n. Take contamination smear samples (Section 7.5)

**CAUTION:** Length of stay is limited by worker dose limits which in turn depend on the radiation levels experienced. Initial health physics guidance will be provided by a time limit which is established based on assumed radiation levels. If higher levels are encountered, the time of stay must be reduced accordingly. Constant communications with additional health physics and supervision personnel outside of the containment is necessary.

- o. Grab small samples of loose material (if any) and place in plastic bags.
- p. Return to the No. 2 personnel air lock
- q. Close the inner hatch door
- r. Open the outer hatch door and exit
- s. Carefully remove protective clothing in accordance with health physics practices to avoid unnecessary spread of contamination.

### 7.2.3

#### Emergency Plans

Contingency planning and emergency preparedness is necessary prior to containment entry. Emergency plans must be developed for at least the following situations:

##### a. Failure of Personnel Breathing Apparatus

This procedure should instruct the data acquisition team to immediately withdraw from the containment, with the unaffected member and the back-up person providing assistance to the affected team member.

##### b. Personal Injury

Same as in a., except it may be necessary to provide immediate assistance at the place of occurrence, depending on the situation.

##### c. Personnel Lock Seal Failure

This would result in airborne release to the control building which does not directly affect containment operations but might result in an upset of supervision or communications between the efforts of the personnel inside and the support group outside of the containment.

- d. **Malfunction of personnel hatch door interlocks preventing rapid egress.**
- e. **Extreme variability of beta and soft gamma radiation**

Personnel should wear several TLD's in order to properly assess the worker doses.

- f. **Communications Systems Failure**

Procedure should indicate the reentry team should withdraw back to the hatch or out of the containment until communications are restored.

- g. **Lighting Failure**

A strong battery-powered light should be ready to be set up just inside of the containment to provide lighting during egress.

- h. **Structural Damage Resulting in Hazardous Conditions to Personnel**

Visual observation should be made to avoid areas which may have been rendered unsafe during the incident.

- i. **Faulty Radiation Monitors**

Diverse, high level radiation monitors should be carried into the containment by the reentry personnel

- j. **Contingency Planning**

If the initial reentry cannot be made as planned, alternate procedures should be available and ready to use as fall back positions. These should include possible alternates such as: entering through the No. 1 personnel air lock, respray the containment and reenter, reduce contamination levels near the personnel lock by using water hoses, use of robots for radiation surveys, etc.

See Section 7.8 for evaluation of other possible hazards.

### 7.3 No. 2 Personnel Lock Contamination Control Zones

#### 7.3.1 General

Contamination control must be employed at the No. 2 personnel lock for containment entry. Despite the double door lock and precautions taken to vent the containment, personnel traffic into highly contaminated areas results in a resuspension of particulates which could spread contamination into the control and service buildings. In order to minimize the spread of contamination and provide an efficient means of access to the containment, contamination control zones are suggested as shown on Figure 7-1. The control zones are established by using the ante room to the personnel lock, the corridor in the control/services building and the existing health physics and change rooms.

In addition to contamination control zones, it is necessary to provide space to install communications, television, monitors, etc. in a central location in order to provide proper supervision of the reentry and data acquisition efforts. This could be established in the control room or turbine building, however, it would be more desirable to provide an isolated communications center for supervision that includes voice communications and later in the data acquisition stage, television monitoring. In order to provide other interested people with information, additional voice and television monitors should be installed outside the protected area. The communications center is shown on Figure 7-1.

#### 7.3.2 No. 2 Personnel Airlock Contamination Control Features

The ante room of the No. 2 personnel lock and the hot instrument repair shop can be completely stripped of extraneous materials and prepared for conversion into an entry/egress area (ante room) and a communications center (hot instrument repair shop). The door and wall between the two rooms would be sealed off from each other to maintain the communications center as a clean area. A temporary door should be constructed between the entry/egress area (Control Area I) and the adjacent corridor (Control Area II). The north area of the corridor should be sealed off, leaving the doors into the health physics and change room as the sole exit path. Health physics procedures are discussed in Section 7.4.

In order to ensure that air flow and infiltration occurs in the proper direction to minimize recontamination of clean areas (i.e., air flow is directed from clean areas, to moderately contaminated areas, to highly contaminated areas), temporary vent duct should run from each of the control zones to the auxiliary building filter and vent system.

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## 7.4

Health Physics Procedures and Personnel Equipment

The health physics procedures and required personnel equipment for personnel entry to the containment have essentially been established in the plant procedures manual. The general radiation protection program is given in Procedure 1003 - Radiation Protection Manual. Since containment conditions are expected to be somewhat different than anticipated when plant procedures were written, all procedures employed should be reviewed and revised as necessary.

Specific procedures governing containment reentry are:

- 1630 Reactor Building Entry
- 1630.2 Reactor Building Entry (Unit 2 only)
- 1670.8 Emergency Reentry for Repair or Rescue
- 1670.15 Post Accident Reentry and Recovery Plan

In addition, there are a number of ancillary procedures that should be followed which deal with radiation/radioactivity/smear surveys, and discussing protective clothing, personnel dosimetry, decontamination, etc:

- 1605 Portable Air Sampling for Radioactive Particulates
- 1606 Air Sampling for Radioactive Iodine
- 1607 Air Sampling for Radioactive Gas
- 1608 Air Sampling for Tritium
- 1609 Loose Surface Contamination Surveys
- 1611 Area and Equipment Decontamination
- 1612 Monitoring for Personnel Contamination
- 1613 Radiation Work Permits
- 1616 Use of Respiratory Protection Devices
- 1628 Program for Medical and Bioassay Examinations
- 1632 Radiation Shutdown Survey
- 1632.2 Radiation Shutdown Survey (Unit 2 only)
- 1640 Personnel Dosimetry, Issuance, Administrative, and Record Keeping
- 1641 Self-Reading Dosimeter Usage and Record Keeping
- 1642 Operation and Calibration of the TLD System
- 1676 Radiation Protection Responsibilities for Planned and Unplanned Releases
- 1681 Control of Contaminated Spills
- 1682 Control of Contaminated Tools, Equipment, and Material
- 1683 Handling of Contaminated Vacuum Cleaners
- 1686 Use of Protective Clothing
- 2202-1.2 Unanticipated Criticality

Strong chemical decontamination solutions included in Procedure 1611, Area and Equipment Decontamination, will not be used without explicit prior approval in each instance since a number of these chemicals are flammable, could cause irreparable damage to equipment, or could cause difficulties with radwaste processing and/or solidification.

The following specific protective clothing, respiratory protection, personnel dosimetry, and monitoring devices are suggested for the initial entry in addition to those listed in Procedures 1630, 1630.3, 1670.8 and 1670.15:

Required Personnel Clothing

- Hard hat with miner's lamp
- Self-contained breathing apparatus (60 minutes) (e.g., Bio Pak 60 - Bio Marine)
- 3-5 layers of full anti-C's with surgical cap, hood, rubber boots, outer layer plastic suit
- Rain gear including hat and coat
- TLD (several including finger rings to assess the directional variance of beta and gamma radiation expected).
- High range self-reading dosimeter
- Alarming dosimeter
- Regular self-reading dosimeter
- All dosimetry in plastic bags

Survey Equipment

Person #

Air sampler (particulate and iodine)	*
Gas sampler (noble gases)	*
Explosive gas meter	*
Teletector with lead collimator on probe	1
Smears	3
High range beta detector	2
Beam flashlight	2
Two-way radio communications	All

\* Standby person in airlock

Personnel on the initial entry should be two health physics personnel due to their familiarity with equipment, survey and radiation safety procedures and one person familiar with containment systems layout.

The administrative radiation limits should be set in accordance with Procedures 1003 and 1630.

Atmospheric samples should be taken of the airlock through the leak test connections before personnel open the outer door. These should be analyzed for particulate, iodine, and gaseous radioactivity, explosive or toxic gases, and oxygen sufficiency.

Before the inner door is opened, beta, gamma, and smear surveys should be performed and two-way communications checked.

When the inner door is cracked open and before personnel enter the containment, the teletector with probe extended should be used to determine the gamma dose rates inside the containment in the vicinity of the hatch and especially the dose rates near the floor and the ceiling where sump and operating deck radioactivity could cause extremely large dose rates. In addition, before personnel enter the containment, the explosive gas and oxygen meters should be utilized to determine what concentrations exist in the containment atmosphere. If all of the above readings are within permissible levels for personnel entry, then a beta reading should be taken on the deck in front of the inner hatch with the door open before personnel entry. The structural integrity of the floor slab should also be inspected as much as possible before personnel entry. When all of the above steps have satisfactory results, then actual personnel entry into the containment can commence.

The recommended maximum permissible general area radiation fields for entry should be based on a time and motion study with contingencies, and the administrative limits noted above. If the radiation levels are above these, then determine if the major contribution is from plateout on the 347' elevation (most likely). If the operating deck plateout is the major contributor, then additional remote decontamination may be required. If locally deposited radioactivity (305') is controlling, then water should be used to attempt to clear a pathway. (See Section 9).

When the initial entry is made, attempt to obtain as complete a beta/gamma/smear/particulate/iodine/noble gas survey as integrated dose permits.



## 7.5 Radiation/Radioactivity Mapping

### 7.5.1 Equipment Required

Equipment noted in the procedures listed in Section 7.4 are also recommended during in-containment work following the initial entry.

### 7.5.2 Radiation/Radioactivity Mapping Procedure

Before opening the inner hatch of the airlock, the following radiation/radioactivity surveys should be made to the extent feasible:

#### Airborne Particulates and Iodine

To determine whether or not the seals on the inner door are leaking.

#### Noble Gases

Same reason as above

#### Smears

Same reason as above

#### Gamma Survey of Inner Door Area

To determine expected gamma dose rates immediately inside of the airlock in order to estimate stay times.

After the inner door is cracked open, the surveys should be repeated.

The gamma survey can easily be performed by inserting the teletector probe through the cracked open door to determine general gamma radiation levels, how intense the plateout on the floor is and approximately what the plateout on the operating deck might be. The Rad-Owl with window open can be held through the open door at floor level to determine beta plateout.

If all of the readings are within acceptable limits (see Section 7.4), then the initial entry may proceed.

For the initial entry, it probably will not be possible to perform a detailed survey of the entire containment due to high radiation levels. Rather, it would be more important to survey the areas needed first for cleanup and subsequent tasks. In this regard, the area around the No. 2 personnel airlock, the equipment hatch, the stairways, the elevator and the pathways between should be of prime importance. The operating deck, the ladder to the polar crane, and the polar crane itself are

important but most likely will have to be surveyed later after they are flushed by water due to the high plateout generated radiation levels expected.

The surveys to be taken on the initial entry should be radiation levels, hot spots, general area and plateout. Beta plateout surveys on surfaces, especially floors are important. The smear surveys should be isotopically analyzed to determine which isotopes are present so that the decontamination chemicals can be chosen appropriately. The airborne particulates, iodine, noble gases, tritium (if feasible) will indicate if the respirator protection factors are adequate. All of the above surveys will affect the allowable personnel stay times in the containment. Each of these survey duties should be divided up as described in Section 7.4.

## 7.6 Damage Assessment

### 7.6.1 Containment Status Survey

After detailed radiation maps are made (Section 7.5), a thorough assessment should be made of the containment, including equipment, structures, instrument and electrical equipment, wire, cable and cable tray, etc. A complete status of the containment is necessary, but radiation levels may dictate special methods in certain areas. Some of the survey and data acquisition may have to be deferred until after some decontamination and shielding has taken place.

Visual observations are extremely important but permanent records should also be obtained. The installation of television cameras in strategic locations on the 305' and the 347' elevations, coupled with appropriate lighting, are needed to aid in the supervision of data acquisition and decontamination. Television pictures of reentry tasks should be video taped and voice recordings made of the telemetered visual observations for future reference. Photographic (including stereographic pictures) should be made to assist work planning for future operations inside the containment.

The status survey should be consistent with the prioritized listing of data acquisition requests as discussed in Section 7.2.1. Radiation levels may require changes in the sequence of the survey, however, in order to make efficient use of personnel and keep worker dose low.

The survey of the physical status of the containment should follow the general outline provided below for visual observation and certain sample acquisition:

#### a. 305' Elevation

- Floor slab
- Structural columns
- Elevator shaft walls and east stairwell walls
- Ventilating duct integrity
- Cable tray and chase integrity
- Physical status of the containment air coolers and piping
- Acquisition of material samples to assess chemical composition of plateout (it is assumed the radiological survey for dose rates and surface contamination was performed)
- Retrieval of small instruments
- West stairs up to 347' and down to 282' elevations

b. 347' Elevation

- Floor slab
- Structural columns
- Elevator shaft and east stairwell walls
- Ventilating duct integrity
- Neutron shield tanks (in refueling cavity)
- CRDM leads
- CRDM shroud and vessel head insulation
- Fuel handling machines
- Incore instrument service area
- Acquisition of material samples
- West stairs up to 367' elevation

c. Above 347' Elevation

- Steam generator insulation
- Reactor coolant pump motor
- Pressurizer
- Pressurizer relief valves
- Polar crane bridge and trolley
- Material samples from polar crane trolley
- Containment spray header piping

d. 282' Elevation

- Shield walls and blockouts
- Evidence of hydrogen burn
- Structural columns
- Ventilating duct integrity
- Cable tray and chase
- Material samples
- Preselected instruments
- Effects of water
- Reactor coolant drain tank rupture disk vent line
- As radiation levels permit, inspection of equipment, supports and structures

## 7.7                    Man-Rem Dose Commitment for Initial Entry

### 7.7.1                General

The initial containment reentry for radiation mapping is necessary to provide for planning subsequent entries for data acquisition and cleanup. A certain worker dose can be expected for this operation. With careful planning, the reentry can be conducted with worker doses which are within current plant administrative limits. This is achieved by predictions of radiation fields, work planning, and special procedure considerations (addressed in other parts of Section 7.0).

### 7.7.2                Radiation Field Predictions

A prediction of expected radiation fields, especially the identification of hot spots, should allow work planning and the preparation of the procedures for entry and data acquisition to consider the proper balance between worker dose and data acquisition. For the case of initial entry, it is appropriate to allow higher worker doses for radiation field mapping, as discussed in Section 7.5, consistent with administrative guides and Federal Regulations related to quarterly dose limits.

The prediction of radiation fields following remote decontamination indicates that substantially all of the 305' and 347' elevations, and portions of the 282' elevation can be mapped using three teams of three people (plus people standing by in case of emergency) with a man-rem dose of 5 to 20 rem total for the nine people who enter the containment, with no individuals exceeding the quarterly limit.

### 7.7.3                Work Planning

The prediction of radiation fields should be used in conjunction with procedure dry runs using the 1/2-inch scale model, and stay times verified by experience. Simulation training should be conducted in full protective clothing and breathing apparatus to obtain proper times for each procedure step. This planning will allow tradeoffs to be made for optimizing the surveys if the radiation levels are significantly different from predictions.

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## 7.8 Potential Problems and Hazards Analysis

There are a number of potential problems and hazards that may be faced, not only on initial entry but also on subsequent entries. A summary list is as follows:

- Explosive gases
- Oxygen deficient atmosphere
- Toxic gases or particulate material
- Fire
- Electrocution
- Asphyxiation due to respirator problems
- Personal injury (cuts, falls, broken bones, concussion)
- Structural failure (due to hydrogen burn)
- Lack of lighting - lights burned out
- Overexposure due to direct radiation
- Inhalation overexposure
- Personal contamination
- Unanticipated criticality
- Falling objects

### 7.8.1 Explosive Gases

There already has been a hydrogen detonation as discussed in Section 3. It is possible that there are still pockets of hydrogen left. In addition, hydrogen and methane can be generated by radiation induced decomposition of organic materials. Section 7.4 describes the equipment and procedures necessary to test for explosive gases. The containment should not be entered if the concentration of explosive gases is above 1%. Purging should be used to reduce this as much as possible.

### 7.8.2 Oxygen Deficient Atmosphere

Since there has already been a hydrogen detonation some of the oxygen has been used up in the combustion process. Purging the containment before personnel entry should alleviate this problem but there is still a possibility that pockets of oxygen deficiency exist. This may not be a problem on initial entry since SCBA gear should be worn due to airborne radioactivity problems.

### 7.8.3 Toxic Gases or Particulate Material

The nature of damage in the containment could have released toxic gases or particulate material into the containment due to radiation dose, the hydrogen detonation effects on materials, etc. SCBA gear should provide necessary protection until air samples are taken.

### 7.8.4 Fire

Fire is an important consideration especially when large amounts of plastic are used for contamination control and when torch cutting and welding operations are proceeding. Fire extinguishers, fire hoses, and fire observers should be available during these operations.

**7.8.5            Electrocutation**

With all of the decontamination water, electrical equipment and extension cords during the hands-on decontamination phase, a possibility of electrocution should be considered. Electrical equipment in an area being decontaminated should be deenergized. Auxiliary lighting should be used. Extension cords should not lie on the floor and extension cord connections should be watertight.

**7.8.6            Asphyxiation Due to Respirator Problem**

Personnel having difficulties with their respirator should follow Procedure 1616 and leave the containment immediately. If personnel are unable to obtain air, they should disconnect the respirator hose or remove the respirator while exiting the containment as expeditiously as possible. Personnel should take care in testing their respiratory equipment before entering the containment.

**7.8.7            Personal Injury**

Care should be taken by personnel to follow standard safety procedures for the work place. Cuts, falls, broken bones, concussions, etc. are all possible injuries that should be avoided especially due to the difficult conditions inside the containment.

**7.8.8            Structural Failure**

When the hydrogen detonation occurred, it could have caused structural damage in the containment. Personnel should look for cracks in the floor or separation from the walls, before venturing into the containment.

**7.8.9            Lack of Lighting**

Operating plants have burned their lights out by leaving the lights on during operation. The refueling outages have then been delayed while lamps were being replaced. Soon after the incident the lights in the containment were turned off but it is possible that they may be burned out. The regular lights in an area might not be used during decontamination of the area because the water or steam jets could break the lights. Miner's lamps and auxiliary lighting could be used.

**7.8.10           Overexposure due to Direct Radiation**

Personnel will be protected by proper use of their survey instruments, personnel dosimetry, and calculated stay time in high radiation areas. Frequent checking of their self-reading dosimeters is required. Prompt compliance with health physics instructions on the termination of stay times is mandatory. These methods will be used to minimize the possibility of overexposure.

#### 7.8.11 Inhalation Overexposure

Personnel should be trained in the proper use of respirators and tested for proper fit. Whole body counts, both baseline and after containment entry, should be carried out to check for possible inhalation exposures.

#### 7.8.12 Personal Contamination

Several layers of protective clothing should be worn inside of the containment. Personnel should be trained in the proper procedures for donning and removing this clothing as described in Procedure 1686. Decontamination of personnel should be treated as described in Procedure 1612.

#### 7.8.13 Unanticipated Criticality

While the likelihood of accidental criticality remains small, special instrumentation should be installed to detect and alarm such an occurrence as described in Section 4.2.13. In the event of such an alarm, personnel should evacuate the containment as quickly as possible.

#### 7.8.14 Falling Objects

Since there was a hydrogen detonation, there is a possibility that there is structural damage to floors and walls in the containment. In addition, the anchors for cable trays, piping, etc. could have been loosened. The stairways and elevator could be damaged. An inspection of the structural integrity of the containment and equipment inside could be performed. Personnel should be extremely cautious concerning loose equipment until the inspection is complete. Hard hats should be required. Climbing on equipment supports should be discouraged. Scaffolding should be erected until the integrity of structures has been ascertained.



## 7.9 Alternate Initial Containment Entry with Remote Controlled Manipulators

### 7.9.1 General

In the event that a decision is made to enter the containment building at a time when radiation levels are too high to permit manned access, a remote controlled mechanical vehicle (Robot) will be evaluated and considered for the initial containment entry. Utilization of this type of remote controlled manipulator(s) would limit exposures to health physics personnel, and allow entry into the containment to secure radiation surveys, dose rate assessment evaluations and observations of the general containment conditions at the point of entry on the 305' level. Remote controlled manipulators are capable of obtaining dose rate data, taking various samples of surface contamination, and providing a visual (TV) assessment of the general condition of the containment. In addition, a robot could provide essential data to aid in the remote decontamination effectiveness evaluation. (Section 5.0)

Meetings have been held with representatives from Atomic International (AI) concerning the applications and availability of remote manipulators. AI explained and provided information and documents concerning three remote manipulator units (see Section 7.9.5.1 through Section 7.9.5.3) that were available for immediate delivery or use. The remote manipulators available are: PaR Model 3500, located at AI's headquarters in Canoga Park, California, and two Wireless Observing Remote Manipulators "WORM". One WORM is located at the Rocky Flats facility and the other at Lawrence Livermore Laboratory and both are the property of the Department of Energy. The "WORM" would require modifications to accommodate a wireless television system. AI estimated that it would require 3 to 4 months to complete the required modifications.

### 7.9.2 Vital statistics on the remote controlled manipulators:

#### 7.9.2.1 Wire Controlled Mobile Manipulator

PaR Mobile Manipulator, developed by Programmed and Remote Systems.

##### 7.9.2.1.1 Design Functions

Remote controlled device to replace a man in a hazardous environment.

##### 7.9.2.1.2 General Description

Tracked vehicle supporting vertically telescoping tube which supports PaR Model 3500 mechanical arm. Connects with controller by means of a cable. Drawbar sufficient to handle approximately 200 feet of cable.

**7.9.2.1.3      General Specifications**

**Mechanical Arm (PaR Model 3500)**

Weight	110 Pounds
Reach	49 Inches
Handling Capacity (any position)	100 Pounds

**Vehicle with Arm**

Weight	500 Pounds (approx.)
Vertical Reach	Greater than 9 Feet
Minimum Height	Approximately 5 Feet
Width	30 Inches
Length	30 Inches
Power Requirements	120 VAC

**7.9.2.2      Radio-Controlled Mobile Manipulator**

WORM - Wireless Observing Remote Manipulator, developed by Rocky Flats.

**7.9.2.2.1      Design Function**

Remote rescue device to recover injured man in hazardous environment.

**7.9.2.2.2      General Description**

Tracked, low profile vehicle equipped with mechanical arm and television with lighting. Battery powered, radio-controlled. Vehicle has demonstrated capability to climb standard industrial stairs.

**7.9.2.2.3      General Specification**

**Vehicle with Arm and TV**

Weight	Approximately 650 Lbs.
Length	52 Inches
Width	26 Inches
Height (Arm extended Vertically)	85 Inches
Draw Bar Pull	250 Pounds

**Mechanical Arm only**

Handling Capacity (any position)	Greater than 20 Lbs.
Reach (Horizontal)	60 Inches
Power Requirements	120 VAC

**NOTE:** The "WORM" manipulator units at Rocky Flats and the Livermore Labs will require modifications to accommodate a wireless closed circuit television system. Also, the antenna system for the remote radio controls may require a significant modification for in-containment operations due to signal dissipation by the building walls.

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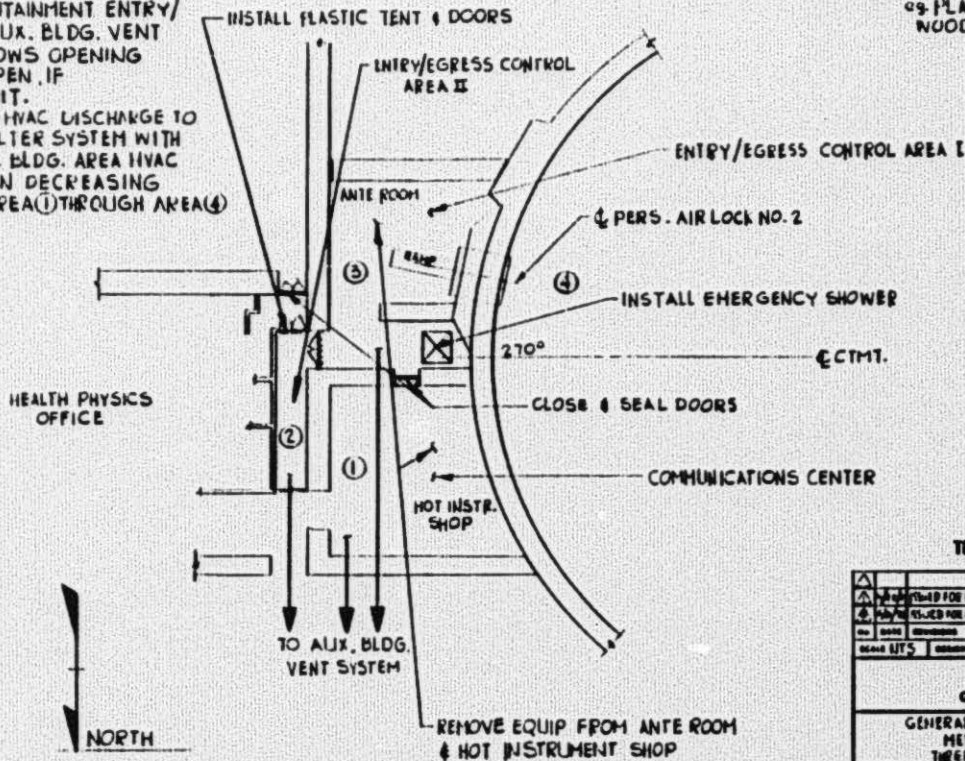
ORIGINAL  
POOR

**NOTE:**

INSTALL CONTAMINATION CONTROL ENVELOPE FOR CONTAINMENT ENTRY/EGRESS, VENT TO AUX. BLDG. VENT SYSTEM. THIS ALLOWS OPENING HATCH & LEAVING OPEN, IF CONDITIONS PERMIT. INTEGRATE PROPOSED HVAC DISCHARGE TO AUX BLDG. VENT/FILTER SYSTEM WITH EXISTING CONTROL BLDG. AREA HVAC SO AS TO MAINTAIN DECREASING PRESSURE FROM AREA ① THROUGH AREA ④

**LEGEND**

~~~~~ TEMP CONTROL BARRIER,  
eg PLASTIC SHEETING IN  
WOODEN FRAMES



**TMD-2 INITIAL PLANNING STUDY**

|           |                     |      |          |          |          |
|-----------|---------------------|------|----------|----------|----------|
| Δ         | APPROVED FOR EDPB 1 | RES  | OK       | OK       | OK       |
| Δ         | APPROVED FOR REVIEW | RES  | OK       | OK       | OK       |
| DATE      | APPROVED BY         | DATE | DATE     | DATE     | DATE     |
| DEAN LITS | REVIEWED            | RIC  | REVIEWED | REVIEWED | REVIEWED |

**BECHTEL**  
GAITHERSBURG, MD.

GENERAL PUBLIC UTILITIES CORP  
METROPOLITAN EDISON  
TREE HILL ISLAND - UNIT 2

CONTROL ACCESS  
AT NO. 2 PERSONNEL HATCH  
FIG 7-1

|  |           |                 |     |
|--|-----------|-----------------|-----|
|  | APP No.   | CONTROLLING No. | REV |
|  | 13587-003 | SK-TMD/CBE-5    | 1   |

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FIGURE 7-2

TMI-2 CONTAINMENT DECONTAMINATION

DATA ACQUISITION TASK LOG

| Item/<br>Date<br>Recorded | Sponsor/<br>Requesting<br>Organization | Correspondence<br>Reference | Entry Task                                  | Responsible<br>Project<br>Team Member | Assigned<br>Priority |
|---------------------------|----------------------------------------|-----------------------------|---------------------------------------------|---------------------------------------|----------------------|
| 1                         |                                        |                             | Radiation Survey @ El. 305'                 |                                       | 1                    |
| 2                         |                                        |                             | Radiation Survey @ El. 347'                 |                                       | 1                    |
| 3                         |                                        |                             | Radiation Survey @ El. 282'                 |                                       | 2                    |
| 4                         |                                        |                             | Contamination Samples @ El. 305'            |                                       | 1                    |
| 5                         |                                        |                             | Contamination Samples @ El. 347'            |                                       | 1                    |
| 6                         |                                        |                             | Contamination Samples @ El. 282'            |                                       | 2                    |
| 7                         |                                        |                             | Install Radiation Monitoring                |                                       | 2                    |
| 8                         |                                        |                             | Install TV Cameras                          |                                       | 2                    |
| 9                         |                                        |                             | Replace (Modify) Vital Instrumentation      |                                       | 2                    |
| 10                        |                                        |                             | Photographic Survey                         |                                       | 3                    |
| 11                        |                                        |                             | Material Samples                            |                                       | 4                    |
| 12                        |                                        |                             | Replace Personnel Hatch Seals (Save-O-Ring) |                                       | 3                    |
| 13                        |                                        |                             | Visual Inspection of Components             |                                       | *                    |
| 14                        |                                        |                             | Air and Water Samples                       |                                       | 2                    |
| 15                        |                                        |                             | Inspect Polar Crane Trolley                 |                                       | 3                    |
| 16                        |                                        |                             | Visual Observation of Structures            |                                       | 2                    |

\* By Component

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TMI-2 INITIAL PLANNING STUDY

FIGURE 7-3

TMI-2 CONTAINMENT DECONTAMINATION  
DATA ACQUISITION SUMMARY INFORMATION

1. Item \_\_\_\_\_
2. Date Recorded \_\_\_\_\_
3. Sponsor/Requesting Organization \_\_\_\_\_
4. Correspondence Reference \_\_\_\_\_
5. Title \_\_\_\_\_
6. Summary of Objectives \_\_\_\_\_  
\_\_\_\_\_
7. Reasons/Justification for Data Acquisition \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
8. Data Acquisition Plan and Schedule \_\_\_\_\_  
\_\_\_\_\_
9. Summary of Safety Assessment \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
10. Method of Funding \_\_\_\_\_  
\_\_\_\_\_
11. Priority Assessment \_\_\_\_\_
12. Approvals \_\_\_\_\_

## 8.0 HEALTH PHYSICS PROCEDURES FOR HANDS-ON DECONTAMINATION

### 8.1 Protective Clothing and Respiratory Protection

The protective clothing and respiratory protection requirements are also discussed in Section 4.1.5 and 7.4. They are summarized here for completeness.

Three layers of protective clothing should be used as a minimum with a raincoat and hat over the top and rubber boots on the feet. The outer layer of clothing should be waterproof plastic. SCBA's with 60 minute capacities should be used initially. Later air line masks and hoods with air filled suits can be used once the air supply is set up and protection factors provided by the particular systems are adequate. The air filled suit will provide a more comfortable and more efficient working environment. Hard hats with miner's lamps could also be used at least until auxiliary lighting is available. The protective clothing can be put on in the new access control building. The outer layer of clothing can be removed upon exiting the plastic enclosure surrounding the area inside the containment being decontaminated or at the airlock step off pad. The second layer should be removed outside the access control point or the secondary plastic enclosure. The third set can be removed at the step off pads in the containment access control facility described in Section 4.3.

## 8.2

Entry Procedures

The health physics procedures for containment entry are given in Sections 7.4 and 8.1 and in the following procedures:

|         |                                         |
|---------|-----------------------------------------|
| 1630    | Reactor Building Entry                  |
| 1630.2  | Reactor Building Entry (Unit 2 only)    |
| 1670.8  | Emergency Reentry for Repair or Rescue  |
| 1670.15 | Post Accident Reentry and Recovery Plan |

and a number of ancillary procedures listed in Section 7.4.

These procedures should be followed for hands-on decontamination except that certain surveys may only be necessary for the initial entry and can be discontinued when shown to be of negligible value.

Entry will be through the containment access control facility described in Section 4.3.



### 8.3 Exit Procedures

The health physics procedures for containment exit are given in Sections 7.4 and 8.1 and in the procedures listed in Section 8.2.

These procedures should be followed for hands-on decontamination also except that, as the cleanup progresses, the respiratory protection and protective clothing requirements can be reduced. The respiratory protection might consist of air-line masks and hoods with air cooled suits rather than SCBA's after the decontamination gets underway. Later, cannisters might be used instead of supplied air. The personnel exit should be through the equipment hatch and the containment access control facility described in Section 4.3.

8.4 Contamination Control Procedures and Facilities

Contamination control procedures are provided in plant procedures:

|      |                                                           |
|------|-----------------------------------------------------------|
| 1003 | Radiation Protection Manual                               |
| 1609 | Loose Surface Contamination Surveys                       |
| 1612 | Monitoring for Personnel Contamination                    |
| 1681 | Control of Contaminated Spills                            |
| 1682 | Control of Contaminated Tools, Equipment,<br>and Material |
| 1683 | Handling of Contaminated Vacuum Cleaners                  |
| 1686 | Use of Protective Clothing                                |
| 1780 | Protective Clothing Laundering                            |

These procedures should be followed to the extent they are applicable to plant conditions. Additional contamination control facilities would be available in the containment access control facility described in Section 4.3.

### 8.5 Personal Equipment Decontamination Procedures

The decontamination procedures for personal equipment are given in the following procedures:

- 1003 Radiation Protection Manual
- 1611 Area and Equipment Decontamination
- 1612 Monitoring for Personnel Contamination
- 1682 Control of Contaminated Tools, Equipment and Material
- 1683 Handling of Contaminated Vacuum Cleaners

These procedures should be followed except that vacuum cleaners should not be required to be cleaned upon reaching 50 mr/hr and should not be required to be cleaned to less than 25 mr/hr. Otherwise, they would have to be replaced frequently. Equipment should be considered clean if the loose surface contamination is less than 1000 dpm and the fixed contamination gives less than 0.4 mrem/hr at one inch.

An important point is that equipment that can function inside of plastic wrapping should be so protected before being taken into the containment so that it does not become contaminated in the first place.

Personnel dosimetry should be kept in clear plastic bags so that it will not become contaminated and the self-reading dosimeters can still be read.

## 8.6 Personnel Exposure Control, Monitoring and Administrative Limits

### 8.6.1 Administrative Limits

Administrative limits are set as goals to be sought after and not as absolute limits. These administrative limits are chosen to ensure that worker exposures do not exceed 10 CFR 20 limits.

The following are recommended administrative limits:

- 1 rem/quarter whole body with no NRC Form 4 \*
- 2.5 rem/quarter whole body with NRC Form 4 \*
- 7.5 rem/quarter skin \*
- 18.75 rem/quarter extremities \*
- Wear cannister respirators when surface contamination is greater than  $10^5$  dpm/100 cm<sup>2</sup>
- Wear air-line masks or SCBA when surface contamination exceeds  $10^6$  dpm/100 cm<sup>2</sup>
- Wear respiratory protection when the airborne isotopic radioactivity is unknown and greater than  $3 \times 10^{-10}$  uCi/cc but known not to be alpha

\* These administrative limits are to ensure compliance with 10 CFR 20 and are given in Procedure 1003, Radiation Protection Manual.

Other administrative limits are given in the Radiation Protection Manual, Procedure 1003 and in other ancillary procedures listed in Section 7.4.

### 8.6.2 Work Surveillance

Health physics personnel should time all personnel inside the containment. The timing function should be done from the communications center.

Residual gamma and beta radiation levels and hot spots should be surveyed after each step in the decontamination phase is completed for each area to determine the decontamination factor and whether or not personnel will be allowed access to the area and for what period of time without further decontamination. Work should be surveyed before each crew begins work and after they complete their allotted stay time.

Cart mounted continuous airborne particulate, iodine and noble gas monitors with a tritium detection capability should be available to continuously monitor airborne radioactivity. The monitors should have local and communications center displays and alarms to permit surveillance of the work areas from the communications center.

Airborne particulate and iodine surveys should be performed hourly during initial decontamination or whenever some operation is performed that might be expected to produce high airborne radioactivity.

#### 8.6.3            Radiation Monitoring

The special radiation monitoring equipment should be installed as described in Section 4.2.13 and should have readout in the communications center. Since the supervisor in the communications center will have two-way communications with personnel inside the containment, he can control their stay times based on surveys and continuous monitor readings. He should have a set of large survey maps of the containment by elevation and section views which should be continually updated with the latest readings and survey results.

#### 8.6.4            Emergency Procedures

Emergency procedures should be followed as described in the plant emergency procedures given in:

|         |                                 |
|---------|---------------------------------|
| 1004    | TMI Emergency Plan              |
| 2202    | Plant Emergency Procedures      |
| 2203    | Plant Abnormal Procedures       |
| 2204-7  | Fire Protection Procedures      |
| 2204-12 | Radiation Monitoring Procedures |

Additional information is given in the following procedures:

|          |                                         |
|----------|-----------------------------------------|
| 1003     | Radiation Protection Manual             |
| 1612     | Monitoring for Personnel Contamination  |
| 1670.8   | Emergency Reentry for Repair or Rescue  |
| 1670.15  | Post Accident Reentry and Recovery Plan |
| 1681     | Control of Contaminated Spills          |
| 2202-1.2 | Anticipated Criticality                 |

There are other ancillary procedures which should be followed that are listed in Section 7.4.

In essence, the supervisor in the communications center should have two-way communications with and TV pictures of personnel working inside the containment with the aid of temporary lighting. He can advise personnel of the proper actions to be taken for the particular emergency involved. He should also inform the control room immediately. If any alarm involving the containment sounds in the control room, the control room should immediately inform the supervisor in the communications center.

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**8.6.5 Backup Workers**

The need for backup workers will be determined after initial entry. Should an emergency occur, additional personnel should be prepared for emergency entry into the containment.

Fire observers with fire extinguishers will be needed whenever torch cutting or welding is being performed.

**8.6.6 Shielding**

Temporary shielding for the hands-on decontamination phase is described in Section 9.6.

**8.6.7 Ventilation Control**

The ventilation control system is described in Section 4.2.3. The steam generator compartments should be sealed at the top to ensure that the flow of air is from less contaminated areas toward the more contaminated areas in order to minimize recontamination of cleaned areas.

Plastic enclosures or tents should be set up around equipment or hot spots being decontaminated with filtered (HEPA and charcoal) temporary ventilation exhaust. The temporary ventilation can consist of portable blowers and elephant trunks.

Equipment or areas which have been cleaned should be sealed off with plastic to prevent recontamination while the rest of the containment is being decontaminated.

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9.0 HANDS-ON DECONTAMINATION

9.1 Procedural Outline and General Plan

9.1.1 Gross Decontamination

A detergent solution washdown is considered to be the prime method for the initial hands-on decontamination for the following reasons:

- a. It would allow personnel to stay relatively far away from high levels of contamination due to the distance that the spray will travel (up to 50 feet).
- b. The likelihood that other methods will not be able to reach the dome from the polar crane without scaffolding, with consequent high exposures.
- c. The need for large quantities of water to flush the high levels of loose surface contamination away rapidly to minimize exposure times and sweep it to the sump.

The implementation of hands-on decontamination would occur after completion of the remote decontamination procedures. Gross decontamination would be performed using demineralized water with a mild, chloride-free detergent delivered through the fire protection system. The system lineup would be as shown in Figure 4-14. The maximum hose size should be limited to 1-1/2" for safety. There should be no attempt to perform extensive cleanup using this method in order to minimize the quantity of liquid radwaste generated. This operation would start from the personnel airlock at the equipment hatch, if the service building is completed, to allow early equipment access if the floor below is structurally sound. Otherwise, the other personnel airlock would be used. The gross decontamination would initially involve cleaning the 305' elevation, especially the stairs and in front of the equipment hatch, and then proceed up the stairs to the operating floor, clearing a pathway toward the polar crane, allowing personnel to decontaminate the containment from the top down. Temporary shielding of hot spots along the pathway may be required.

While the dome will be difficult to decontaminate due to its inaccessibility, cleanup is necessary since contaminated material would otherwise continue to come loose from the dome, recontaminating everything below. The gross decontamination of the dome might be accomplished by hosing down the ladder to the polar crane and then hosing the dome from the crane (a distance of 50 feet). If this is not possible, then an alternate method of using multiple cranes should be attempted. Scaffolding may be necessary to reach the dome for decontamination.

The hatch in the floor on the 347'6" level could be removed using the polar crane, if still usable, otherwise a hand rigged crane could be used. Removing the 347' hatch would allow equipment to be moved to the 347' elevation. A boom crane could be rigged to lift

personnel up to decontaminate the dome if the polar crane could not be used. Installing a water cannon on the operating floor would be another possibility.

After the dome is cleaned, the polar crane would be next. The operating floor, 305' elevation outside of the "D" rings, steam generator compartments, equipment compartments, etc., will be decontaminated working from the top down.

Equipment exteriors would be flushed with water when that particular area was being cleaned. Since much equipment will have to be replaced, extensive interior cleaning is probably not justified unless it can be performed rapidly and will result in a major decrease in radiation level.

#### 9.1.2 Detailed Decontamination

Detailed decontamination would first be performed using saturated steam at low pressure with a mild, chloride free detergent from hand held steam nozzles. The steam nozzles should be sufficiently long to allow personnel to stand back from the contaminated surface to minimize exposure. Again, decontamination would proceed from the top of the containment towards the bottom. In this case, the time spent cleaning a given area would be longer than for the initial gross decontamination, but the dose rates should be lower. The steam decontamination method should provide a considerable decontamination factor for building surfaces and equipment exteriors so that they will no longer be a high source of radiation. Residual contamination will still be present, however.

Hydrolasers were considered for use as the prime method for detailed hands-on decontamination in the containment but the steam cleaning method was determined to be preferable. The disadvantages of the hydrolaser are:

- a. The higher airborne radioactivity it would generate. (The hydrolaser tends to dislodge activity without dissolving it and solubilities are higher in the high temperature condensate than in cooler hydrolaser water).
- b. The longer time period required to cover the area involved and consequently higher personnel exposures.
- c. The larger quantity of water required compared to steam cleaning.
- d. The personnel injury hazard due to high pressure jet.
- e. The relatively short distance the spray will reach with consequently higher personnel exposure by being close to the contamination.



- f. The removal of coatings by the jet allowing rust to form on the liner or resulting in bare concrete which would be even harder to decontaminate later.

During the steam cleaning, certain highly contaminated areas on the lower levels should be partitioned off with plastic sheeting to prevent it from recontaminating those areas already cleaned. These areas should include the steam generator compartments and other equipment compartments below the operating floor.

Personnel would be directed in the decontamination effort through the use of TV and two-way communication systems including microphones inside of the masks for ease in understanding.

Due to the possibility of radiolytic decomposition of the epoxy coatings, generating methane gas bubbles which migrate to the surface and burst leaving craters which can trap contamination, and the fact that there is no solvent which will remove the epoxy, there may be a need to remove large areas of epoxy coating by mechanical means, especially where plateau sources are high (e.g., the operating deck). Grinding and sand blasting generate airborne radioactivity, but needle guns generate chips which can be vacuumed up.

Hot spot decontamination on smooth surfaces can be performed using a mild, chloride free detergent such as Radiacwash and manual scrubbing. Contamination residing on complex surfaces which cannot easily be removed with the above methods should be prevented from recontaminating clean areas, e.g., using plastic or peeloff coatings.

#### 9.1.3 Task Planning

All tasks should have written approved procedures before they are initiated. All personnel should be trained in the procedure before commencing each task. Progress meetings should be held on each shift turnover.

#### 9.1.4 Personnel Preliminary Training

9.1.4.1 Preliminary training should include the RWP training course, which discusses basic principles of radiation, contamination, 10 CFR 20 limits, administrative limits, methods of measurement, biological risks, posting of signs on areas, radiation work permit procedures, general methods of minimizing exposure, general methods to prevent personal contamination, general methods to prevent the spread of contamination, airborne radioactivity, respiratory protection equipment, and emergency procedures.

#### 9.1.4.2 Visual Aids

Portable TV cameras mounted on tripods, with remote slewing controls, and a two-way audio system should be used in the containment, similar to the way it is presently being used in the cleanup of the auxiliary building. This system would enable the workers to see the actual work

location and the existing conditions prior to containment entry. It would also allow the workers to be remotely directed in their decontamination efforts and allow the workers to ask questions as they proceed. Health physics personnel would be able to monitor the workers without receiving exposures themselves.

Closeup still photographs (including stereographic photographs) and slides can also be used to show fine detail of some operations. Similar equipment on Unit 1 could be used as models for photographs.

## 9.2 Gross Surface Decontamination

### 9.2.1 General

General gross surface decontamination will be performed using a detergent solution flush. The situation will be evaluated upon initial entry. Water lances, flared nozzles, or fire nozzles may be used depending upon the condition. The decontamination solution should be demineralized water with a mild, chloride free detergent. The gross decontamination would be used to establish an entry pathway into the containment, and to flush readily removable contamination that the remote decontamination efforts missed. This effort would have to balance the generation of liquid waste versus the high man-rem that would be received in the detailed decontamination without eliminating loose contamination first.

### 9.2.2 Prerequisites

- a. Complete remote decontamination.
- b. Flush containment with demineralized water to clean out all tritiated water.
- c. Pump out all contaminated water from the containment and reflood with demineralized water to act as a shield as discussed in Section 5.
- d. The fire protection system in the containment should be connected to the demineralized water supply. The normal fire protection water supply to the containment should be secured.
- e. The detergent solution is mixed with the proper quantities of demineralized water in a mixing tank and is transferred to the sodium thiosulfate tank for storage. (see Figure 4-13).
- f. The containment atmosphere shall have been purged of noble gases and iodine removed by the building filtration system.
- g. Personnel shall have been thoroughly trained in the use of protective clothing and respiratory protection.
- h. Incandescent lamps in the area to be decontaminated are turned off if the sealed domes have been damaged by the hydrogen detonation. Quartz-iodine temporary lighting should be used instead.
- i. To the extent possible all electrical equipment in the area to be cleaned will be deenergized before commencing decontamination.

### 9.2.3 Method

The method will consist of rapid manual washdown of contaminated areas.

### 9.2.4 General Procedure

The gross decontamination effort should begin at the personnel airlock through the equipment hatch if the service building is completed. This airlock was selected since it would permit the earliest equipment access to the containment. If access through this hatch is not permissible, then the other personnel airlock will have to be used.

First an entrance path would be cleared between airlocks by flushing the radioactivity outward and away from the airlock with detergent solution. Miners lamps on hard hats could be used at first, then portable quartz-iodine lamps would then be set up in the flushed area to allow progress in decontaminating up the stairway to the operating floor. The dome lights could be on during this time, but not any local permanently installed lamps.

After the stairway to the operating floor is flushed, then gross plateau should be cleared from the operating floor to allow reasonable stay times. Next, a pathway to the polar crane (caged ladder on containment wall) can be flushed.

Plastic sheeting should be used to seal off the steam generator compartments and small compartments on the lower elevations to prevent radioactivity from these areas from becoming airborne and recontaminating the areas already cleaned.

Next, the polar crane and dome (at most 50 feet above the crane) will be flushed. A hoist would be required to pull a hose up to the crane. If the polar crane is operable, the bridge will be rotated periodically to allow easier flushing of the dome and then the sides of the containment.

If the radiation levels are too high to permit access to the polar crane, a water cannon could be set up on the operating deck to start flushing the containment dome. The cannon has several disadvantages: The water usage of the cannon would be higher than manual hoses. In addition, the DF of the cannon on the dome would probably not be as good as that for a spray from the polar crane.

The flushing should then proceed downward toward the operating floor. Once the containment dome and upper walls are completed, then the operating floor can be done, always flushing the radioactivity away from the treated area. The 305' elevation outside of the "D" rings would then be flushed.

Only the externals of most equipment will be flushed unless the equipment (such as the cooling coils of the containment air coolers) are shown to be exceptional hot spots.

The steam generator compartments may have such high radiation levels due to internal contamination of the reactor coolant system that only gross surface flushing from above may be possible. Once the steam generator compartments are completed, work could commence on the 282' elevation. The reactor cavity and incore instrumentation tunnel should not be flushed until last due to the higher radiation levels expected there. All sprays of floors should be directed toward the drains or sumps.

### 9.3 Nominal Surface Decontamination

#### 9.3.1 Manual Steam Decontamination

##### 9.3.1.1 General Information

While the original flush of the containment surfaces is performed quickly to minimize the generation of radwaste while still eliminating loose surface contamination, the steam cleaning phase will be much more thorough. A mild detergent should be used in the wet, low pressure steam in order to maximize DF while minimizing the number of decontamination cycles necessary (and thus minimizing the exposure).

It is assumed that the previous decontamination steps will have removed sufficient loose radioactivity from the dome and upper walls of the containment to preclude airborne activity from recontaminating other areas so that steam cleaning of these areas will not be necessary. Otherwise, scaffolding would have to be erected for steam cleaning.

The containment radioactivity levels should have decreased to the point where the containment atmosphere filtration can be used to remove airborne radioactivity generated by the steam cleaning.

The polar crane should be the first item to be steam cleaned since the contamination will fall downward. After the crane is cleaned, it should be wrapped in plastic to prevent it from being recontaminated. Steam cleaning should then progress downwards in the containment in the same order that the water flushing was performed.

In the steam cleaning operation, however, the equipment internals should also be decontaminated if possible. After the steam cleaning is performed, it should be possible to perform hands-on maintenance on most equipment which does not contain reactor coolant. After each area or piece of equipment is steam cleaned, it should be covered with plastic to prevent recontamination.

##### 9.3.1.2 Prerequisites

Prerequisites for steam cleaning are the same as for the water flushing except that the containment filtration system should be operating with the exhaust going through HEPA and charcoal filters.

- a. Leave shielding water in the sump.
- b. Portable steam generating units are available inside the containment. One generator can supply steam for cleaning the polar crane. The portable steam generator should be on the operating floor with a steam hose rigged up to the crane level.

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- c. The detergent is mixed in the water in the tank feeding the portable steam generating units.
- d. Personnel must still wear protective clothing and respiratory protection.
- e. Incandescent lamps in the area to be decontaminated are turned off, if the sealed domes were damaged in the hydrogen detonation. (Steam hitting the lamp would break it and could electrocute personnel). If the normal lighting is not available, quartz-iodine temporary lighting should be used for that area instead.
- f. If possible, all electrical equipment in the area to be cleaned is deenergized before starting to clean that area.

#### 9.3.1.3 Method

The method used will be long handled steam nozzles manually directed.

#### 9.3.1.4 General Procedure

The general steam cleaning procedure is similar to that of the water flush except that the entrance pathway will not have to be cleaned first and the containment dome should not have to be steam cleaned. Otherwise the procedure starts with the polar crane and progresses downward. Plastic sheeting should be used to seal off the steam generator compartments and small compartments on lower elevations. Plastic should be wrapped around equipment and areas immediately after they are cleaned to prevent recontamination. Dessicant should be used when equipment is wrapped.

The operating floor (347'6" elevation) should be cleaned next. Then the intermediate elevation, the "A" steam generator compartment, the "B" steam generator compartment and the lowest elevation should be cleaned. Finally, the reactor cavity and incore instrument tunnel can be cleaned. All steam nozzles should be aimed to direct the contamination on floors toward the drains or sumps.

### 9.3.2 Manual Hot Spot Decontamination

#### 9.3.2.1 General Information

It is expected that even after the remote decontamination, manual water flushing and steam cleaning, that there will be hot spots where contamination levels are considerably higher than elsewhere. These areas may create high radiation levels in areas with heavy traffic or where long stay times are required, or may create a problem with spread of contamination. These areas must therefore be cleaned up or contamination fixed in place with plastic or coatings. The general method for cleaning of a hot spot in an otherwise relatively clean area is to scrub from the outer

fringes toward the center with sponge mops and buckets of cleaning solution, flushing with small quantities of water, and vacuuming up the liquid with a wet-dry vacuum cleaner with no plastic bag liner. The vacuum cleaner should be emptied by attaching a hose directly to the floor drain or sump and opening the drain. Whenever the vacuum cleaners are used for pickup of solids, a plastic bag liner will be used to minimize the spread of contamination. The process can be repeated with the use of an electric floor cleaning/polishing machine with brushes rather than steel wool which would abrade the surface. The detergents used should be chloride free (less than 0.1 ppm), low foaming and compatible with the radwaste processing system. Stronger chemicals listed in Section 5.4 can be used on more stubborn hot spots. It is envisioned that the DF achieved by the various remote and hands-on decontamination methods will be satisfactory so that general epoxy coating removal can be postponed until later. Still, it may be necessary to remove the coatings from certain areas due to stubborn hot spots that create a high radiation field or remain a source of loose contamination. Horizontal surfaces, where significant plateout of radionuclides can be expected, could have more severely damaged coatings which will be more difficult to decontaminate. Needle guns should be used to remove epoxy coatings. The chips should be kept damp with a low pressure, low flow demineralized water spray and then vacuumed with a wet-dry vacuum cleaner to minimize airborne activity. A surface covered with small spots will be exceedingly difficult to decontaminate by any method other than complete removal of the coating. This method is discussed in Section 9.3.3.

#### 9.3.2.2 Hot Spot Mapping

After each decontamination step, alpha/beta/gamma and smear surveys should be performed to determine the effectiveness of the previous step and to locate stubborn areas of contamination requiring more attention and additional decontamination steps. The latest survey results should be posted in the shift change briefing room on large equipment arrangement drawings covered with plexiglass.

#### 9.3.2.3 Quantifying Effectiveness of Hot Spot Decontamination

After each attempt to decontaminate a hot spot, alpha/beta/gamma and smear surveys should be performed on the hot spot area and the results compared with previous surveys. Isotopic identification of smears by use of a Ge(Li) detector may prove helpful in determining particularly recalcitrant isotopes and selection of chemicals especially effective on these isotopes.

#### 9.3.2.4 Insulation

It has been the experience in the past that insulation becomes internally contaminated to high levels so that the only feasible method to decontaminate these hot spots is by removal of the insulation. If the insulation is internally contaminated and is allowed to dry out, it can easily become a source of airborne radioactivity. This does not necessarily mean that all insulation must be removed immediately. Rather, surface decontamination efforts will be made followed by radiation and contamination surveys to determine the magnitude of the residual radioactivity. If the



residual radioactivity does not present a radiation level problem, then the insulation can be wrapped in plastic or painted to prevent airborne radioactivity from being generated and to prevent the insulation from being contaminated by drips and sprays from other decontamination efforts.

The man-rem expenditure for removal of reflective insulation would have to be balanced with the dose created by leaving it in place. This should be evaluated when the status of the insulation is assessed after containment entry.

### 9.3.3 Chemical Decontamination

Since the nature of the contamination on the surfaces in the containment is known by Ge(Li) analysis to be fission product isotopes which normally form soluble compounds, mild chemicals can be selected which have a high probability of removing that contamination in a minimum total contact time. Typical past practices which have proved their effectiveness will be applied early in the decontamination effort and their effectiveness will be measured for this particular case. The final stages of this work should become more efficient as more empirical performance data is available. Early grab samples of materials should be used to start decontamination tests as soon as the data acquisition in the reactor building starts.

#### 9.3.3.1 Reagents

In general, chemical reagents, to be effective, must be able to wet the surface to be decontaminated, complex the materials released from the surfaces, prevent localized corrosion, and not leave behind corrosive residues. Proprietary chemicals are available which have these properties. The chemical properties of the reagents will have to be matched to the materials of construction in the system to be decontaminated. In general, however, chemical decontamination with caustic, oxidizing solutions and with acidic, complexing solutions will not be possible since it is desired to avoid corrosion of the NSSS major equipment and piping, and since the radwaste system must be capable of processing the liquid waste. The chemical reagent of first choice will be a chloride-free mild detergent. Other stronger chemicals are listed in Section 5.4 in order of increasing strength.

#### 9.3.3.2 Equipment

- a. Sponge mops
- b. Cart-mounted 55 gallon drums of detergent solution with electric spray pumps, flexible hoses, and spray nozzles.
- c. Wet-dry vacuum cleaners with filtered exhaust.
- d. Electric powered floor polishers with brushes.

### 9.3.3.3 Application Techniques

The solution will be sprayed on surfaces so as to keep the surfaces wet. To minimize the total reagents used, multiple short duration applications of a reagent is a more efficient use of chemicals than to apply the entire supply of solution in one application.

Uniform distribution of decontaminants can be accomplished by using a single spray nozzle on a wand or multiple distribution system such as multiple nozzles on a single wand or multiple nozzles from specially fabricated distribution headers. Several manufacturers can supply appropriate nozzles. The design criteria will have to consider the desired angle of the spray, the required volume of liquid flow for proper operation, and the extent of surface area to be wetted.

A mobile solution sprayer system should be purchased or fabricated to assist in decontamination of hot spots. Several mobile carts with a 55 gallon steel drum fitted with electric immersion heaters, spray pump, and a flexible hose with a long handled spray nozzle should be available for cleaning hot spots. The solution will be cleaned up by wet-dry vacuum cleaners.

### 9.3.4 Mechanical Decontamination

Mechanical decontamination essentially results in a portion of the contaminated surface being removed by mechanical rather than chemical means. In this case, impact tools appear to have advantages over abrasive tools due to the larger amount of airborne radioactivity generated by the abrasive tools.

#### 9.3.4.1 Equipment

- a. Electrically operated needle guns
- b. Low pressure, low flow rate demineralized water spray.
- c. Wet-dry vacuum cleaners with filtered exhaust.

Impact and abrasive tools should be considered as a last resort when required by high radiation levels, to remove surface contamination, because such operations generate an abundance of fine particles. Those particles would be difficult to confine in the local area and would tend to distribute widely. The end result will be recontamination of previously cleaned areas. The surface should be kept damp and chips collected with a wet-dry vacuum cleaner. Working inside of a plastic tent will also minimize the spread of airborne radioactivity.

Use of sand blasting, shot peening, and such similar surface treatments is not recommended for the containment. Those techniques should only be used to remove contamination from equipment which can be moved to a glove box or plastic tent enclosure outside the containment.

After chemical sluicing and powered tools have been used to remove contamination, residual localized contamination will then either have to be shielded in place, treated with strong chemical reagents, or dislodged with hand-held tools such as chisels, hammers, scrapers, etc. The operator may have to be protected by a shadow shield wall, or rubber matting draped over the contamination while working this close to the contamination. Care must be exercised to be sure that the operator's hands are not in contact with the contaminated surfaces due to concern for extremity exposures especially from beta radiation. Contamination removed should be picked up by a vacuum cleaner or scraped up and deposited in a contaminated materials drum.

When using abrasive tools, the area should be tented with plastic to reduce spread of finely divided particles beyond the work area. The surface being decontaminated should be kept damp. Frequent use of the vacuum cleaner will reduce background caused by the accumulation of radioactive debris.

When using manually-powered tools, the hottest spots should be worked first. In extreme cases heavy rubber gloves or lead lined gloves may be necessary to reduce exposure to the extremities.

#### 9.3.4.2 Applications Sequencing

When the manual steam cleaning is completed, decisions will have to be made as to the best way to minimize dose commitment for the immediate follow-on operations. The following options should be arranged in the proper sequence for each area within the containment based upon radiation surveys and evaluation of which sequence of options will lower the total dose commitment:

- a. Erect shadow shield walls in front of significant radioactive sources.
- b. Determine the beta to gamma dose rate ratio for the hot spots. See Section 2 for the assessment of the TMI-2 beta to gamma ratio.
- c. Drape hot spots with rubber sheets to stop betas. Lead can be placed on top to stop gammas. (Neglecting the rubber sheeting can increase the dose rate due to betas generating Bremsstrahlung in the lead sheets).
- d. Manually scrub hot spots.

#### 9.3.5 Quantifying Effectiveness of Decontamination

Alpha/beta/gamma and smear surveys should be performed before and after each decontamination step. The results will be compared and decontamination factors calculated. Isotopic analysis of smears can be done to determine if certain isotopes are more difficult to remove than others or tend to cause more recontamination than others.

Steam cleaning should be repeated as long as reasonable decontamination factors are achieved for each pass.

#### 9.4 Equipment Decontamination

##### 9.4.1 Procedures

Equipment decontamination should begin with flushing the exterior surfaces using a solution of detergent in demineralized water as described in Section 9.2. Next, the exterior and accessible portions of the interior will be steam cleaned using detergent in steam from demineralized water as described in Section 9.3.1.

Equipment designated for replacement does not require the full decontamination effort. A cursory exterior decontamination to ease handling will suffice.

After these two methods have been tried, the non-salvageable, partially decontaminated equipment should be disconnected from the system, have the hold down bolts removed, be wrapped in plastic, and removed from the containment. Outside the containment the equipment can be placed in wooden crates and shipped for burial.

Once equipment that is to be saved is decontaminated, it should be wrapped in plastic to prevent recontamination. Dessicant can be added to retard corrosion.

##### 9.4.2 Criteria for Removal and Disposal in Lieu of Decontamination

Each piece of equipment will have to be evaluated as to the need to replace it. That equipment which is to be replaced need not receive more than a cursory exterior decontamination to allow handling.

### 9.5 Recontamination Prevention

Recontamination can be minimized by wrapping hot sources in plastic to prevent them from contaminating other areas being cleaned. For example, the lower areas in the containment should be sealed with plastic during flushing and steam cleaning of the upper areas in the containment.

Once an area or piece of equipment is decontaminated, it should be wrapped in plastic to prevent recontamination.

During the manual steam cleaning of the containment the purge system should be operated to continually remove and filter out the suspended radioactivity before it can redeposit.

The sump should be pumped of all radioactive liquid before the decontamination effort begins and after each step in the decontamination effort to prevent the radioactivity from getting resuspended.

## 9.6

Temporary Shielding

One step in a general area decontamination operation will be to provide temporary shielding over significant radioactive sources in the area to be cleaned. Sufficient shielding should be installed so that the background in the immediate vicinity will originate primarily from generally distributed surface contamination in the area. After the general background from surface contamination has been lowered through decontamination operations, concerted efforts will be devoted to cleanup, one hot spot at a time.

Temporary shielding will most often be installed to attenuate the whole body penetrating radiation which typically limits a person's dose commitments. However, beta radiation from deposited fission products could lead to significant skin dose rates and may also have to be shielded.

Extremity exposures may also become a limiting factor in certain decontamination operations. Temporary shielding is in general not a practical solution to reduction of extremity exposures. In those instances where the hands are likely to be located in significantly higher dose rates than the body, heavy rubber, or lead gloves would be used on the hands of the person reaching over the temporary shielding materials.

This subsection of the report details use of dense shielding such as lead and concrete and less dense shielding such as water and rubber to reduce gamma and beta dose rates.

Selection of temporary shielding materials will be influenced by:

- a. Civil/structural considerations (allowable floor loadings, strength of pipe anchors, etc.).
- b. Radiation attenuation factor desired.
- c. Transmission factors for the appropriate gamma energy.
- d. Physical limitations on space available for shielding and allowable configuration of shielding.
- e. Suitable methods of attachment.
- f. Trade-offs on man-rem acquired from placing shielding versus man-rem reduction during subsequent work.
- g. Possibility of removing hot equipment from containment in lieu of shielding.

**9.6.1 Materials****9.6.1.1 Lead**

Lead provides the greatest gamma attenuation factor of any of the materials usually considered for temporary shielding. If one assumes the energy of the fission products released to the containment is typical of Cs-137, then the intensity of the transmitted radiation through each 3/4" of lead is about one-tenth of the radiation dose rate entering the shielding.

**9.6.1.1.1 Sheets and Plates**

Sheets of lead (nominally 1/16", 1/8" or 1/4") can be used to drape pipes and equipment. The thinner sheets of 1/16" and 1/8" are more flexible and can be rather easily formed and bonded in place around pipe supports and valves. The thicker 1/4" sheets are less flexible and are more difficult to handle because of their weight (15 lbs/Ft<sup>2</sup>). Trade-offs in total dose commitments will have to be made between application of multiple thinner sheets, application of thicker sheets or plates or bricks. For each option, the dose commitment will be influenced by:

- a. The number of persons required to move the shield into place.
- b. Availability and applicability of mobile equipment to support the shield during movement.
- c. Requirement to install additional support structure to accommodate weight of shielding.
- d. Ability of personnel to benefit from shielding and distance from source during installation of shielding.

Plates of lead can be bolted directly onto flat contaminated hot spots, on vertical concrete surfaces or bolted to angle iron frames. Large washers should be used beneath the bolt heads or nuts. Free standing, unsecured angle iron frames should not be used to support shadow shielding located between the radioactive source and operating personnel. Heavy shadow shields of lead plates should be tied to nearby structural members for stability. Lead plates can be inset into the angle iron frames to obtain greater support than if the plates were simply bolted to the outside of the frames.

**9.6.1.1.2 Bricks**

Lead bricks can be purchased in rectangular configurations of 2" x 4" x 8". The bricks can be stacked flat or on edge to obtain the desired 2, 4, or 8-inch shield thickness between the source and the operating personnel. The transmission factors are shown as follows for Cs-137:

| <u>Thickness<br/>of Lead<br/>Inches</u> | <u>Approximate<br/>Transmission Factor<br/>(for Cs-137)</u> |
|-----------------------------------------|-------------------------------------------------------------|
| 2                                       | $5 \times 10^{-3}$                                          |
| 4                                       | $2 \times 10^{-5}$                                          |
| 8                                       | $4 \times 10^{-10}$                                         |

Since each brick weighs 26.25 pounds, the allowable floor load limits will have to be carefully factored into the planned shielding design. If the lead bricks are stacked with the 4" x 8" dimension flat, the shadow wall should be limited to about 4 feet due to stability considerations. Higher brick walls should be secured by external bracing or steel plates. If the 2" x 8" dimension is the basis of the stack, unsecured walls should not be constructed above about 30". The bricks should be staggered as is typically done in a single course brick wall.

Installation of lead brick walls in front of a hot area can result in significant dose commitment to the personnel. Because lead bricks can be easily damaged during handling, much time is consumed to carefully place the lead bricks in a close-packed array. Deformed bricks can prevent close fitup of bricks and result in radiation streaming through gaps in the shielding.

#### 9.6.1.1.3 Shot

Bags of lead shot can provide effective, flexible lead shielding which can be placed more rapidly around irregular shapes than if rigid lead plates or bricks were to be used. The effective density of bags of lead shot is about 65% of the density of solid lead. The approximate attenuation factors for lead shot (single size, ungraded) are as follows:

| <u>Thickness<br/>of Lead Shot<br/>Inches</u> | <u>Approximate<br/>Transmission Factor<br/>(for Cs-137)</u> |
|----------------------------------------------|-------------------------------------------------------------|
| 2                                            | $5 \times 10^{-2}$                                          |
| 4                                            | $2 \times 10^{-3}$                                          |
| 8                                            | $4 \times 10^{-6}$                                          |

The cloth bags used to package lead shot are not resistant to decontamination chemicals. Therefore, the bags of shot need to be protected from decontamination chemicals and water. If bags of shot have to be emplaced before the general area decontamination has been completed, the cloth bags containing shot should be protected from water and chemicals using heavy polyethylene sheeting beneath and over the top of the shielding.



9.6.1.1.4      Lead Blankets

Lead blankets can be purchased in a range of sizes. The thickness is generally 1/2 inch. They have grommets around the edges allowing them to be fastened to piping, valves and other equipment. They are more flexible than lead sheet but are not as dense. The blanket density is 1.9 gm/cm<sup>3</sup> whereas lead is 11.35 gm/cm<sup>3</sup> so that six times the thickness of blanket will be needed to give the same attenuation as solid lead. Approximately 4.5 inches of lead blanket (approximately nine layers of blanket) are required to reduce the radiation level by a factor of ten.

9.6.1.2      Concrete Blocks

Solid concrete blocks will provide moderate attenuation factors and have these advantages as a shielding material:

- a. Good structural properties enable free standing shield walls to be constructed to considerable heights without compromising safe operations.
- b. Reasonable availability
- c. Competitively priced

Concrete blocks are not as susceptible to deformation during handling which would tend to compromise making a close packed array of blocks. Concrete blocks are quite heavy to handle and place. A solid 8" x 8" x 12" long block weighs about 54 pounds, a solid 12" x 8" x 12" long block weighs about 80 pounds, and a solid 8" x 8" x 16" block weighs 72 pounds. Equipment such as dollies must be provided so workers can rapidly transport concrete blocks to the emplacement point. The work of stacking blocks will be quite strenuous for personnel working in protective clothing and respiratory protection equipment; therefore, workers should be selected accordingly. Concrete blocks cannot be effectively decontaminated and will result in additional radwaste.

The transmission factors for concrete blocks, assuming a Cs-137 radiation source are as follows:

| Thickness of<br>Concrete Blocks<br>Inches | Approximate<br>Transmission Factor<br>(for CS-137) |
|-------------------------------------------|----------------------------------------------------|
| 8                                         | 0.10                                               |
| 12                                        | 0.03                                               |

Precast concrete panels could also be used for local shielding.

## 9.6.1.4

## Other

After the fission products which were released into the containment as liquids and gases have come to rest, fission products are expected to be present on all surfaces. Some of the fission products will have penetrated into the epoxy coatings on the metal and concrete surfaces. Diffusion of volatile forms of radioactive iodine and gaseous xenon, which are precursors of the cesium nuclides, will have penetrated into those surfaces before decaying into Cs. These nuclides will tend to replenish surface contamination as decontamination progresses.

Where beta dose rates on floors are a problem, rubber mats or aluminum will provide significant radiation attenuation from the beta radiation. Lead sheet should only be used on top of the rubber or aluminum, since the betas will produce Bremsstrahlung gammas in the lead sheet, which could increase, rather than decrease, the dose rate. The rubber blankets (nominal 1/4" thickness) typically used by power company line crews will completely attenuate beta radiation up to about 1.3 Mev. A few of the fission products have average beta energies above this figure, namely Ru-106 and Pr-144. However, a significant fraction of beta radiation will be attenuated by the rubber mats and the mats should be used to lower the potential skin dose to the operators. No significant gamma attenuation can be expected from use of these 1/4" rubber mats. The rubber mats have the advantage over aluminum since the mats can be cut to fit on location much more easily.

Steel plates may be used to provide total beta shielding and partial gamma shielding. Typical applications would be to cover particularly troublesome hot spots on the wall or floor. Transmission factors for steel are as follows:

| Thickness of<br>Steel Plates<br>Inches | Approximate<br>Gamma Transmission<br>Factors for Cs-137 |
|----------------------------------------|---------------------------------------------------------|
| 1                                      | 0.5                                                     |
| 2                                      | 0.2                                                     |
| 4                                      | 0.02                                                    |

Plywood may be used to provide significant attenuation of beta dose rates. Typical applications are to construct packaging for HEPA filters, charcoal adsorbers, and other "open" sources which will have high beta to gamma dose rate ratios. The packing boxes can usually be fabricated in modular sizes (slightly larger than the filters) and still provide maximum utilization of whole 4' x 8' sheets.

| <u>Thickness<br/>of Plywood<br/>Inches</u> | <u>Approximate<br/>Beta Energy Required<br/>to Penetrate Mev</u> |
|--------------------------------------------|------------------------------------------------------------------|
| 1/4                                        | 1.0                                                              |
| 1/2                                        | 1.7                                                              |
| 3/4                                        | 2.4                                                              |
| 1                                          | 3.0                                                              |

The most prevalent fission products expected to have been released into the containment are nuclides of Cs, Sr, Y, Ba, La, Ru, Ce, Pr, Nb and Zr. Quarter inch thick plywood will attenuate the beta particles from certain of the Cs nuclides and Sr-90; however, the other radionuclides present (90% of the total beta emitters) will emit a significant fraction of more energetic beta particles capable of penetrating the 1/4" plywood. The 3/4" plywood is sufficiently thick to attenuate essentially all the beta particles emitted from the fission products which have been able to survive radioactive decay up to the time hands-on decontamination begins. Plywood cannot be decontaminated. Use of plywood will result in solid radwaste.

#### 9.6.2 General Area Shielding

The majority of the general area shielding should not be installed until after the water flushing and steam cleaning decontamination operations are completed for the particular area unless it is essential to reduce radion levels during these operations, since the shielding would have to be removed to allow decontaminating the area and then new, non-contaminated shielding material would have to be installed. The area shielding should be used along pathways with heavy traffic to cover some hot spots. In general, though, the area shielding will be used after the major area decontamination operations are concluded. The general area shielding should be used, in particular, to reduce beta radiation from fixed surface contamination.

#### 9.6.3 Equipment Shielding

Internally contaminated equipment which cannot be readily decontaminated by surface cleaning methods should have local shielding to lower dose rates to personnel passing nearby. Since the external dose rates generated by internal contamination are due to gamma radiation, heavy shielding will be needed. Since solid concrete blocks can be stacked to a height of 8 feet (enough to protect personnel) without additional structural support, and since they are cheaper and easier to handle than lead or steel, they should be the shielding material chosen for shield walls around large equipment where space is available.

Lead blankets and thin lead sheet can be tied or bent around valves, piping and small pieces of equipment.

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#### 9.6.4 Hot Spot Shielding

Hot spots on floors should be investigated as to the beta-to-gamma ratio. If beta is controlling, then rubber mats will provide a quick and easy fix. If the gamma dose rates are still significant after beta shielding is installed, then lead sheet can be added on top of the rubber mat. If considerable gamma shielding is necessary, then solid concrete blocks could be placed one layer deep on the floor and personnel can walk on top of the blocks.

Hot spots on walls can be shielded by stacking concrete blocks where space is available. Steel or lead plates can be used if space is available for angle bracket supports without impeding traffic or if the plates can be readily tied into existing structures. However, the shielding may be needed before the polar crane is operational, so manually moving such steel or lead plates may prove impossible. Temporary jib cranes or cherry pickers could be used for some areas.

## 9.7 Specific Equipment/Area Decontamination/Removal

### 9.7.1 Containment Air Cooling Unit

At the time of the incident, the containment air cooling system was operating in the recirculation mode. Contamination of the air coolers and associated duct work may be quite high. Airborne radioactive materials which were transported into the containment cooling unit will represent the most significant source of radioactivity on the south end of the 305' floor. Materials will tend to deposit on the:

- a. Multi-layered, finned tube heat exchangers
- b. Finned external surface of fan motors
- c. Five drain pans at base of housing
- d. Crevices in the internally bolted, caulked flanged joints where subassemblies mate
- e. Internal and external surfaces
- f. Exhaust plenums outside housings

Contamination on the accessible metal surfaces of the motor frame can be flushed away using water containing a low concentration of detergent or by steam cleaning using a decontaminating agent such as Radiac-wash.

Contamination on the finned tube coils can be removed by manual steam cleaning.

Cleanup of the drain pans and the external and internal surfaces of the housings should be one of the final cleanup operations. Systematic flushing of the external surfaces should then proceed downward from the damper and fan enclosure to the main plenum. Cleanup of internal surfaces should begin by inserting the steam nozzles into the inlet dampers (propped open) at the top of the system. The operator should then unbolt the access panels above the coils and place steam spray nozzles on the expanded metal screen over the coils. The job will require auxiliary water-proof lighting and rubber or heavy plastic coveralls. The lower housing can then be decontaminated using the steam nozzles.

The caulked and bolted flanges still contaminated after the flush down operations will require hands-on decontamination work. The most difficult flanges to decontaminate will be the internally located flanges on major subassemblies. The external flanges on the damper, fan housing, and inlet bells should be less difficult to decontaminate. The surfaces should be wire brushed using power tools and the localized hot spots should be scraped with putty knives and similar tools. Thoroughness will be important during wire brushing to be sure all surfaces of bolts, nuts, corners, etc., are brushed. Frequent wash down of the drip pans should be done to minimize background dose rates.

The chemical reagents planned to be used should be verified to be compatible with the following materials of construction:

- a. Cupro nickel 90/10 (ASTM-B-395, B-111, B-171)
- b. Cd plated steel
- c. Stainless steel, type 304
- d. Carbon steel (ASTM-A-181, 234, 366)

If background radiation from the cooling unit is too high after the decontamination work previously described has been completed, four options are available:

- a. Repeat decontamination with more corrosive reagents
- b. Disassemble contaminated portions of the cooling system and dispose of contaminated subassemblies as waste.
- c. Disassemble contaminated portions of the cooling system and process through the decontamination systems in the containment service building
- d. Install shielding around coolers

Disassembly operations, if they become necessary, would probably only affect the cooling coils, damper enclosure, and fan enclosures. All other surfaces should be decontaminable using very high pressure water sprays (2000 psig) or steam cleaning.

To withdraw the coils (30 coils total), the nuts would have to be run off the captive bolts holding the coil service panels (10 in all) in place (or cut off with a cutting torch). Powered socket wrenches should be used if working time permits.

The access panels (5 in all) above the coils would have to be opened in a similar fashion. The stainless steel bolts holding the expanded metal screen in place would have to be removed or cut off. The mesh would have to be tilted out of the way or cut into smaller pieces for removal through the access panel. Then the 6-8 bolts securing each coil to its support would have to be removed. Each coil then can be removed from the support rack by following the sequence of instructions described in the installation manual. The coils would then go either to solid waste disposal or the decontamination facility.

To handle the coils, a plastic lined, shielded box should be used. Rigging will have to take into account the nominal 1000 pounds per coil and the weight of the box. Provisions will have to be made to drain the clean water from the coils before transport begins.

If the approaches previously described in this subsection represent more dose commitment than is considered to be worthwhile, then the assembly could be subdivided using cutting torches and such equipment as arc saws. The major pieces would then become:

- a. Five fan and damper housings (cut above flange into plenum above coils)
- b. Five inlet plenums (cut above mesh screen above coils)
- c. Five coil sections and surrounding plenum (cut below top flange of lower plenums)
- d. Five lower plenum sections

Some additional subdivision may be necessary in order to provide sufficient clearance between the box and the equipment hatch during removal from the containment.

#### 9.7.2 Instrument Racks

All but one of the instrument racks are located on the 282'6" elevation. There is one instrument rack on the 347'6" elevation. Since all of the instrument racks on the 282'6" elevation are submerged they should only be given a cursory decontamination to remove loose material and lower radiation levels prior to being removed from the containment for packaging, shipping and burial. The one instrument rack on the 347'6" elevation should also receive only a cursory decontamination effort before being removed for burial if it can be determined that it serves no operating instruments. The decontamination of the instrument racks can be done during the general area cleaning.

#### 9.7.3 Polar Crane

The polar crane will be the first piece of equipment to be decontaminated in order to allow sufficient stay time for cleaning the dome and since the surfaces at the higher elevations must be cleaned first. In addition, the polar crane will be needed for the placement of equipment necessary for decontamination operations.

The crane should first be washed down in the initial gross decontamination phase. It should also be steam cleaned at the beginning of that phase.

The majority of the decontamination should be by steam cleaning. The steam temperature should be hot enough to cut through the grease on the cables so that they will be fairly well decontaminated. The cables will have to be regreased and the motors dried out before restarting can be attempted.

#### 9.7.4 Fuel Handling Bridges

The fuel handling bridges can be decontaminated during the steam cleaning of the operating floor unless the dose rates from the reactor vessel make work close to the reactor too difficult. In this case, the cleaning of the fuel handling bridges can be postponed until last when the reactor cavity is cleaned. The runoff will go into the refueling canal and down into the reactor cavity.

#### 9.7.5 Missile Shields

Steam cleaning of the missile shields above the reactor may have to be postponed until last when the reactor cavity is cleaned due to the high dose rates expected in the reactor area.

#### 9.7.6 Impingement Barrier Area

The impingement barrier area on the 282'6" elevation will be highly contaminated from being partially submerged and close to the source of the contamination (the RCDT). Flushing with water, steam cleaning, and hot spot decontamination will all be required.

#### 9.7.7 Letdown Cooler Area

The letdown coolers will probably be highly contaminated internally since the letdown system was in operation during the incident. The exterior surfaces should be cleaned by water and steam as quickly as possible to avoid overexposures. It is expected that the majority of the dose rate will be due to the internal contamination which will be flushed out during reactor coolant system decontamination. The coolers are in a specially shielded area so that local shielding will not be necessary unless maintenance must be performed inside the room. Otherwise, the doorway should be posted to prohibit entry.

#### 9.7.8 Containment and Reactor Cavity Sump Areas

These sump areas will be extremely contaminated, possibly even with fuel fines, from being underwater. Thorough flushing with water and steam cleaning with a detergent solution should be utilized. The sump pumps may have to be removed and replaced due to water and radiation damage and contamination producing radiation levels too high to permit maintenance. The sumps will possibly remain highly contaminated even after the decontamination efforts described above. Another method to decontaminate would be to leave the sumps filled with the decontamination solution to soak the radioactivity loose from the walls.

#### 9.7.9 Steam Generator Compartments

The steam generator compartments would be sealed off with plastic from the upper part of the containment while decontaminating the dome, polar crane and upper walls to prevent radioactivity from becoming airborne and recontaminating the cleaned up areas. This plastic sheeting should remain in place during cleanup of the steam generator compartments to keep the airborne radioactivity generated by compartment cleanup from depositing



on cleaned areas in the containment. The procedure used for the steam generator compartments will be to flush with water, steam cleaning, and scrubbing with mops. Areas where personnel will be frequently exposed should have the steam generator insulation removed if it is a source of radiation or airborne radioactivity. Other insulation can be temporarily wrapped in plastic to keep down the airborne activity.

#### 9.7.10 Elevator

One major source of exposure in the auxiliary building elevator was the bottom of the shaft. It is expected that the elevator in the containment will also be highly contaminated at the bottom of the shaft. Flushing with water and steam cleaning will be utilized for thorough cleaning. The contaminated water should be picked up with a wet-dry vacuum cleaner. The walls of the elevator shaft, being formed of grouted concrete block, may not be able to be effectively decontaminated. In this eventuality, the walls will have to be removed and disposed of as solid radwaste.

#### 9.7.11 Cable Trays

Water flushing will suffice to remove the loose surface contamination on cables so that they can be cut up and removed from the containment. Then the cable trays, if still salvageable, can be steam cleaned. Steam cleaning with the cables in place would not be effective so the steam cleaning should be delayed until after the cables are removed.

#### 9.7.12 Ventilation Ducting

The exterior of ductwork can be decontaminated with water flushing and steam cleaning since it is not insulated. The radiation levels on the ductwork, after exterior decontamination, will determine whether or not the interior should be decontaminated or the old ductwork shipped for burial and simply replaced.

The interior of ductwork may also be extremely contaminated due to plateout from the containment atmosphere. Decontamination of the interior of the ductwork is not necessary and is not recommended. The man-rem exposures involved make it impractical to decontaminate the ductwork. Therefore, it is more economical to completely replace the old ductwork entirely if radiation levels prevent leaving the duct in place. In this case, the contaminated duct work would be wrapped in plastic and crated for burial.

## 9.8 Liquid Radioactive Waste Generation

### 9.8.1 Flushing of Gross Containment Activity

The flushing of gross containment activity will be done with demineralized water containing a mild, chloride free detergent. This method will not be used for thorough decontamination. The expected quantity of liquid radwaste generated by this step is 250,000 gallons or more. This water can be reused after processing. However, recycled original sump water cannot be used due to tritiated water concentration.

### 9.8.2 General Area Decontamination

The general area decontamination will be performed using steam made from demineralized water containing a mild, chloride free detergent. The expected quantity of liquid radwaste generated in this step is 200,000 gallons. The water used in the gross decontamination can be processed and reused in this step.

### 9.8.3 Equipment Decontamination

Equipment will be decontaminated in the same manner as the areas described in Sections 9.8.1 and 9.8.2. The quantity of additional liquid radwaste generated in this step is 50,000 gallons.

### 9.8.4 Hot Spot Decontamination

Hot spots will be decontaminated by manual scrubbing using recycled water from Sections 9.8.1, 9.8.2 and 9.8.3. The amount of liquid radwaste generated by this step is estimated at 100,000 gallons.

### 9.8.5 Processing of Decontamination Liquids

Since the decontamination liquids will contain detergent which will tend to foam somewhat, even though low foaming types should be used, evaporators cannot be used satisfactorily for processing unless an adequate anti-foaming agent can be defined. Processing by demineralization would be much more feasible.

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9.9 Solid Radioactive Waste Generation During Decontamination

9.9.1 Compactible Waste

Large quantities of solid waste will be generated in the hands-on decontamination process. These materials include:

|                                                                       |                        |
|-----------------------------------------------------------------------|------------------------|
| Plastic sheeting                                                      | 3,000 Drums            |
| Absorbent paper, brown paper roll                                     | 1,000 "                |
| Anti-contamination clothing (too hot to be reused or throwaway paper) | 1,000 "                |
| Plastic booties, cloth grove liners, and rubber gloves                | 1,000 "                |
| Mops - all                                                            | 20 "                   |
| Vacuum cleaner filters                                                | 50 "                   |
| Mask cannisters (spent)                                               | 50 "                   |
| Smears                                                                | 10 "                   |
| Planchets                                                             | 10 "                   |
| Masks                                                                 | 10% of Total Inventory |
| Rags                                                                  | 1,000 Drums            |

9.9.2 Decontamination Tools and Materials

All tools and equipment used inside the containment will become contaminated beyond the point where they could be cleaned up with a reasonable effort and released as noncontaminated. This does not mean that the equipment is unusable. The equipment can be decontaminated to the point that it no longer presents a significant radiation level and re-used in contaminated areas.

The equipment would have to be stored as contaminated material. A hot tool crib is proposed for the containment service area as described in Section 4.1. It is probable that some equipment will be too contaminated to be successfully decontaminated to a radiation level that will permit continued use. These tools or pieces of equipment must be disposed of as contaminated solid waste.

The following is a preliminary list of such equipment:

|                                             |             |
|---------------------------------------------|-------------|
| 55 gallon drums (hot spot decon solution)   | 50%         |
| Handcarts for 55 gallon drums (tape wheels) | 50%         |
| Carts for air cylinders                     | 50%         |
| Air cylinders (4 per cart)                  | 20%         |
| Air tanks (backpacks)                       | 10%         |
| Floor polishing machines                    | 50%         |
| Vacuum cleaners                             | 50%         |
| Temporary lights                            | 20%         |
| Temporary cable                             | 50%         |
| Temporary piping                            | 50%         |
| Air hoses                                   | 50%         |
| Fire hoses                                  | 100%        |
| Tools                                       | 50%         |
| Miscellaneous (shield blocks, etc.)         | 3,000 Drums |

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9.9.3

## Processing of Decontamination Solids

The solid materials which are compressible should be packed into 55 gallon drums. It would be most expeditious to install a high ratio compactor (e.g., 7 to 1) either inside the containment equipment hatch or immediately outside the hatch in the containment service building. The intent is to minimize the handling of plastic bags full of contaminated material to reduce handling exposures and the chance of breaking the bags with possible release of contamination. Another compactor should be located conveniently to the protective clothing removal area at the No. 2 personnel airlock to facilitate compaction of highly contaminated (non-recoverable) anti-contamination clothing.

The tools and materials to be disposed of will have to be wrapped in plastic and crated or drummed for burial.

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## 9.10

Inventory of Requirements for Decontamination  
Equipment and Clothing

The items listed below are the estimated quantities of clothing and equipment required for the decontamination efforts:

a. Clothing

|                        |                     |
|------------------------|---------------------|
| Cloth coveralls        | 2 x 10 <sup>5</sup> |
| Paper coveralls        | 10 <sup>6</sup>     |
| Plastic coveralls      | 10 <sup>6</sup>     |
| Raincoats              | 10 <sup>5</sup>     |
| Plastic booties        | 10 <sup>6</sup>     |
| Rubber boots (pair)    | 10 <sup>5</sup>     |
| Rubber galoshes (pair) | 10 <sup>5</sup>     |
| Cloth glove liners     | 10 <sup>6</sup>     |
| Rubber gloves          | 10 <sup>6</sup>     |
| Surgical caps          | 10 <sup>5</sup>     |
| Cloth hoods            | 2 x 10 <sup>5</sup> |
| Plastic hoods          | 10 <sup>6</sup>     |
| Rain hats              | 10 <sup>5</sup>     |
| Hard hats              | 10 <sup>4</sup>     |
| Miners lamps           | 10 <sup>2</sup>     |

b. Respiratory Protection Equipment

|                                                                         |                 |
|-------------------------------------------------------------------------|-----------------|
| Mask with backpack (60 minute capacity) (e.g., Bio Pak 60 - Bio Marine) | 10 <sup>3</sup> |
| Backpack oxygen tank (60 minutes)                                       | 10 <sup>4</sup> |
| Mask with backpack (30 minute capacity) (e.g, Scott Air Pak, MSA)       | 10 <sup>2</sup> |
| Backpack air tank (30 minutes)                                          | 10 <sup>3</sup> |
| Backpack air tank (10 minutes)                                          | 10 <sup>3</sup> |
| Particulate cannisters                                                  | 10 <sup>5</sup> |
| Particulate/charcoal cannisters                                         | 10 <sup>6</sup> |
| Masks with airhose/cannister combination connections                    | 10 <sup>3</sup> |
| Air suit and hood                                                       | 10 <sup>3</sup> |

c. Equipment

|                                             |                                   |
|---------------------------------------------|-----------------------------------|
| Temporary ventilation blowers               | 20                                |
| Temporary ventilation duct (elephant trunk) | 10 <sup>3</sup> feet              |
| Vacuum cleaners (wet-dry)                   | 30                                |
| Floor polishers                             | 10                                |
| Brushes for floor polishers                 | 10 <sup>2</sup>                   |
| Plastic sheet                               | 10 <sup>6</sup> feet <sup>2</sup> |
| Plastic sheet (reinforced)                  | 10 <sup>5</sup> feet <sup>2</sup> |
| Plastic bags for 55 gallon drums            | 2 x 10 <sup>4</sup>               |

|                                                      |                                   |
|------------------------------------------------------|-----------------------------------|
| 2 x 4's (framing for tents)                          | 10 <sup>3</sup> feet              |
| HEPA filters for temporary ventilation               | 500                               |
| Charcoal filters for temporary ventilation           | 100                               |
| Plywood sheets (1/2" sheathing)                      | 100                               |
| Plywood sheets (3/4" sheathing)                      | 100                               |
| Rubber mats                                          | 10 <sup>4</sup> feet <sup>2</sup> |
| Lead sheet 1/8"                                      | 10 <sup>4</sup> feet <sup>2</sup> |
| Lead sheet 1/4"                                      | 10 <sup>3</sup> feet <sup>2</sup> |
| Lead sheet 1/2"                                      | 10 <sup>3</sup> feet <sup>2</sup> |
| Lead plate 1"                                        | 500 feet <sup>2</sup>             |
| Lead blankets                                        | 10 <sup>4</sup>                   |
| Solid concrete blocks                                | 10 <sup>4</sup>                   |
| Lead bricks                                          | 10 <sup>4</sup>                   |
| Temporary lights                                     | 10 banks                          |
| Fire hose                                            | 10 <sup>3</sup> feet              |
| Air hose                                             | 10 <sup>4</sup> feet              |
| Carts mounted with 4-300 feet <sup>3</sup> air tanks | 20                                |
| Handcarts with 55 gallon drums and sprayers (decon)  | 10                                |
| Needle guns                                          | 10 <sup>2</sup>                   |
| Sponge Mops                                          | 10 <sup>4</sup>                   |
| 55 gallon drums                                      | 10 <sup>4</sup>                   |
| Temporary cable                                      | 10 <sup>4</sup> feet              |
| Temporary piping                                     | 10 <sup>3</sup> feet              |
| Tools                                                | Undetermined                      |
| Cutting torches, hoses, oxygen and acetylene tanks   | 30                                |

10.0 PROTECTION OF ESSENTIAL NSSS AND BOP SYSTEMS AND COMPONENTS DURING DECONTAMINATION

During the remote and hands-on decontamination activities within the containment, efforts will be made to ensure the continued safe operation of the plant and the protection of equipment necessary for plant operation.

10.1 Identification of Essential Systems/Components

Essential systems in the containment can be categorized as follows:

- a. Systems necessary for continued safe shutdown operation of the unit, primarily systems essential for removal of reactor core heat.
- b. Systems required during containment decontamination.

10.1.1 Systems Essential for Removal of Reactor Core Heat

There are two modes of operation for reactor core decay heat removal, both of which have different system requirements. They are as follows:

a. Natural Circulation

Steam generator(s) are in a steaming or solid water mode, natural circulation of primary fluid exists - heat is removed through the steam generators.

b. Decay Heat Removal System Operation

The decay heat removal system is recirculating water through the reactor vessel. Heat is removed through the DHR coolers.

10.1.1.1 Natural Circulation Operation

In this mode of operation, the pressurizer can be operated either solid or with a steam bubble. Consequently, the systems and components necessary to support these optional operating conditions would vary.

The systems and components in the containment essential to this mode of operation include:

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a. Instrumentation

Reactor coolant system: pressures/temperatures  
 In-core detectors: in-core thermocouples  
 Steam generator: levels and temperatures  
 Pressurizer: temperature (hot pressurizer conditions only)  
 Nuclear instrumentation

b. Electrical

Power supply cabling and connectors, etc., for instrumentation  
 Instrument signal cabling  
 Pressurizer heaters and heater cables (hot pressurizer conditions only)  
 Power supply cabling and connectors for system relief valves

c. Mechanical

All pressure boundary components  
 Letdown and makeup system  
 Sampling system  
 Pressurizer pressure relief valves  
 Insulation

The natural circulation mode of operation is heavily dependent upon instrumentation and electrical systems. If the B steam generator closed cycle cooling system is in operation, the dependence on secondary side instrumentation is reduced; however, primary side instrumentation is still needed.

10.1.1.2 Decay Heat Removal System Operation (or Auxiliary Decay Heat Removal System)

The critical systems and components in the containment essential to this mode of operation are significantly less than the equipment required for natural circulation:

a. Instrumentation

Nuclear instrumentation  
 Incore thermocouples

b. Electrical

Power supply cabling and connectors for instrumentation  
 Instrument signal cabling  
 Motor operated valves (or valves open before operators are flooded)

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c. Mechanical

Reactor vessel and RCS piping  
 Decay heat removal system  
 Piping and drop line valves in the  
 containment

The capability to remove reactor core heat with a decay heat removal system is dependent on a minimal number of essential systems and components in the containment.

10.1.2 Systems and Components Required During the Containment  
 Decontamination Phase

Due to the high levels of contamination and radiation postulated to exist throughout the containment, and the shutdown status of the plant, most of the in-containment systems will not be required to support decontamination. Section 4.2 describes the decontamination support systems, some of which are new systems, while others employ portions of existing systems (i.e., hard piping, small valves).

There are however, several components which are essential to the work effort during decontamination. The following components should be made operable as soon as feasible after containment reentry:

- a. Containment elevator
- b. Jib cranes (reactor vessel head storage stand area and incore instrumentation service area)
- c. Polar crane - trolley and bridge
- d. All other service cranes and hoists with the exception of the RV service structure hoists
- e. Containment lighting
- f. Electrical power outlets
- g. Containment air coolers

Containment ventilation will be essential for personnel comfort and safety during decontamination. The containment purge system and instrument air systems are also required during the decontamination phase for building ventilation.

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## 10.2 Protection of Systems and Components During Remote Decontamination

As described in Section 5.0, the containment spray headers and nozzles will be used to inject steam, demineralized water and chemical solutions into the containment. The effect of containment spray on equipment in the containment is twofold:

- a. Spray fluid chemistry - effects on material
- b. Effects on equipment operability

### 10.2.1 Chemistry Control of Containment Spray (Rinse)

Control of spray water chemistry is necessary to minimize material corrosion on equipment in contact with containment spray water.

Detergent and chemical spray solutions should be evaluated and approved prior to being used. However, all water rinses (i.e., initial high volume spray rinses, rinses following detergent and chemical rinses) should meet the following chemistry requirements:

#### Untreated Water (Makeup Water)

|              |                      |
|--------------|----------------------|
| pH           | 5.5 to 8.0 (assumed) |
| Chloride     | < 10 ppm             |
| Fluorides    | < 5 ppm              |
| Conductivity | < 25 u mho           |

Water sprayed into the containment for the purpose of rinsing should be treated with disodium phosphate and trisodium phosphate ( $\approx 0.67$  parts  $\text{Na}_2\text{HPO}_4$  to 1.0 part  $\text{Na}_3\text{PO}_4$ ). Water sprayed into the containment should contain 5-15 ppm sodium phosphate.

### 10.2.2 Effects of Containment Spray on Systems and Components

The use of good quality water in the containment spray is a preventative measure. The control of this water will minimize corrosion and offer some protection in areas where water can collect. A treated water rinse after the detergent and chemical rinses will dilute water solutions that collected in cracks and crevices and provide additional corrosion protection. Corrosion rates and potential long term problems associated with stress corrosion will be minimized. There should be minimal detrimental corrosion effects associated with the use of water meeting the quality requirements in Section 10.2.1.

The most significant effect of containment spray is on equipment operability. The equipment most susceptible to spray are electrical components, connectors and cabling and instrumentation. Increasing containment humidity, condensing steam on equipment and spraying water directly on components may eventually result in failure

of equipment. However, since spray activation and high humidity conditions have existed in the time following the incident, additional effects due to the remote decontamination procedures presented in Section 5 should be minor.

The following are potential candidates for failure:

- a. Incore instrument thermocouples - Incore detector wiring, cabling and connectors will be directly exposed to spray water.
- b. Pressurizer heater cables and connectors are extremely sensitive to moisture.
- c. Electric motors on the polar crane and jib cranes.
- d. Containment lighting
- e. Electrical and outlet plugs and power systems

Contingency plans for loss of equipment essential to plant operation should be available prior to initiating containment spray. The unit should be in an operating mode that requires a minimal number of essential systems and components in the containment. If possible, the decay heat removal system (or alternate decay heat removal system) should be in operation for removal of reactor core decay heat.

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### 10.3 Protection of Systems and Components During Local Hands-on Decontamination

Hands-on decontamination will require large quantities of water and chemical solutions. Methods may involve proven decontamination techniques as well as untried techniques. Control of these decontamination procedures and instituting precautionary measures to minimize potential equipment damage will be required.

#### 10.3.1 Administrative Controls for Systems and Component Protection

Methods and techniques for decontamination of the containment and the equipment in the building should be in the form of procedures. These procedures should be reviewed and approved through the normal procedure review and approval channels.

Decontamination procedures can be generic whereby specific techniques, methods, chemical reagents, etc., are approved for general use. These procedures can also be unique, i.e., for one time use or special situations.

The following items must be considered during the review and approval and/or prior to implementing the decontamination procedure:

- a. Personnel safety
- b. Equipment or components to be decontaminated
- c. Chemical reagents to be used
- d. Compatability of chemical reagents with material to be decontaminated
- e. Evaluation of the need for protection of essential equipment
- f. Potential for further equipment damage during decontamination

Administrative control of decontamination procedures will provide assurances that decontamination of the containment and equipment will minimize further equipment damage and not jeopardize existing plant operating conditions.

#### 10.3.2 Physical Protection of Essential Components During Decontamination

Essential components can be protected in a variety of ways during hands-on decontamination. Physical protection would include:

- a. Protective water-proof covers on electrical components and instrumentation
- b. Treated water rinse after chemical reagent rinse

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- c. Deenergization of electrical equipment prior to decontamination
- d. Identification and tagging of essential equipment
- e. Installation of temporary protective barriers around equipment
- f. Blankets, tarps, etc.
- g. Roping off vital areas

Protection of essential equipment is a prerequisite to decontamination. Some of the essential equipment and systems are identified in Sections 10.1.1 through 10.1.3.

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10.4 Protection of Systems and Components - Long Term

Most of the systems and components in the containment will be inactive during the decontamination of the containment. During the period of time these systems will not be in service, preventative measures are required for long term protection. Systems and components should be placed in a long term wet layup condition, as follows:

a. Steam Generators (including main steam and feedwater piping)

When the steam generators are no longer required for reactor core heat removal, they should be placed in a full wet layup condition with water meeting the chemistry requirements for wet layup conditions.

Provisions for periodically adding chemicals to the steam generators and recirculating water through the steam generators must be available.

1. The B Loop closed cycle cooling system can be used as a wet layup system for the B steam generator.
2. The A Loop feedwater/main steam systems can be used for steam generator A for the short term, however, provisions for long term chemical addition and recirculation should be made.

b. Auxiliary Systems (intermediate closed cooling water, nuclear services closed cooling water, etc.)

These inactive systems should be flushed and filled with treated water meeting the chemistry specifications for wet layup conditions and equipment protection.

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11.0 MAINTENANCE OF NSSS COMPONENT INTEGRITY11.1 Inventory of Critical NSSS Components in the Containment

An inventory of NSSS components is shown in Table 11-1. These components have been subjected to undesirable environmental conditions, and, in some cases, these environmental conditions still exist. One of the major concerns is corrosion of carbon steel resulting from containment spray water, high containment humidity and submergence of components in water.

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## 11.2 Effect of Changing Sump Level on NSSS Components

At present there are a number of NSSS components that are submerged in sump water. Increasing containment sump water level will ultimately flood other components.

As of June 4, 1979, the containment sump water level was measured to be at 289.37 feet ( 6.9 feet deep). The submerged NSSS components are as follows:

- a. Letdown coolers (carbon steel)
- b. RCS cold leg piping (partially submerged)  
(carbon steel)
- c. Steam generator holddown nuts/bolts  
(carbon steel)
- d. Steam generator support skirt  
(carbon steel)
- e. Steam generator lower head (primary  
inspection and manway closures/studs/  
nuts) (carbon steel)
- f. RCS cold leg and steam generator insulation  
(partially submerged) (stainless steel)

The NSSS components which may soon be totally submerged are as follows:

| <u>NSSS Components</u>                                                                    | <u>Elevation</u>                  |
|-------------------------------------------------------------------------------------------|-----------------------------------|
| a. Letdown cooler isolation<br>valves MU-V1a, V1B, V2A,<br>V2B (stainless steel)          | 289.25'<br>(partially submerged)  |
| b. Intermediate cooling water<br>valves IC-V1A, V1B<br>(carbon steel)                     | 289.125'<br>(partially submerged) |
| c. Decay heat dropline valves<br>DH V1A (stainless steel)                                 | 293.5'<br>(operator elevation)    |
| DH V1B (stainless steel)                                                                  | 290.5'<br>(operator elevation)    |
| d. Reactor vessel support<br>skirt pad (carbon steel)                                     | 291.2'<br>(base)                  |
| e. Reactor vessel hold down<br>bolts/nuts (carbon steel)<br>(See Figure 11-2 for details) | 292.3'<br>(top)                   |

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|                                         |                    |
|-----------------------------------------|--------------------|
| f. Reactor vessel lower head            | 290.5'<br>(bottom) |
| g. Reactor vessel lower head insulation | 289.9'<br>(bottom) |

Carbon steel material submerged in containment sump water will corrode. The degree of corrosion will depend on the chemistry of the water.

#### Containment Sump Water

The containment sump water is estimated to have a pH of about 8.5 - 8.6 with a chemistry of about 2760 ppm caustic (NaOH) and about 12,000 ppm boric acid ( $H_3BO_3$ ). The caustic has probably reacted with the boric acid to form sodium tetraborate or borax ( $Na_2B_4O_7$ ). As a result, the sump water is expected to contain about 6940 ppm sodium tetraborate and about 3500 ppm boric acid.

#### Corrosion Rate Testing

The Babcock & Wilcox Alliance Research Center (ARC) conducted corrosion tests of materials in containment spray solution of the following concentrations:

##### Solution A

- 1.22% boric acid ( $H_3BO_3$ )
- 1% sodium thiosulfate ( $Na_2S_2O_3$ )
- pH 9.5 with sodium hydroxide (NaOH)

##### Solution B

- 1.22% boric acid ( $H_3BO_3$ )
- 0.6% sodium thiosulfate ( $Na_2S_2O_3$ )
- pH 7.5 with sodium hydroxide (NaOH)

##### Solution C

- 1.22% boric acid ( $H_3BO_3$ )
- pH 9.5 with sodium hydroxide (NaOH)

Although these solutions are somewhat different from the TMI-2 containment sump water (i.e., Solutions A & B contain sodium thiosulfate) the tests provided corrosion rate information which is applicable to TMI-2.

872016

Conclusions/Recommendations

- a. Based on the results shown in Table 11-2, the corrosion rates are higher in a partially submerged condition than in a submerged condition. Therefore, it would be desirable to maintain components submerged to minimize corrosion.
- b. Increasing or decreasing sump level during decontamination, containment sump water processing, etc., will expose components to a wet/dry environment. Corrosion rates will increase in the area where material is re-exposed to air. Cycling of water level should therefore be minimized.
- c. The present solution in the containment sump should provide an inhibiting effect on the corrosion of carbon steel. Chemicals need not be added to the sump water.
- d. Corrosion rates are expected to be in the range of 0.1 to 1.0 mil. per year.

372017

### 11.3 Effect of Sump Dewatering on NSSS Components

Containment sump water will eventually be pumped out of the containment for processing, exposing previously submerged components to the containment atmosphere. As shown in Table 11-2, corrosion is greater for exposed carbon steel surfaces than for submerged material. Subjecting these components to high building humidity and/or alternately wetting and drying the material will also induce higher corrosion rates.

Complete dewatering of the containment through the sump will not be possible for several reasons:

- a. The containment floor and equipment drainage piping would normally drain water to the sump. However, some floor drains may be plugged with loose debris forming localized pools of water.
- b. The absence of a floor drain inside the steam generator support cavity and the geometrical arrangement of the steam generator base support precludes the complete dewatering of this area by drainage. Referring to Figure 11-1, approximately two inches of water will remain in this cavity when the containment is dewatered, enough water to partially submerge the steam generator hold down bolts and nuts.

### Conclusions and Recommendations

- a. Reduce containment relative humidity by periodically running the containment air coolers. Continue with this operation until remote decontamination with the containment spray system begins.
- b. After completion of remote decontamination with the containment spray system, dewater the containment sump completely and re-flood per Section 11.4.

372018

#### 11.4 Desirability of Sump Reflooding with Inhibitors

Once the containment sump is drained, components that were once submerged will be exposed to the containment environment. This environment includes exposure to air, varying humidity conditions and direct exposure to containment spray water that is to be used in the remote decontamination phase.

Contaminated water in the containment sump will be drained prior to remote decontamination with the containment spray system. During this remote decontamination phase, the sump may again be drained several times.

If the containment sump is to remain in a dewatered condition for an extended period of time (i.e., ~4 weeks) after the initial dewatering, the following is recommended:

- a. Reflood the containment sump to a minimum of one foot with treated water. One foot is sufficient to cover the steam generator holddown studs/nuts.
- b. The treated water should be as follows:

##### Nitrate-Borax Treatment

- o pH at 77°F 9.5
  - o Nitrates (i.e., sodium nitrate) 2000-3000 ppm
  - o Tetraborate (i.e., sodium tetraborate) 200-300 ppm
- c. Reflooding with this solution should not be done using the containment spray system. Reflooding should be done through the containment sump drain line via DH-V6A or 6B.

#### Final Rinse/Reflood of Containment Sump

After remote decontamination with the containment spray system is completed, the containment sump should be drained and reflooded to a minimum of one foot with treated water.

- a. The containment spray system can be used to reflood the containment sump with treated water prior to building entry. This will also serve as a final rinse of the containment.
- b. Chemistry requirements for the makeup and treated water are specified in Section 10.2.1, i.e., 50 - 100 ppm sodium phosphate solution.

8/2019

TABLE 11-1CRITICAL NSSS COMPONENTS  
IN THE CONTAINMENT

1. CF-V1A, V1B Core Flood Tank Isolation Valves
2. CF4A, 4B, 5A, 5B Core Flood Check Valves
3. DH-V1, V2 Decay Heat Drop Line Valves
4. Reactor Coolant Pump Motors
5. Reactor Coolant Pump Casings
6. Reactor Coolant Pump Internals
7. Reactor Coolant Pump Motor Stands
8. Reactor Coolant Pump Constant Load Supports
9. Control Rod Drives (Control)
10. Axial Power Shaping Control Rod Drives
11. Fuel Handling Bridges and Fuel Transfer System Cabinets (Electrical)
12. Reactor Coolant System Piping (Cold Legs/Hot Legs)
13. Reactor Vessel
14. Reactor Vessel Head Studs/Nuts/Washers
15. Reactor Vessel Head
16. Steam Generators
17. Pressurizer (including Pressurizer Heaters)
18. Plenum Assembly
19. Core Support Sub Assembly
20. Core Support Shield Assembly
21. Internal Vent Valves
22. Core Flood Tanks
23. Insulation

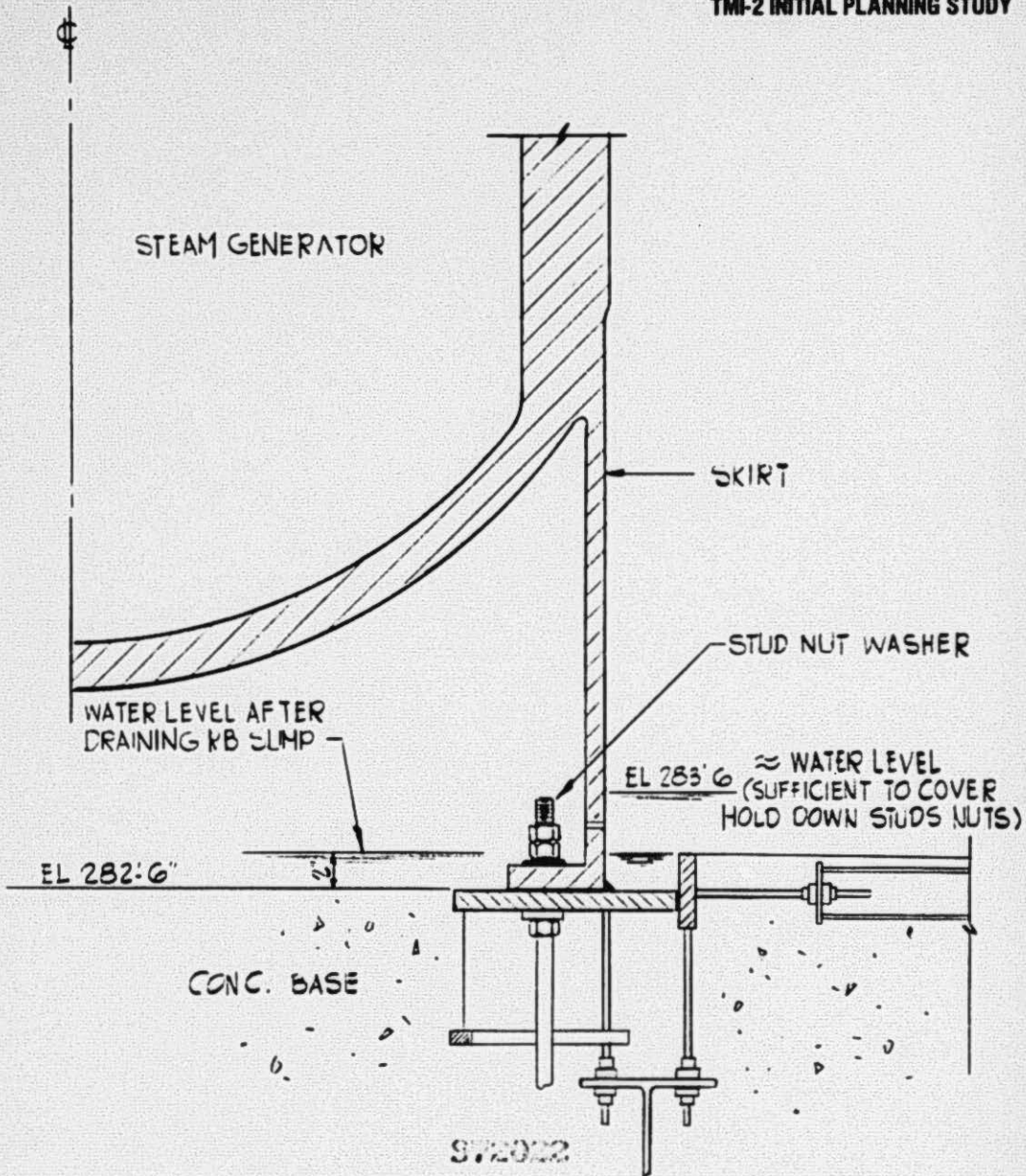
972020

TABLE 11-2

CORROSION RATES OF CARBON STEEL EXPOSED IN LONG TERM TESTS IN  
SIMULATED CONTAINMENT SPRAY SOLUTIONS

| <u>MATERIAL</u>                                  | CORROSION RATE - MILS PER YEAR |        |        |                   |        |        |                   |        |        |
|--------------------------------------------------|--------------------------------|--------|--------|-------------------|--------|--------|-------------------|--------|--------|
|                                                  | <u>SOLUTION A</u>              |        |        | <u>SOLUTION B</u> |        |        | <u>SOLUTION C</u> |        |        |
|                                                  | 4 wks                          | 14 wks | 26 wks | 4 wks             | 14 wks | 26 wks | 4 wks             | 14 wks | 26 wks |
| CARBON STEEL<br>(SUBMERGED)                      | 0.29                           | 0.24   | 0.39   | 5.62              | 1.62   | 1.85   | 0.023             | 0.008  | 0.011  |
| CARBON STEEL<br>(PARTIALLY SUBMERGED)            | 2.95                           | 1.36   | 0.81   | 8.37              | 12.4   | 7.82   | 0.18              | 0.014  | 0.016  |
| CARBON STEEL STRESSED<br>(SUBMERGED)             | 0.28                           | 0.29   | 0.07   | 4.26              | 2.65   | 1.83   | 0.07              | 0.02   | 0.008  |
| CARBON STEEL UNSTRESSED<br>(PARTIALLY SUBMERGED) | 1.67                           | 1.54   | 0.92   | 4.20              | 4.69   | 7.46   | 0.14              | 0.02   | 0.01   |

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2004

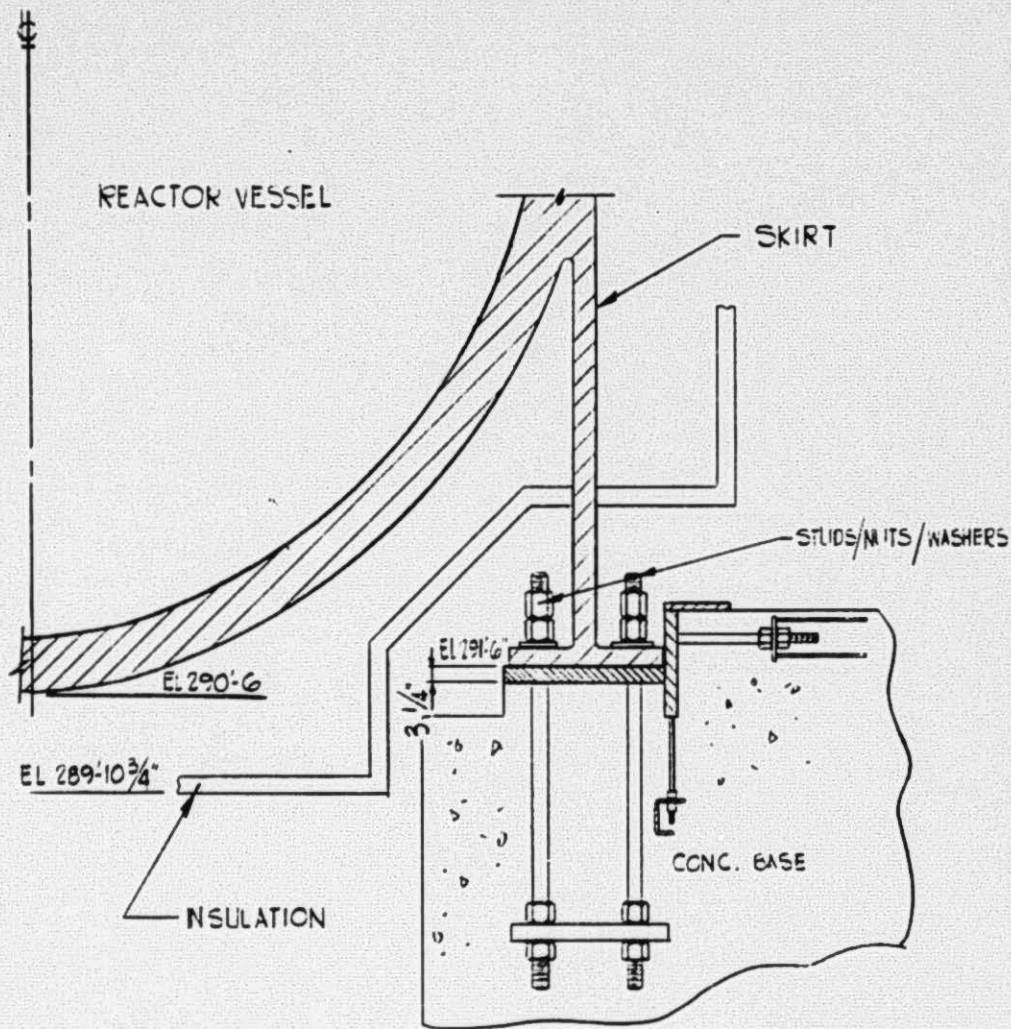


POOR ORIGINAL

STEAM GENERATOR BASE SUPPORT

FIG. 11-1

SK-TMI/CRE-12



REACTOR VESSEL BASE SUPPORT

FIG. 11-2  
SK TMI/CRE - 13

POOR  
ORIGINAL