XA04N0057

NUREG-0662

INIS-XA-N--040

Environmental Assessment for Decontamination of the Three Mile Island Unit 2 Reactor Building Atmosphere

Draft NRC Staff Report
For Public Comment

TMI Support Staff
Office of
Nuclear Reactor Regulation

U.S. Nuclear Regulatory Commission

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Manuscript Completed: March 1980
Date Published: March 1980

TMI Support Staff
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

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1.0 Summary and Recommendations

The krypton-85 (Kr-85) released to the reactor building during the accident at TMI-2 must be removed from the reactor building in order to permit greater access to the building than is currently possible. The gases currently in the building emit sufficient radiation (1.2 rem/hr total body, 150 rad/hr skin dose) that occupation of the reactor building is severely limited even with protective clothing. Greater access is likely to be necessary to maintain instrumentation and equipment required to keep the reactor in a safe shutdown condition. In addition greater access would facilitate the gathering of data needed for planning the building decontamination program. An additional consideration is that prolonged enclosure of the Kr-85 within the building greatly increases the risk of its successive uncontrolled releases to the outside environment.

The staff's evaluation of alternative methods for removing the krypton shows that each could be implemented with little risk to the health and safety of the public. The reactor building purge system, charcoal adsorption system, gas compression, selective absorption process system, and cryogenic processing system could each be operated to keep levels of airborne radioactive materials to unrestricted areas in compliance with the requirements of 10 CFR Part 20 (Ref. 1), and the design objectives of Appendix I to 10 CFR Part 50 of the Commission's regulations (Ref. 2), and with the applicable requirements of 40 CFR Part 190.10 (Ref. 3).

Table 1.1 shows the environmental impact of each alternative for removing the Kr-85 from the reactor building atmosphere.

Because the integrity and operability of components within (and part of) the reactor building are important to continued safe shutdown and inhibiting future radioactive releases to the environment, one of the most important factors in any decontamination option is the time required for its implementation. The Kr-85 in the reactor building has prevented maintenance of internal reactor-building components for about a year. All options for removal of the Kr-85 to allow access to the reactor building, except for the purge option, would require at least 1-1/2 additional years to implement. This time would be required for design and procurement, installation, testing, and operation of new systems.

The alternative of purging the reactor building atmosphere through the hydrogen control system is clearly the most expeditious method available for removing the krypton. It also results in the greatest environmental impact in terms of public dose during normal operations, even though such doses are well within applicable regulations (Refs. 1, 2). The other alternatives take much longer to implement and also require either long-term storage of large quantities of charcoal containing Kr-85 or long-term storage of large quantities of pressurized Kr-85 gas in piping or vessels. Inherent in these storage methods is the risk of subsequent accidental releases of the krypton due to either failure of the storage containers or operator error.

Table 1.2 summarizes the advantages and disadvantages of each of the alternative methods evaluated for removing the krypton from the reactor building atmosphere.

The staff is fully aware of the public sentiment against the planned or accidental release of any further radioactive materials from TMI-2, regardless of how small the dose consequences are suspected to be. Particular concern has been expressed against purging the Kr-85. However, based on past experience, it is likely that future accidental releases or operational incidents will occur if storage is continued. The possiblity of future accidental releases is also increased by continued reliance on unmaintained equipment. The staff therefore believes that a balance must be struck between the impact of a onetime preplanned release of krypton (and its additional benefits of allowing component maintenance inside the reactor building and the cleanup process) versus the impact of one or more accidental smaller releases while storing the Kr-85 for 1-1/2 years or more for subsequent low-impact processing (and its negative effect of precluding significant work inside of the building during this period). The staff is unable to determine that the cumulative psychological stress resulting from the threat or actual occurrence of one or more minor releases over a 1-1/2 year period is not more significant than the stress that would result from a single larger but preplanned krypton release.

With all of the above considerations in mind, the staff recommends that purging of the reactor building atmosphere to the environment be selected as the decontamination option for disposal of the Kr-85.

Based on our estimate of doses to the public from releases during the decontamination of the reactor building atmosphere by purging through the hydrogen control system, and our estimate of occupational dose, the staff concludes that this action does not constitute a significant environmental impact and that the environmental impacts for each of the alternative methods would be less than those considered in the TMI Final Environmental Statement (Ref. 4). The staff concludes that the health and safety of the public will not be endangered by operation of the system in the proposed manner and that such activities can and will be conducted in full compliance with the Commission's regulations (Refs. 1, 2). Accordingly, the staff does not propose to prepare a separate Environmental Impact Statement on this action.

In accordance with the Commission's Nov. 21, 1979, "Statement of Policy and Notice of Intent to Prepare a Programmatic Environmental Impact Statement" (see Appendix A), this staff Environmental Assessment is being submitted to the Commission for their review and discussion. In addition, the President's Council on Environmental Quality (CEQ) is being consulted on this. Comments are also being solicited from the public.

Table 1.1
Environmental Impacts of Alternatives for Removing the Krypton-85 from the Reactor Building Atmosphere

	Total Offsite Dose to Maximum Exposed Individual		
Method	Normal Processing	Accidents	Occupational Exposures
Reactor Building Purge	Beta skin dose - 11 mrem Total body gamma dose - 0.2 mrem	Beta skin dose - 25 mrem Total body gamma dose - 0.3 mrem	1.3 person-rem
Charcoal Absorption Systems	Less than Cryogenic Processing System	Ambient Charcoal System Beta skin dose - 41 mrem Total body gamma dose - 0.5 mrem Refrigerated Charcoal System Beta skin dose - 124 mrem Total body gamma dose - 1.5 mrem	47 person-rem
Gas Compression System	Less than Cryogenic Processing System	Beta skin dose - 410 mrem Total body gamma dose - 5 mrem	42 person-rem
Cryogenic Processing System	Beta skin dose - 0.01 mrem Total Body Gamma dose - less than 0.0002 mrem	Beta skin dose - 1700 mrem Total body gamma dose - 20 mrem	137-255 person-rem
Selective Absorption Process System	Less than Cryogenic Processing System	Absorption Process Beta skin dose - 6 mrem Total body gamma dose - 0.1 mrem Gas Storage Beta skin dose - 1700 mrem Total body gamma dose - 20 mrem	45 person-rem

Table 1.2
Comparison Among Alternatives for Removing the Krypton from the Reactor Building Atmosphere

Method	Advantages	Disadvantages	Estimated Installation Cost
Reactor Building Purge	. Immediately available for use . Noncomplex system . Known technology . No further uncontrolled releases after purging . No requirement for long term storage and surveillance of Kr-85	. Beta skin dose - 11 mrem Total body gamma dose - 0.2 mrem . Stress considerations associated with release	$75,000 (licensee estimate)
Charcoal Adsorption	. Offsite dose effects less than Cryogenic Processing System . Known technology . Ambient Charcoal System - noncomplex system	. 2-4 year delay . Long-term storage and surveillance of Kr-85 in large volume of charcoal . Possible future uncontrolled releases of Kr-85. . Refrigerated Charcoal System - complex system	$120-160 million (licensee estimate)
Gas Compression System	. Offsite dose effects less than Cryogenic Processing System . Known technology . Noncomplex system, but under pressure	. 2-4 year delay . Long-term storage and surveillance of Kr-85 under pressure . Possible future uncontrolled releases of Kr-85.	$50-75 million (licensee estimate)
Cryogenic Processing System	. Beta skin dose - 0.01 mrem . Total body gamma dose - 0.0002 mrem . Known technology	. 20-30 month delay . Complex system. . Long-term storage and surveillance of Kr-85 . Possible future uncontrolled releases of Kr-85.	$10-15 million (licensee estimate)

Table 1.2 (Continued)

Method	Advantages	Disadvantages	Estimated Installation Cost
Selective Absorption Process System	. Offsite dose effects less than Cryogenic Processing System	. 2-4 year delay . Process has only operated on small scale units. . Complex system. . Long-term storage and surveillance of Kr-85. . Possible future uncontrolled releases of Kr-85.	$4-10 million (staff estimate)

2.0 Proposed Action

This NRC staff assessment responds to a proposal submitted by Metropolitan Edison Company (the licensee) for decontaminating the TMI-2 reactor building atmosphere by purging to the environment through the building's existing hydrogen control system (Ref. 5). The assessment evaluates what effect decontamination or failure to decontaminate will have on the licensee's work force, on the public health and safety, and on the environment. It includes a consideration of occupational exposures, the potential for accidental releases, and discusses several alternatives for decontaminating the reactor building atmosphere by use of the hydrogen control system. Decontamination of the reactor building equipment, interior walls and surfaces, and treatment and disposition of the water in the reactor building sump will be addressed in a Programmatic Environmental Impact Statement to be issued by the staff later in 1980.

3.0 Introduction

As a result of the March 28, 1979 accident at the TMI Unit 2 facility, significant quantities of radioactive fission products and particulates were released into the enclosed reactor building atmosphere as a result of substantial fuel failure in the reactor core. At the present time, the dominant radionuclide remaining in the reactor building atmosphere is krypton-85 (Kr-85), which has a 10.7 year half-life. Based on weekly sampling of the reactor building atmosphere since the accident, the concentration of the Kr-85 in the building is about 1.0 μCi/cc, which yields a total inventory of approximately 57,000 curies. The licensee, in its November 13, 1979 submittal (Ref.5), based its evaluations on an estimated Kr-85 concentration in the reactor building of 0.78 μCi/cc at that time, which yielded a total inventory of approximately 44,000 curies. Reactor building atmosphere sampling and analysis are discussed in detail in Section 5.0.

At the present time the reactor is being maintained in a safe shutdown configuration, with the damaged fuel in the reactor vessel. The reactor building air cooling system is maintaining the building at a slight negative pressure (approximately -0.7 psig) with respect to the outside atmosphere. This pressure differential ensures no leakage of the reactor building atmosphere to the environment. However, before the facility can be either decommissioned or recovered for eventual operation, the damaged fuel must be removed from the reactor vessel and building, placed in containers if necessary, and stored or shipped offsite. The radiation levels in the reactor building are such that occupancy is severely restricted. Less restricted access to the reactor building is likely to be required to facilitate the gathering of data needed for planning the building decontamination program, and for the subsequent work required to accomplish decontamination and cleanup operations. Less restricted occupancy will require that the building atmosphere be decontaminated to protect workers from exposure to beta and gamma radiation associated with the Kr-85 in the reactor building atmosphere.

On November 13, 1979, the licensee submitted a request to the NRC staff for authorization to decontaminate the reactor building atmosphere by controlled purging (feed and bleed) through the reactor building hydrogen control system (Ref. 5). In a letter to the licensee on December 18, 1979, the staff withheld approval of the request to purge the building and stated the NRC would prepare an Environmental Assessment on the subject in early 1980 (Ref. 6). The staff reviewed the licensee's submittal, including its discussion of various alternatives to reactor building purging. As a result of the review, staff requested additional information in the form of 33 questions, by letter on December 18, 1979 (Ref. 7). The licensee responded to the staff's request on January 4, 1980 (Ref. 8). Pursuant to the requirements set forth in the Commission policy statement of November 21, 1979 (see Appendix A) and the February 11, 1980 Order by the Director of the Office of Nuclear Reactor Regulation (Ref. 9), the NRC staff has prepared this environmental assessment. This assessment includes the staff's evaluation of the licensee's modifications to the reactor building hydrogen control system, as well as a discussion of the need to decontaminate the reactor building atmosphere (see Section 4.0), and alternatives to controlled purging to the environment (see Section 6.0).

4.0 Need for Decontamination of the Reactor Building Atmosphere

4.1 Summary

Less restricted access to the reactor building is necessary facilitate the gathering of data needed for planning the building decontamination program prior to removing the fuel from the reactor vessel and building. Less restricted access to the reactor building is also necessary in order to repair or replace nuclear instruments, to maintain the reactor building air cooling system, and to decontaminate the building, its equipment and piping. In these operations, occupational exposure is a significant concern. Current radiation exposure levels within the reactor building severely restrict access to the building. In order to maintain the instrumentation and equipment and remove the fuel, the Kr-85 in the reactor building atmosphere must first be removed. Furthermore, continuing to isolate the Kr-85 within the reactor building is not a viable alternative to its disposal since some uncontrolled release is likely to occur in the future.

4.2 Discussion

The TMI-2 reactor is presently being maintained in a safe shutdown subcritical condition with damaged fuel in the reactor vessel. The reactor must continue to be maintained subcritical and this damaged fuel must be removed from the reactor vessel and placed in a safe configuration prior to either plant recovery to an operable status or to decommissioning. The licensee is presently relying on boron in solution in the reactor coolant to maintain the core subcritical because it is believed that some of the control rod material melted during the accident and may now be drained out of the core. Most of the instrumentation provided for monitoring the reactor neutron flux is presently inoperable. Only one nuclear instrument channel is operating. If this instrument fails there will be no direct measurement to provide assurance that the reactor core is not going critical again. Therefore, it will then be necessary to infer the reactivity status of the core by continuing to periodically obtain reactor coolant samples and to analyze their boron concentration. In order to repair or replace any of the damaged nuclear instruments, the licensee needs less restricted access to the upper operating deck areas in the reactor building.

Based on a reactor building Kr-85 concentration of 1.0 μCi/cc (see Section 5.2), the total body gamma dose rate from the krypton cloud alone to an individual inside the building is approximately 1.2 rem/hour. The beta dose rate from the cloud to the unshielded skin of an individual inside the building is approximately 150 rads/hour. Protective clothing could be used to shield workers from direct beta radiation from the krypton cloud. However Kr-85 has the unique capability of infiltrating and diffusing through protective garments. Furthermore, the protective garments would not diminish the gamma dose rate of 1.2 rem/hr. Decontamination of the reactor building atmosphere would eliminate the inefficiency and burden of working in specialized protective clothing and self-contained breathing apparatus that would otherwise be required.

The benefits from the removal of the contaminated atmosphere from the reactor building are significant since the krypton cloud contributes approximately 75% of the total body gamma field on the operating floor (at the 347' elevation) of the reactor building. Meaningful progress toward the eventual removal of the damaged core and the cleanup of the reactor coolant system cannot begin until the reactor building atmosphere is decontaminated.

The damaged fuel contains most of the fission products which were generated during operation of the reactor. These fission products are continuing to generate heat (approximately 200 kilowatts at present) in the reactor core due to their radioactive decay. The reactor coolant system is removing this decay heat from the core by natural convection circulation. Approximately 50% of the heat is being removed by the secondary cooling system through the "A" steam generator, while the remainder is being dissipated to the reactor building atmosphere due to heat losses from the reactor coolant system. The reactor building atmosphere is being maintained at approximately 75°F by the reactor building air cooling system. This cooling action is maintaining the reactor building at a slight negative pressure (approximately -0.7 psig) with respect to the outside atmosphere. This pressure differential prevents leakage of the reactor building atmosphere to the environment. Other factors which effect the pressure differential between the reactor building atmosphere and the outside atmosphere include (1) pressure differential due to wind currents over and around the building, (2) changes in barometric pressure, and (3) changes in external air temperatures.

The building's air-cooling system's fans were qualified for 3 to 4 hours of continuous operation in a 100% relative humidity environment. They have been operating nearly continuously since the March 28, 1979 accident in a high-humidity environment. Therefore, these fans can reasonably be expected to fail at any time. Their failure would result in a decrease of heat removal from the reactor building atmosphere which would in turn cause the atmospheric pressure in the reactor building to increase and become positive relative to the outside atmosphere. The licensee has calculated that the reactor building internal pressure could rise to 1-2 psig if this cooling system fails. The staff has calculated that for worst-case conditions, this pressure could rise to as high as 4 psig.

With the reactor building atmosphere at a positive pressure, uncontrolled leakage of the reactor building atmosphere to the outside environment will occur even without further degradation of the existing reactor building integrity. The reactor building has a design leakage rate of 0.2% by weight per day at 60 psi. The measured leakage rate of the reactor building during its most recent leakrate test (conducted early January 1978) was 0.095% by weight per day at 56 psi. As calculated by the NRC staff, the offsite doses due to uncontrolled leakage from the reactor building at 1-2 psig at its design leak rate are shown in Table 4.1. Uncontrolled leakage would also increase the likelihood of exposures to in-plant workers. Various potential release pathways, including equipment hatch seals, air lock seals, flanged penetrations that use seal gaskets, in addition to inadvertent openings of release pathways due to equipment malfunctions or operator errors, also exist. These potential pathways are sealed by seals which are presently inaccessible for maintenance because of high ambient radiation levels. These seals can be expected to degrade with time which could result in an increase in the uncontrolled leakage from the reactor building if the building were at a positive pressure. Disposal of the Kr-85 in the reactor building atmosphere would of course eliminate the potential for its uncontrolled release.

Based on the foregoing discussion, the staff believes that it is in the best interest of the public health and safety to purge the reactor building promptly prior to completion of the Programmatic Environmental Impact Statement.

Table 4.1

Offsite Doses Due to Uncontrolled Leakage[1]

Offsite Dose During a 1-Day Period, mrem[2]		Offsite Dose During a 30-Day Period, mrem[3]	
Dβ	Dγ	Dβ	Dγ
0.5	0.01	10	0.12

[1]Reactor building at 1-2 psig and leaking at its design leak rate of 0.2% by weight per day (114 curies).

[2]A value for X/Q of 10^{-4} sec/m^3 was used for this calculation.

[3]A value for X/Q of 6.8×10^{-5} sec/m^3 was used for this calculation.

5.0 Reactor Building Airborne Activity

5.1 Gas Sampling and Analysis

Three types of reactor building air samples are collected weekly to determine the nature of airborne containments in the building. Samples are taken for noble gases, particulate, and radioiodine activity. Air samples are taken from two points in the reactor building. The samples are transmitted through two lines running from the dome to the reactor building air sample gaseous monitor.

Redundant inlet and discharge valves are provided for the system to prevent a single-active failure of any valve from imparing the function of the system. Samples are analyzed with a gas chromatograph to determine hydrogen content. A gamma spectrum analyzer is used to determine the isotopic composition of the sample. The Kr-85 gas activity in the reactor building atmosphere is determined by gamma spectroscopy. Isotopic identification is made on the basis of the discrete energy levels at which gamma rays are absorbed in a GeLi detector. Particulate activity is determined in the reactor building atmosphere by pumping building air through a filter. Particulate activity is removed from the air by filters, which are then analyzed using gamma spectroscopy, as described above. To determine the concentrations of the different types of iodine in the atmosphere, a sample of the reactor building air is pumped through a series of filters. Separation of the different forms of iodine is accomplished based on the relative affinity of each iodine species for a specific filter media. Each filter is then analyzed using gamma spectroscopy.

In addition to the routine samples for noble gases, particulates, and iodine, samples are obtained for tritium, and gross beta analyses. The results of the sampling program are presented in the following section, "Source Term Derivation."

5.2 Source Term Derivation

Sample results to date indicate that the dominant isotope within the reactor building atmosphere is Kr-85. Radioactive decay has reduced other radioactive isotopes of xenon and krypton to negligible quantities. Based on samples taken for the period indicated, the source term for Kr-85 is 1 μCi/cc. Particulate levels, primarily cesium-137, are on the order of 1×10^{-9} μCi/cc. Radioactive decay has reduced iodine levels in the reactor building to below minimum detectable activity (MDA) levels of 1×10^{-9} μCi/cc. Although the reactor building air samples have not been specifically analyzed for strontium-89/90, the results of gross beta analyses performed on the air samples show that very little airborne strontium-89/90 is present.

The tritium concentration in the reactor building is 3.6×10^{-5} μCi/cc. This is a calculated value based on reactor building relative humidity of 90% and the concentration of tritium in the reactor building sump.

6.0 Decontamination Alternatives

6.1 Reactor Building Purge

6.1.1 Introduction

The hydrogen control subsystem is an existing subsystem originally installed as a backup system to the hydrogen recombiners. The system is being modified to allow step-wise increases in flow up to a maximum of 1000 cfm. Actual purge rates during any time interval would be dependent on meteorological conditions and reactor building concentrations. The hydrogen control system would remove reactor building atmosphere through a filter system and discharge it to a 160 ft. plant vent stack. Use of this would result in releases of radioactive materials to the environment. However, calculations based on actual meteorological and release rate data can be used to monitor radioactive releases so that they do not exceed the design objectives of 10 CFR Part 50, Appendix I (Ref. 2) and the applicable requirements of 40 CFR 190.10 (Ref. 3).

6.1.2 System Description and Operation

The proposed purge of the Unit 2 building to the atmosphere would use the hydrogen control subsystem of the reactor building ventilation system. Radioactive gases purged from the reactor building would be diluted with less contaminated exhaust air and released via the Unit 2 vent stack, which is 160 feet above grade level. The hydrogen control system (hereafter, the purge system) was originally designed for use as a back up for the hydrogen recombiners. The major components of the purge system include: an exhaust fan, isolation valves, and a filtration system. The filtration system consists of a prefilter, a HEPA filter, an activated carbon filter, and a second HEPA filter. Replacement air to the reactor building would be supplied through a supply valve.

The maximum discharge flow rates during purge system operation would be based on the Technical Specification limit for Kr-85 releases through an elevated vent stack (Ref. 12). Initial purge rates would be expected to be in the range of 50 to 100 cfm. As the Kr-85 concentrations are reduced, the purge rate would be allowed to increase up to a maximum of 1000 cfm. The purge rate during any time interval would be dependent on favorable meteorological conditions (e.g., good dispersion due to high winds) and applicable technical specification limits. Prior to a purging period, meteorological data would be recorded and predicted incremental dose at the site boundary would be calculated. Administrative limits would be set to assure that off-site dose limits are not exceeded. During purge cycles, actual meteorological and release-rate data would be used to calculate accumulated off-site doses to assure that the design objectives of 10 CFR Part 50 Appendix I and the applicable requirements of 40 CFR Part 190.10 are not exceeded (Refs. 2, 3). The licensee estimates that it would take 60 days to reach the MPC level of 1×10^{-5} μCi/cc in the reactor building.

Figure 6.1 provides a flow diagram of the purge system. Modifications to the purge system would include (1) replacing the hydrogen control system exhaust fan with a fan capable of producing a maximum flow of 1000 cfm, (2) recommissioning the auxiliary building and fuel-handling building filter trains, including

ANSI N510 testing of the filter trains, (3) calibrating and reactivating the stack monitor, (4) securing the supplementary filter train by turning off the supplementary fans and closing the isolation door from the stack inlet plenum to the filters, and (5) uncapping the plant's vent stack.

6.1.3 Occupational Exposure

The design criterion for the existing hydrogen control subsystem (the purge system) was that occupational exposure should be maintained "as low as is reasonably achievable." Therefore, the design is consistent with the guidance of Regulatory Guide 8.8 (Ref. 13). The following sections describe the design and operational features included to minimize occupational exposure. Control during a purging interval would be exercised remotely from the Unit 2 control room. An auxiliary operator would be required to be in the auxiliary building during system operation. The auxiliary operator would have communication ties with the control room and be stationed in a low radiation area.

The dose to operators during processing will be approximately 0.8 person-rem. Changing the HEPA and charcoal filters will also contribute to occupational exposure. These filters will have a surface dose rate of approximately 0.4 R/hr. and filter changing will require approximately one-half hour per filter. It is expected that the filters will be changed only once at the end of the purge operation, resulting in approximately 0.5 person-rem. Therefore, the exposure for processing and filter change would be approximately 1.3 person-rem.

6.1.4 Environmental Impact

Based on data taken in the reactor building atmosphere, the radioactive contaminants that exist in this atmosphere are particulates at concentrations on the order of 1 x 10^{-9} μCi/cc, and krypton gas at a concentration of about 1 μCi/cc.

The installed filter system would remove particulates from the process stream. This filter system is expected to have a particulate removal efficiency of at least 99.9%; however, in our evaluation, we used a conservative removal efficiency of 90%. These filters would not be effective in removing the noble gas contaminant, Kr-85. Therefore, the primary isotope that would be released during a purge operation would be Kr-85.

Offsite doses due to Kr-85 releases are estimated here on the basis of historical meteorological conditions in place of real time meteorological conditions. Data used in this evaluation regarding release point information and historical meteorological conditions were taken from the Final Environmental Statement for TMI, Unit 2 (Ref.4). They represent the average annual meteorological dispersion associated with a purge from the reactor building to the nearest site land boundary where the dose would be expected to be highest. The associated X/Q (which is a measure of the dispersion achieved between the release point and the nearest offsite location) is 6.7 x 10^{-6} sec/m^3. To calculate offsite concentrations based on release rate and meteorological factors, the X/Q is multiplied by the release rate in Ci/sec.

The Kr-85 contribution to the beta skin dose would be larger than that of any other source. On the basis of the release of 57,000 Ci, and an average dispersion factor of 6.7 x 10^{-6} sec/m^3, the beta skin dose is estimated to be 16 mrem and the gamma total body dose is estimated to be 0.2 mrem. These numbers represent the maximum dose that could occur to an individual continuiously present at the site boundary during the release period based on average annual meteorological conditions. Using our normal Regulatory Guide 1.109 assumptions (Ref. 14) for the calculation of doses (namely, an occupancy factor of 70%) a skin dose of 11 mrem would be calculated. No credit is taken for dose reduction by building structures. The licensee has proposed to control the releases in such a manner so that they are made only when the meteorological conditions are favorable for dispersing the krypton gas. We have reviewed this approach and conclude that it is entirely feasible to decrease the above calculated dose by another factor of 2 or 3 by this method.

During a purge, irrespective of whether it is controlled by the method suggested by the licensee, or by some other method, the NRC staff would require that all parameters relating to dose be monitored. Constant monitoring would be required for such parameters as meteorological conditions, reactor building isotopic content (calculations and sampling), purge system flow rate, and concentrations at the site boundary (combination of calculation and environmental monitoring). This monitoring would be done to control release rates so that doses are maintained as low as is reasonably achievable.

6.1.5 Accident Analysis

The components for the purge system are located in the Unit 2 auxiliary building. A major rupture in the purge system would allow Kr-85 to be released to the auxiliary building. Any Kr-85 released to this building would be exhausted through the auxiliary building ventilation system to the plant stack. This path would be the same release pathway as that for the normal purge system.

The worst-case accident would be an inadvertent initiation of the purge system at maximum flow of 1000 cfm with a Kr-85 concentration in the reactor building atmosphere of 1 μCi/cc. In our analysis we assumed that 30 minutes were required for the operator to detect the leak and isolate the system. During this 30-minute period, a total of 850 curies would be released. The meteorological dispersion parameter X/Q used for this accident scenario was 6.8×10^{-4} sec/m^3. Using Regulatory Guide 1.109 (Ref.14), the staff calculates that the total body gamma dose caused by this accident would be 0.3 mrem and that the beta skin dose would be 25 mrem. These doses represent only a small fraction of 10 CFR Part 100 limits (Ref. 15).

Summary

The Hydrogen Control System proposed for use to purge the reactor building is an existing system that offers the advantage of decontamination of the reactor building environment in a short period of time when compared to the other alternatives. The time required to implement alternatives to purging would be sufficiently long that guaranteeing continuing reactor building isolation can not be assured.

Other advantages offered by purging are:

(1) controlled releases can be maintained within applicable federal regulations;

(2) purge has a small general population accident dose impact when compared to other alternatives;

(3) purging to the atmosphere eliminates the need for long term surveillance of Kr-85; and,

(4) purging of Kr-85 to the atmosphere can be performed under well-controlled conditions and can meet all the existing Technical Specifications and Regulatory requirement for all operating reactors.

The primary disadvantage of purging the reactor building can be related only to public interpretation of the impact of releasing radioactive materials to the environment. Using the Hydrogen Control Subsystem would require approximately 60 days to purge the reactor building, thus causing psychological distress in the vicinity of the plant.

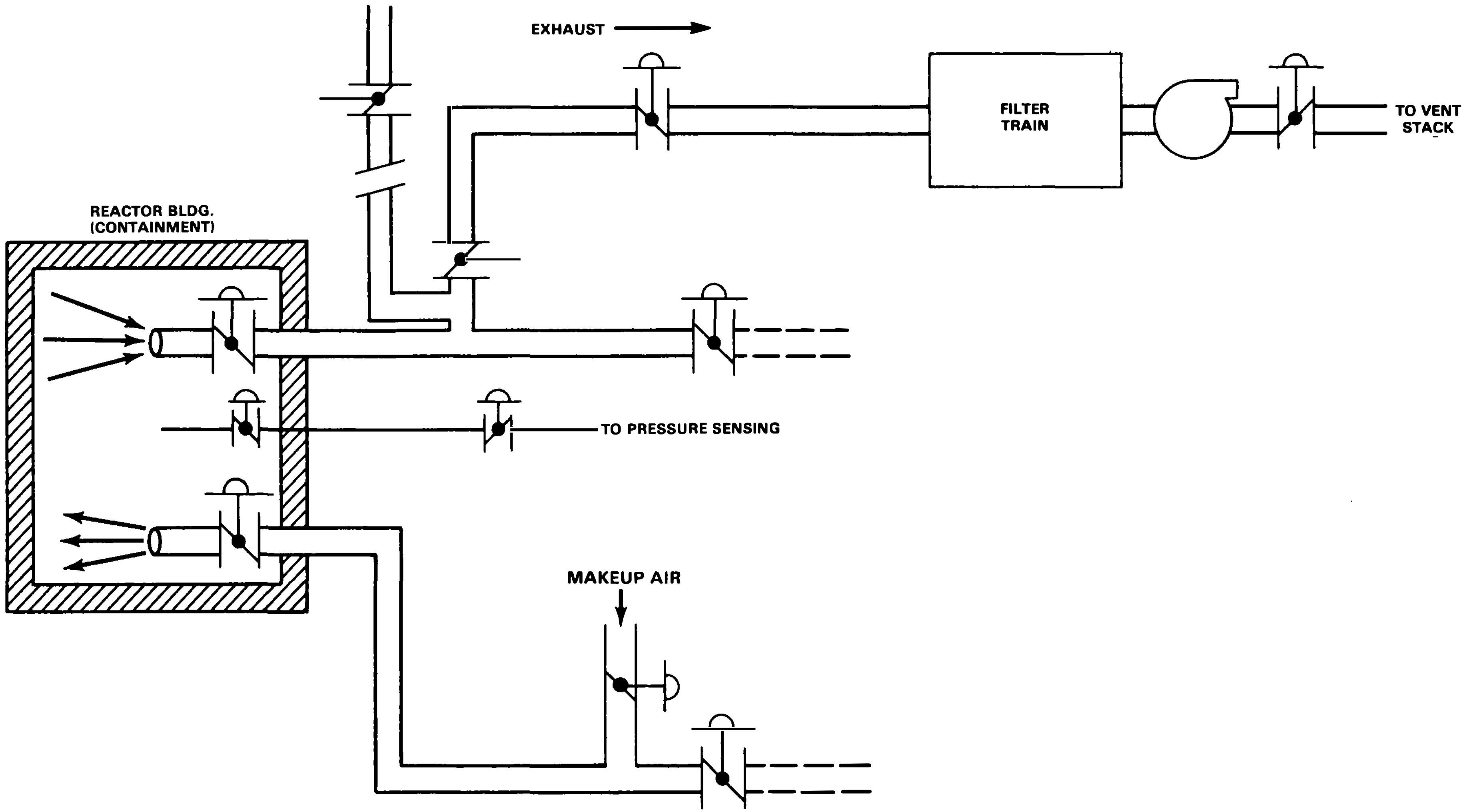

Figure 6.1. Flow Diagram for Purge Using Hydrogen Control Subsystem

6.2 Charcoal Adsorption Systems

6.2.1 Introduction

The NRC staff evaluated both the ambient temperature and refrigerated charcoal adsorbers system. Both systems would require extremely large volumes of charcoal; the ambient system would require 34,000 tons and the refrigerated system 12,000 tons. Both charcoal systems when operating normally would have no releases associated with them; however, during anticipated operational occurrences significant releases can be expected. Since noble gases do not react chemically with charcoal, long term surveillance would be required. The packaging, shipping, and ultimate burial of the large quantity of contaminated charcoal produced in these systems would create significant safety hazards.

6.2.2 System Description and Operation

Ambient Charcoal System. Radioactive airborne activity released from the reactor building would follow the same flow path described for the purge system. If the charcoal in the adsorber system is exposed to humidity in excess of 3%, the charcoal would lose its ability to adsorb krypton. In a charcoal adsorber system the major fraction of the water vapor would be removed in its passage through the cooler condenser. Additional removal could be accomplished by passing the gas through a desiccant dryer. In the event of an operational upset, where excessive moisture or other gases pass through the moisture removal equipment, a guard bed could be used to protect the main charcoal bed. The usual guard bed volume is 2 to 3 ft^3. The main charcoal beds would consist of tanks containing charcoal, which would be arranged in 45 rows of 10 tanks per row. Storage tanks rather than piping would be used to facilitate initial loading of the charcoal. When breakthrough occurred in a bed, the bed would be isolated and used to store the Kr-85. Based on calculations it would require approximately 34,000 tons of charcoal to store the krypton in the Unit 2 reactor building. The tank would require manholes on the top and bottom for loading and disposal of the charcoal. Each tank would have isolation valves manually operated to isolate the tank and remove it from service. The upper limit on tank size would be based on shop fabricating capability and shipping considerations. Figure 6.2-1 provides a flow diagram of the charcoal adsorber system.

Using the above consideration, the maximum tank size would be 12 feet in diameter and 50 feet in length. The system would require 450 atmospheric pressure tanks. Housing the tanks would require a building 700 long, 150 feet wide, and 60 feet high. Figures 6.2-2 provides the conceptual layout for the building to house the charcoal system.

Refrigerated Adsorber System. The input flow path for the low temperature charcoal adsorber system is the same as that for the ambient system. The low temperature system offers the benefit of increasing the adsorption coefficient by a factor of from 2.5 to 3. The increased adsorption coefficient reduces the required volume of charcoal by the same factor. Therefore, a low temperature charcoal adsorber system would require approximately 12,000 tons of charcoal.

However, the advantage gained by reduced charcoal volume is offset by increased system complexity. A malfunction of the refrigeration equipment system could cause an increase in charcoal temperature and therefore cause an uncontrolled release of Kr-85. A vault must be constructed and maintained at 0°F with a mechanical refrigeration unit. The system design must include methods to prevent the loss of cooling, and to withstand the pressure buildup in the event of total loss of cooling ability.

6.2.3 Occupational Exposure

The design criterion for both the ambient and low temperature charcoal adsorption system would include features to maintain occupational exposure "as low as is reasonably achievable." Since the charcoal adsorption systems are designed for full noble gas retention on the charcoal beds, the onsite total body dose has been calculated to be approximately 47 person-rem. This total body dose is based on expected maintenance and surveillance during processing and storage.

6.2.4 Environmental Impact

A properly operating charcoal adsorber system would fully treat and store the Kr-85 in the reactor building atmosphere. Therefore the radiological impact of a normally operating charcoal adsorber system would have no offsite dose effect. However, in evaluating the potential environmental impact of a charcoal adsorber system, serious consideration must be given to the high probability of uncontrolled leakage from the reactor building during construction and testing periods. Construction and testing of a charcoal system would cause a delay of from 2 to 4 years in reactor atmosphere cleanup. It would be reasonable to assume that during the construction period a leak in the reactor building would occur. The effects of isolating the reactor building for extended periods are covered in Section 4.0.

Because a normally operating charcoal adsorber system would have a minimal off site radiological effect, significant releases of gases to the environment would occur only in the event of off-normal conditions, such as equipment failure or operator error. Conditions such as gas dryer malfunction during operation or moisture breakthrough could result in an inadvertent krypton releases.

During its review, the staff's major concerns were the environmental impact of long-term on-site storage, off-site shipments of very large volumes of charcoal, and the long delay caused by construction of the charcoal system. Because of the large quantities of charcoal required with charcoal adsorber systems, the staff believes that the handling and packaging problem make off-site shipments extremely difficult. Moreover, the use of a charcoal system does not solve the problem of final disposal of Kr-85. The use of a charcoal system would make long-term on-site storage necessary. Since the charcoal and krypton do not undergo chemical reactions, long-term (100 years) surveillance would be required because the possibility would exist for an uncontrolled release to the environment.

6.2.5 Accident Analysis

Ambient Charcoal System. In this system 450 tanks containing charcoal would be used. The radioactivity in each succeeding tank would decrease as the activity in the reactor building decreased. The highest activity tank would contain 1430 curies. Assuming that the charcoal tank isolation valve fails and the entire 1430 curie inventory escaped, it has been calculated that the dose effect at the site boundary would be 41 mrem beta skin dose and 0.5 mrem total body gamma dose.

Refrigerated Adsorber System. In this system 150 tanks containing charcoal would be used. The radioactivity in each succeeding tank would decrease as the activity in the reactor building decreased. The highest activity tank would contain approximately 4300 curies. If the same assumptions are used for this system as were used with the ambient system, the dose effects given for the ambient system can be increased by approximately 3 times. Therefore, beta skin dose of 124 mrem and 1.5 mrem total body dose gamma could be expected.

Summary

It is possible to remove noble gas fission products by charcoal adsorber systems at room temperature or with refrigerated charcoal adsorbers systems. Simplicity of operations and applicability to extremely radioactive gas mixtures are the primary advantages of the room temperature charcoal absorber removal method. However, the major disadvantage for a room temperature charcoal adsorber system is the large volume of charcoal required. Additionally, the large volume of charcoal makes off-site shipment impractical. Use of a refrigerated adsorber charcoal system would reduce the volume of charcoal required. To gain a reduction in charcoal volume an increase in equipment complexity must be accounted for. Since the primary activity in the reactor atmosphere is Kr-85, a noble gas fission product that does not ordinarily react chemically, the charcoal adsorber would then be used as physical adsorber to retain the Kr-85. When collected, the krypton-85 will not be fixed in the charcoal bed collector and continued air flow will eventually cause breakthrough and sweep the Kr-85 from the collector. This action can be prevented only by the removal of the charcoal adsorber bed from the process stream. Loaded charcoal beds would then remain in storage indefinitely.

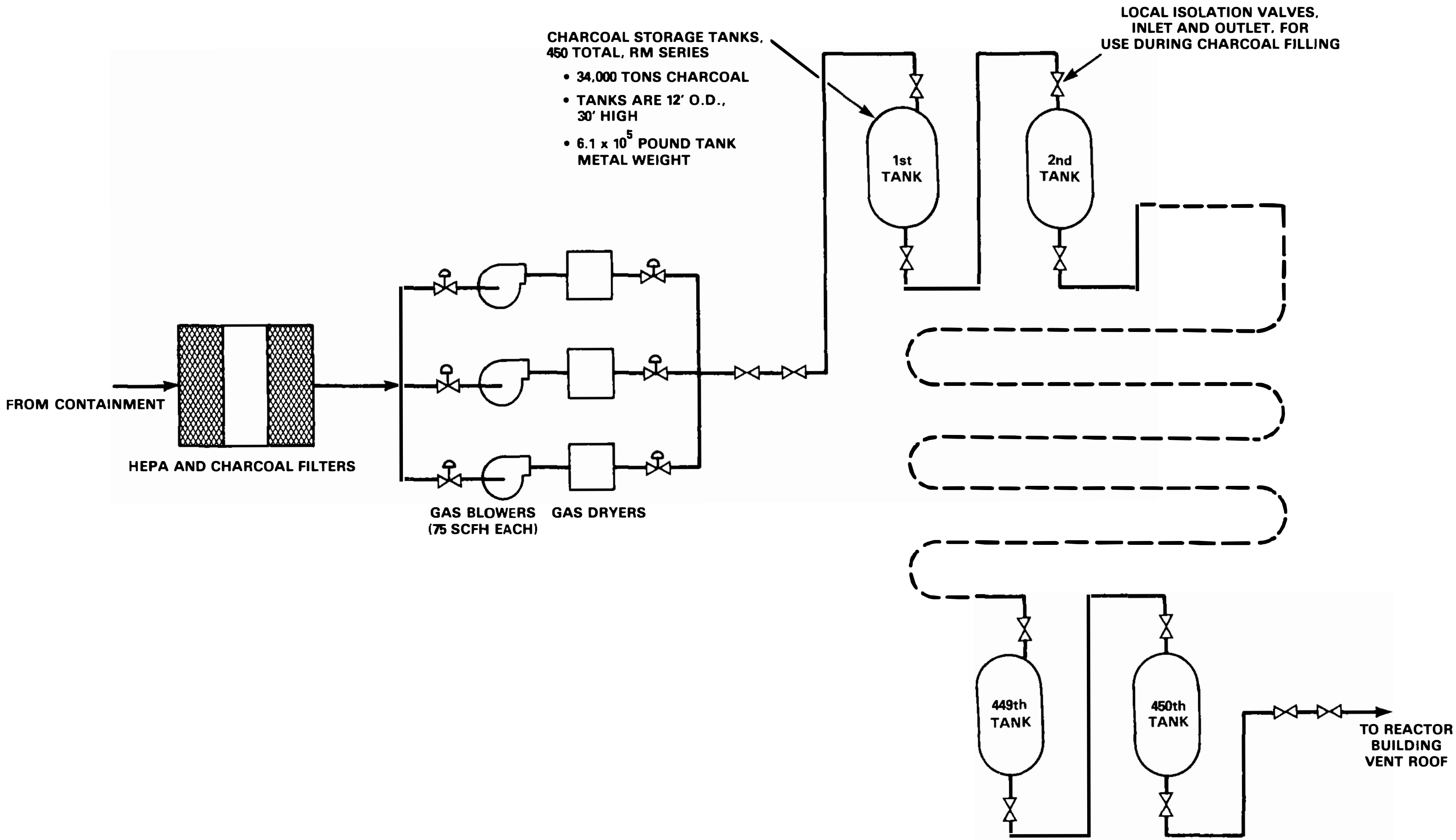

Figure 6.2-1. Flow Diagram for Purge Using Charcoal Adsorption System

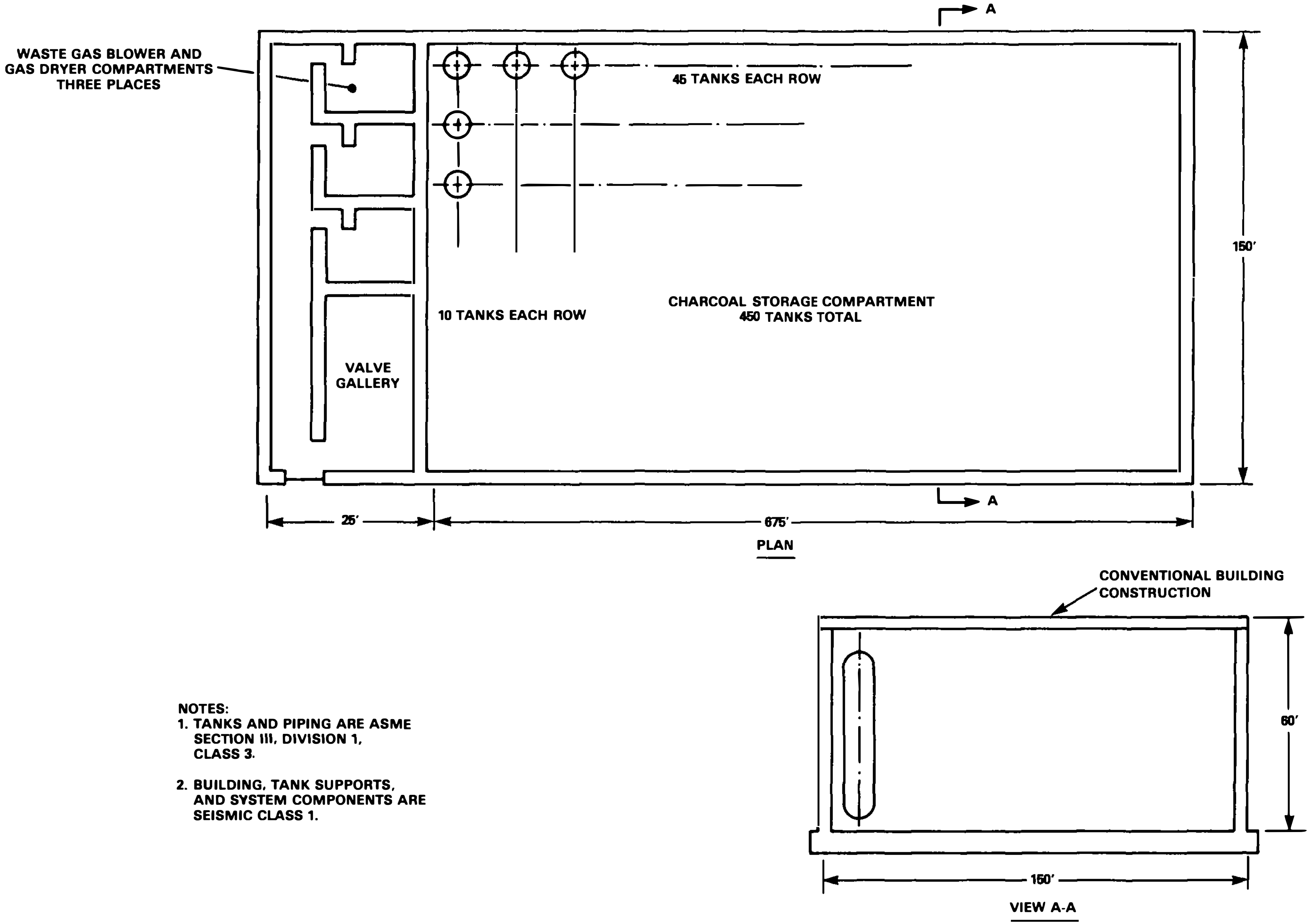

Figure 6.2-2. Conceptual Layout - Charcoal Storage Arrangement

6.3 Gas Compression System

6.3.1 Introduction

The gas compression system involves drawing off the reactor building atmosphere into suitable pressurized storage containers so that the entire building atmosphere, including Kr-85, remains in pressurized storage for approximately 100 years. The total volume to be stored is 23 million cubic feet. This system would reduce the Kr-85 concentration in the reactor building by feed and bleed operation to the maximum permissible concentration of 1×10^{-5} μCi/cc.

6.3.2 System Description and Operation

The gaseous contents of the reactor building may be transferred to pressurized gas containers for long-term storage. The containers can be designed in various pressure/volume combinations to accommodate the reactor building gases.

To reduce activity in the reactor building to maximum permissible concentrations (MPC), a total of 11.5 reactor building volumes (23 million cubic feet) would be transferred to storage. The compressed gas train would include gas dryers, a charcoal adsorber, a HEPA filter, three gas compressors, storage containers, and associated piping and valves. Figure 6.3-1 provides a flow diagram of the system. The compressed gas would remain stored on site for approximately 100 years to allow the Kr-85 to decay. The minimum volume for the storage system would result if the gas were stored at the highest possible pressure. The practical upper pressure limit for gas storage is 2500 psig. At this pressure, 80,000 standard gas bottles (1.54 cubic feet) would be needed to store the gas. At the other end of the spectrum is a large volume, low pressure storage system. For example, if a container the size of the existing reactor building were constructed, the gas could be stored at 170 psig.

The General Public Utilities Corporation (GPU) contracted with MPR Associates to investigate the most practical means for storing the compressed gas (Ref. 16). The gas would be stored at 340 psig in 36-inch outside-diameter standard-wall pipes. One million cubic feet of volume would be required, which would be equivalent to 150,000 linear feet, or 28 miles of pipe. The pipe storage complex recommended is divided into two major sections to minimize shielding. The high activity piping section would include 20% of the piping and would contain 90% of the Kr-85. The high activity section would be segregated into five units to limit Kr-85 releases in the event of leakage, and to optimize inherent shielding. Lower activity pipe units would be placed to the outside of the storage area to act as a shield for the highest activity units in the center. The building to house the high activity piping, the filters, dryers, and gas compressors, would be 260 feet long, 90 feet wide, and 30 feet high. Six inches of concrete shielding would be required. The low activity pipe section would contain 80% of the total piping and 10% of the Kr-85. The building for housing the low activity piping would be 220 feet long, 160 feet wide, and 60 feet high. It would require no shielding.

6.3.3 Occupational Exposure

No significant amount of additional radiation exposure should be incurred by plant personnel during the proposed gas compression operation. All system components are relatively simple and should require minimal maintenance during gas processing. Should maintenance be required, most components could be isolated and purged to decrease radiation exposure during repairs. We estimate an occupational exposure of approximately 6 person-rem during operation and maintenance.

Periodic maintenance requirements of the long-term storage system are a potential source of occupational exposure which cannot be readily assessed. Although a system can be designed for maintenance-free operation, it would be unrealistic to assume that some maintenance would not be necessary during the approximtely 100 years of storage required. We estimate that surveillance and maintenance during long-term storage would result in an occupational exposure of approximately 42 person-rem.

6.3.4 Environmental Impact

Krypton-85 can be removed from the reactor building and stored in pressurized containers with minimal release to the environment. However, the process can be expected to leak from various process components as an anticipated operational occurrence.

While subsequent long term storage in pressurized containers on site will not affect the environment directly, the potential for accidental releases will remain for over 100 years while the stored Kr-85 decays.

6.3.5 Accident Analysis

The gas compression process was analyzed for its radiological consequences following an accidental release of compressed gas from the storage system. The radiological consequences of a failure in the feed train were not analyzed since it was assumed that the feed process would be isolated well before the accidental release approached a magnitude which would equal a release following a storage system failure. The accidents analyzed therefore represent the most severe occurrences with respect to their potential exposure potential at the site boundary. Analyses were performed on accidental releases from several storage configurations.

Assuming the compressed gas storage system was segregated into four units, each of which contained one quarter of the total curie content, a storage system failure with a subsequent release of 14,250 curies to the environment in a two-hour period would result in a site boundary total body gamma dose of 5.0 mrem and a beta skin dose of 410 mrem assuming a X/Q of 6.8×10^{-4} sec/m^3. Both of the calculated site boundary exposures are small fractions of the limits set forth in 10 CFR 100 (Ref. 15).

Summary

Storage of Kr-85 at high pressure for long periods of time in 28 miles of piping and valves will increase the likelihood of an inadvertent uncontrolled release to the environment compared with other alternative methods considered. Slow purging of the storage system over a period of several years would not change the total exposure to the public and would have the same radiological effect on the public as the controlled purge directly from the reactor building. Shipments of compressed Kr-85 offsite would require several hundred truck shipments through populated areas, thus increasing still further the likelihood of an inadvertent release. (See Section 6.4.6 for a discussion of transportation of pressurized radioactive gases.) The extensive time required to build and install the gas compression system (25 to 35 months) would increase the likelihood of inadvertent and uncontrolled leakage from the reactor building.

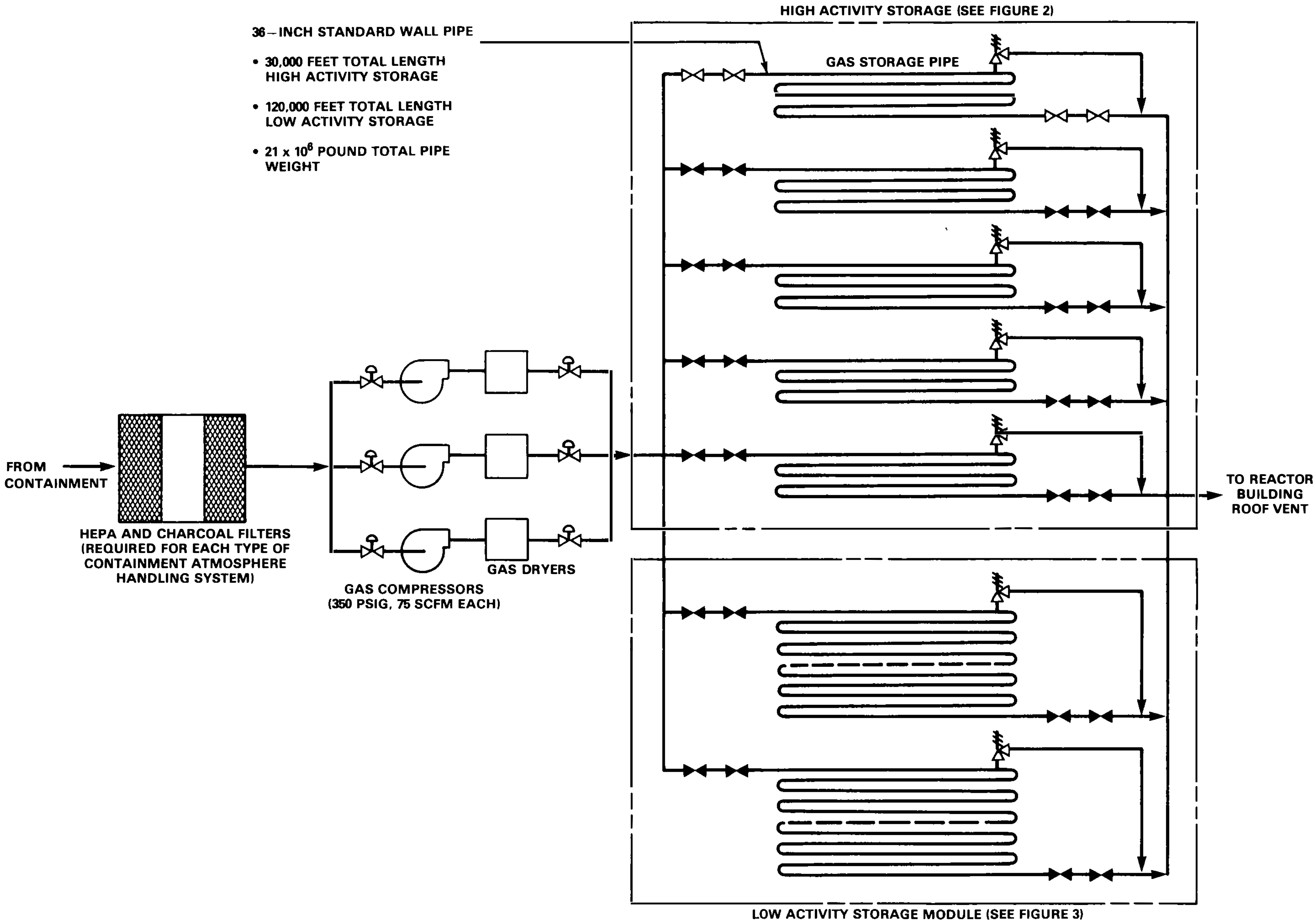

Figure 6.3-1. Flow Diagram of Gas Compression System

6.4 Cryogenic Processing System

6.4.1 Introduction

A potential means of decontaminating the contaminated reactor building atmosphere is through the use of a cryogenic processing system. The operating principle of the cryogenic processing system is the condensation of Kr-85 from the incoming air by direct contact with liquid nitrogen (boiling point, -195.8°C). The liquified Kr-85 is allowed to concentrate and is then vaporized and transferred to an onsite storage facility for subsequent disposition.

6.4.2 System Description and Operation

The licensee has evaluated the availability of an existing cryogenic processing system (CPS) at a commercial boiling water nuclear power plant to decontaminate the reactor building atmosphere. The cryogenic system has never been placed into operation and is being scrapped by its current owner because of anticipated high operational costs and the degree of continued maintenance that the unit would require. Although the system is available for purchase and use by the licensee, the erection of a new building to house the system would be required. The building dimensions would be approximately 110' long by 72' wide and would vary in height from 20' to 35'. The installed cryogenic system would connect with the reactor building through the existing hydrogen control system. The contaminated air from the reactor building would be passed through the HEPA filters and charcoal adsorber of the hydrogen control system and be transported to the cryogenic processing system in the adjacent building.

The cryogenic processing system consists of three processing trains. The major components of each train are the prefilter, catalytic recombiner, aftercooler, and cryogenic treatment subsystem. The three processing trains are supported by a hydrogen storage system, a liquid nitrogen storage system, and a noble gas storage system. A flow diagram of the cryogenic processing system is shown in Figure 6.4-1. The cryogenic processing system can process air from the reactor building at a flow rate of approximately 225 SCFM. Air withdrawn from the reactor building would first pass through the HEPA filters and charcoal adsorbers of the hydrogen control system for removal of trace quantities of airborne radioactive particulates. The air from the hydrogen control system would then be heated in the CPS preheater prior to injection into the CPS catalytic recombiner for oxygen removal and corresponding volume reduction of the recombiner effluent. The effluent gas from the recombiner would then be cooled in a downstream aftercooler and directed to the cryogenic treatment subsystem (CTS). The major components of the CTS consist of two feed compressors, a gas preheater, a trace recombiner, an aftercooler, a separator, three prepurifiers, a cooldown heat exchanger, a removal column, a condenser heat exchanger, a phase separator, a decay column, a hydrocarbon conversion unit, and an ambient heater. (A flow diagram of the cryogenic treatment subsystems is shown in Figure 6.4-2)

The effluent gas from the CPS aftercooler enters the suction side of the CTS feed compressors. The feed compressors transport the gas through the preheater, trace recombiner and aftercooler for gas heating, removal of trace quantities of oxygen, and gas cooling, respectively. Moisture is removed from the cooled gas in a downstream separator. The gas then enters the prepurifier for removal of carbon dioxide and remaining moisture (water). The purified gas then enters the cooldown heat exchanger to reduce the gas temperature to approximately -29°F. The chilled gas enters the removal column where the methane and noble gases (essentially Kr-85 and stable krypton, xenon, and argon) are removed by condensation from counter flowing liquid nitrogen to collect in a pool at the bottom of the removal column. At periodic intervals, the condensed methane and noble gas pool is vaporized and removed from the column via the CPS product compressor and compressed into storage vessels for onsite storage at ambient temperatures. The storage vessels are located inside a secondary concrete containment structure to mitigate the consequences of a rupture of the containment vessel during extended storage. The structure is designed to withstand the pressures generated from failure of all the storage vessels. The licensee estimates that it would take from 20 to 30 months to put the systems into operation.

6.4.3 Occupational Exposure

Of all the alternative systems considered for the decontamination of the containment atmosphere, the CPS is the most complex in that it consists of more and varied components than the other systems and is expected to require a greater degree of maintenance during operation. In addition, the system operates at positive pressure (85 psig) and can be expected to leak as an anticipated operational occurrence. If leakage from the system occurs downstream of the CTS removal column, that leakage will contain highly concentrated Kr-85 (i.e., at least 3 orders of magnitude higher concentration than in preceding portions of the system). Therefore, the expected exposure to workers operating and maintaining the CPS is anticipated to be greater than any of the other treatment alternatives. The licensee estimates the exposure to workers due to processing, maintenance, and required surveillance activities during long-term onsite storage of the Kr-85, would be approximately 570 person-rem. The majority (approximately 90%) of this estimated exposure is due to anticipated surveillance activities (inservice inspection of components, maintenance, and sampling) associated with the long-term storage of Kr-85. The staff does not agree with the anticipated required frequency and dose rates encountered during the licensee's surveillance activities and estimates the population exposure to workers to be in the range of 137 to 255 person-rem. The staff's lower estimate is based on the emphasis and need for maintaining in-plant exposure ALARA and on the assumption that less time is spent in high dose-rate areas.

6.4.4 Environmental Impact

The CPS is designed for a removal efficiency of 99.9% and, therefore, is not a "zero-release" system. During the approximate 2-1/2 month period required to process the reactor building atmopshere, approximately 60 Ci of Kr-85 will be discharged in the purified gas effluent from the system. In addition to this, an unspecified amount of Kr-85 will be discharged to the environment due to anticipated leakage from the system. The staff believes that the CPS can be designed to minimize the environmental impact of uncontrolled leakage by judicious monitoring and rapid system isolation upon indication of an upset condition. In any event, the staff estimates the environmental impact during normal operation of the CPS to be insignificant (i.e., less than 0.01 mrem beta skin dose and 0.0002 mrem total body gamma dose assuming a X/Q of 5 x 10^{-5} sec/m^3).

6.4.5 Accident Analysis

The CPS was analyzed for the hypothetical worst-case failure of the Kr-85 storage system. This failure is based on the assumed rupture of all the noble gas storage vessels and the corresponding breaching of the secondary containment structure. The entire Kr-85 inventory of approximately 57,000 Ci is assumed to be released to the environment over a 2-hour period. For annual average meteorological conditions, the calculated gamma radiation exposure to the total body of an individual at the site boundary would be 20 mrem and a beta skin dose of 1700 mrem, assuming a X/Q of 6.8 x 10^{-4} sec/m^3. The calculated doses are a small fraction of the limits set forth in 10 CFR Part 100 (Ref. 15).

6.4.6 Transportation and Burial

The licensee's proposed design for the CPS includes a noble gas storage system for extended storage and corresponding decay of the concentrated Kr-85 product gas. It would be possible, however, to transfer the product gas to approved (i.e., by DOT and NRC) containers for transportation and burial at a commercial low level waste burial ground. The three commercial low-level waste burials currently in operation are located in Barnwell, South Carolina, Beatty, Nevada, and Richland, Washington. However, the State of South Carolina has imposed a ban on shipments of waste from TMI Unit 2, leaving only the two Western sites as potential recipients of gas-filled containers of Kr-85 from the CPS. Each site has different criteria for acceptance and burial of radioactive gases in Federally approved containers. The Richland, Washington site will accept pressurized containers (up to 1.5 atmospheres absolute) of gases containing not more than 100 curies per container. The containers must also be buried individually and located at least 10 feet from neighboring containers. The site in Beatty, Nevada will accept gas containers that are pressurized up to 1 atmosphere (absolute) and limited to 1000 curies or less. Gas containers containing from 100 to 1000 curies must be surrounded by at least 6 inches of concrete on all sides.

Given the burial site limitations for container pressure and curie content, and the required use of DOT and NRC approved shipping containers, the number of required containers and corresponding shipments for transporting 57,000 Ci of Kr-85 is potentially high. Under ideal conditions, a minimum of 57 and 570 containers would be required for acceptance at Beatty and Richland, respectively.

For the same reasons that the staff is opposed to the shipment of free liquids (i.e., dispersability and lack of control following a container-breaching transportation accident), the staff is also opposed to the shipment of radioactive gases. The potential for exposing the public to concentrations of Kr-85 substantially higher than MPC values (i.e., 1×10^{-5} μCi/cc) following a transportation accident is an unacceptable risk. The staff recommends that shipment of Kr-85 in gaseous form not be given serious consideration should the Commission decide that the CPS is the best of all the alternatives considered in this assessment.

Summary

The primary advantage of the CPS is that the offsite environmental impact from operation of the system is insignificant. Selection of the CPS as the best alternative is not without its disadvantages, however. First, the system would require a specified amount of time to design, construct, house, and test. From consultations with construction/cost engineers at Oak Ridge National Laboratories and in the nuclear industry, the staff estimates that it would take a minimum of 20 months to get a system operational. Second, operation and maintenance of the CPS generates a relatively high occupational exposure. Finally, the onsite storage of concentrated quantities of Kr-85 would require long-term periodic surveillance and would represent a constant threat to workers on the site.

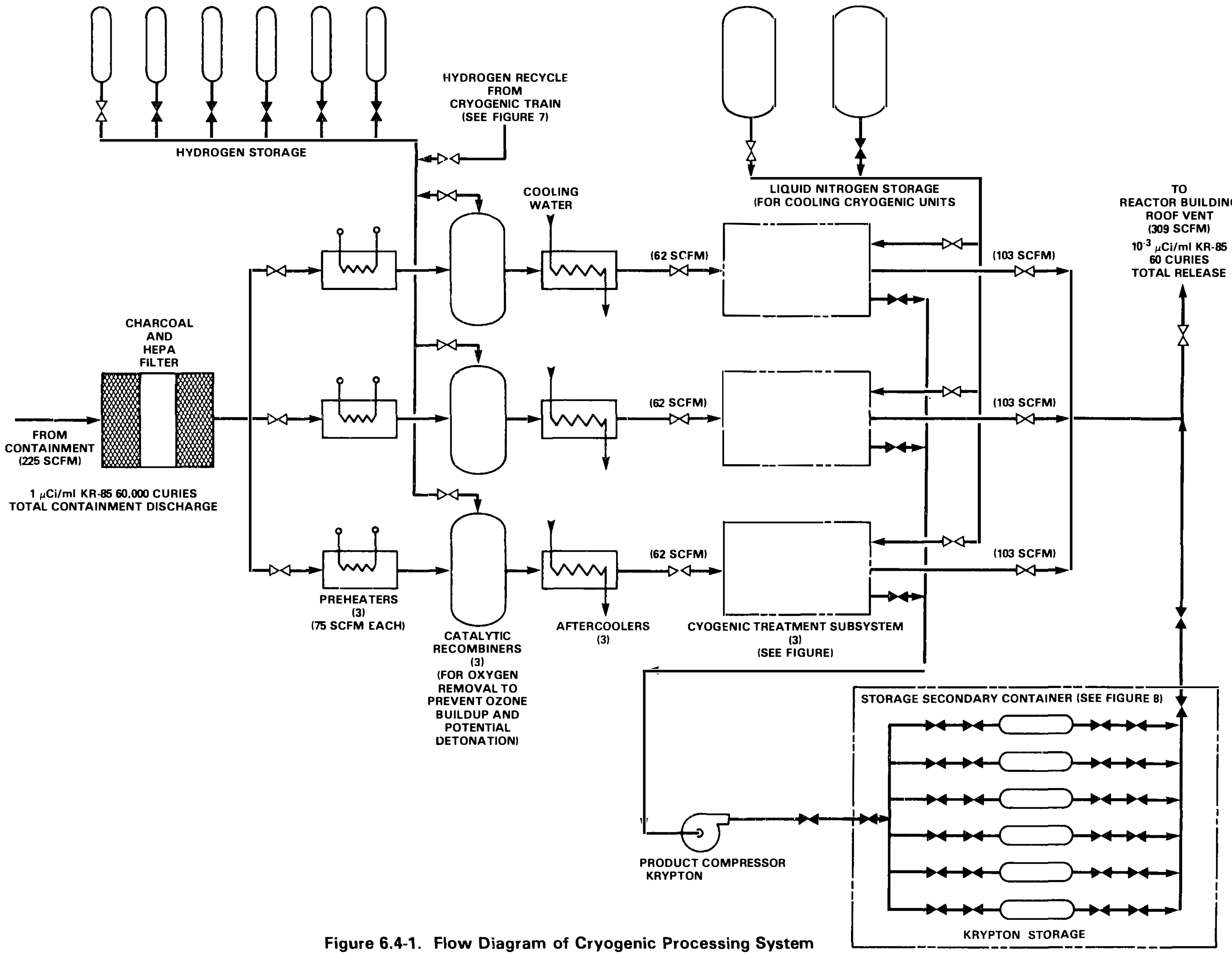

Figure 6.4-1. Flow Diagram of Cryogenic Processing System

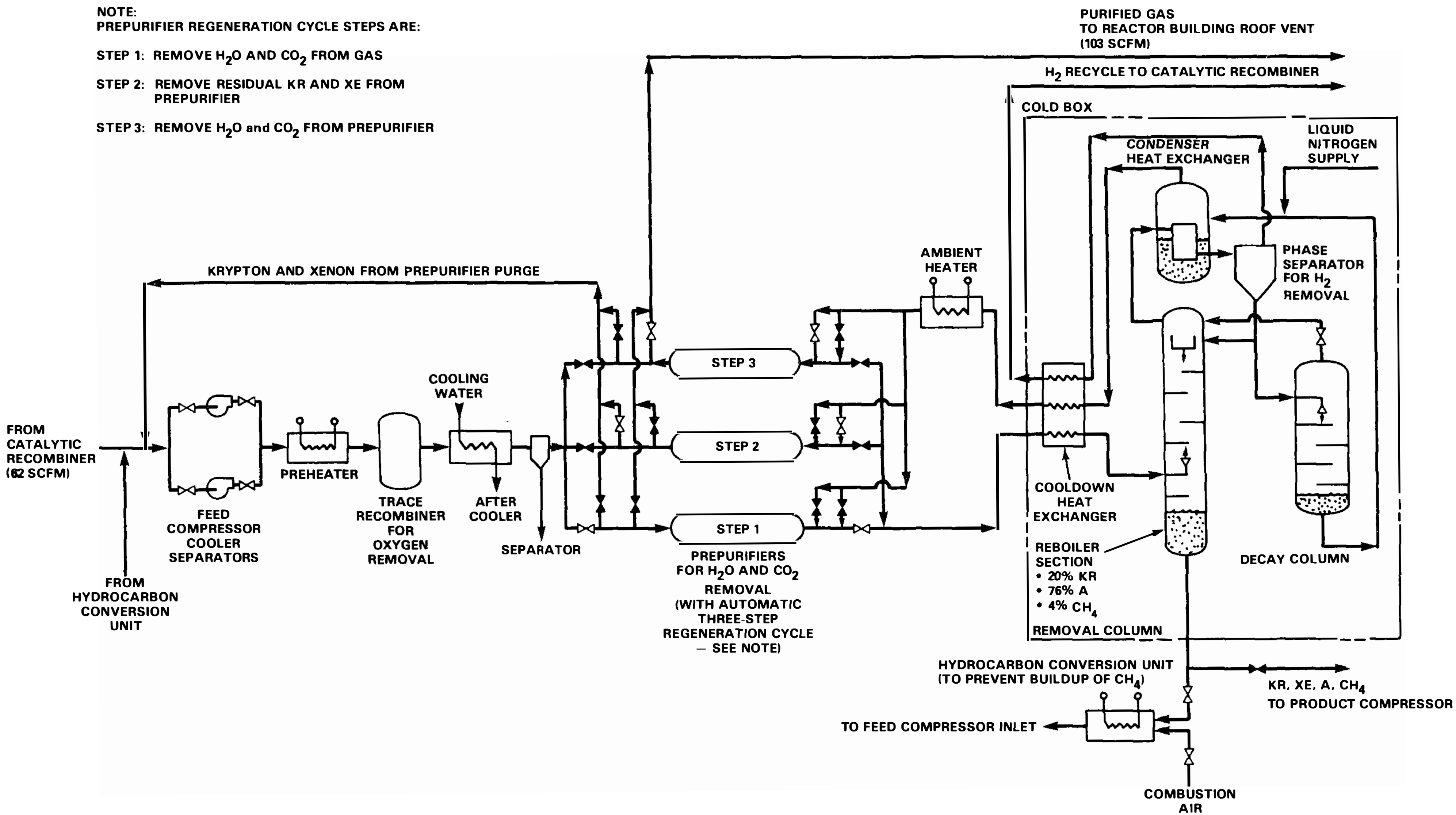

Figure 6.4-2. Flow Diagram of Cryogenic Treatment Subsystem (One of Three)

6.5 Selective Absorption Process

6.5.1 Introduction

The selective absorption process withdraws gases from the reactor building, separates essentially all the krypton from the gases, and returns the gases to the reactor building. Krypton is separated from other gases in a combination absorption stripping column which operates at 125 psig and uses a liquid fluorocarbon as a solvent. The separated and concentrated krypton may then be stored under high pressure in a few standard gas cylinders.

6.5.2 System Description and Operation

A fluorocarbon absorption process for removing noble gas fission products (krypton and xenon), carbon-14, and other radioactive contaminates from gaseous waste, has been under development since 1967 by Union Carbide at the Oak Ridge. After the initial work to obtain solvent chemistry information and to develop the process system, a second pilot plant was constructed. This plant utilized a single column process and has been in operation since 1978. Removal efficiencies greater than 99.9% for krypton have been obtained. Based on the results of the developmental and pilot plant test programs, Union Carbide personnel are optimistic that a larger scale krypton removal system could be used at Three Mile Island (TMI).

In the proposed system several hundred cubic feet per minute of reactor building gases which contain Kr-85 would flow into an absorption column where greater than 99% of the krypton would be removed. After passing through the column, the gas stream would flow back to the reactor building. Krypton would be removed from the column in a separate flow stream and transferred to pressurized containers for long term storage. The krypton removal is a bleed and feed process; therefore, processing approximately 23,000,000 ft^3 of gas (11.5 reactor building volumes) would be required to reduce the krypton level in the reactor building gases to the maximum permissible concentration. To construct and use the selective absorption system at TMI would require approval from the Department of Energy since a patent has been issued. Oak Ridge personnel would then prepare a preliminary design and a commercial firm could be contracted to prepare a detailed system design, component specifications, procure materials, supervise construction, and test system operability. There are no apparent obstacles to the above; however, the estimated time for project completion varies. Oak Ridge personnel have estimated that a system could be placed into service at TMI in two to four years. The two-year estimate is based on maximum effort by all and on a system designed and constructed using standard industrial design criteria and off-the-shelf components. Competitive bidding for equipment and services would not be used. The four-year estimate is based on a system design that complies with nuclear standards and with the usual procurement practices. However, we believe that this period could probably be shortened to between 1-1/2 to two years for a system designed to operate for the limited period of between three to six months. Since only a limited quantity of krypton gas is contained in the absorption process system at any one time, and any dose to the public should there be an accident would be small, it is conceivable that the system can be constructed to standard industrial criteria without undue risk to public health and safety. Correspondingly, a median estimate of completion time may be realistic.

The absorption system is based on the property of a fluorocarbon, namely dichlorodifluoromethane, or Freon 12, to selectively absorb noble gases. The process has been integrated into a single combination column with supporting equipment, as shown in Figure 6.5-1. Contaminated gases are withdrawn from the reactor building, dehumidified, filtered, compressed to approximately 125 psig, and cooled to near -30°F. The gas would then be fed into the absorption section of the combination column and contacted countercurrently with the down-flowing liquid Freon solvent. The decontaminated gas would then leave the top of the column. Decontaminated gases may contain 5 to 10% Freon 12, and would therefore be passed through a turbo expander and a molecular sieve bed (a filter) to recover solvent. The decontaminated gas would then be recycled back into the reactor building until the Kr-85 concentration is within allowable limits. The solvent containing the dissolved Kr-85 would subsequently flow into the intermediate and final stripper sections of the column. The reboiler at the bottom of the column would operate at 104°F and 125 psig. The solvent from which the Kr-85 has been removed would be cooled to -30°F before it would be be pumped back to the top of the column. Trace quantities of water and iodine may be removed from this solvent stream by a molecular sieve and/or silver impregnated zeolite prior to recycling.

The concentrated krypton waste gas would be compressed and placed in high pressure cylinders for storage. Calculations by Union Carbide personnel indicate that the cumulative waste gas collected from processing the contents of the reactor building can be stored in a few standard gas cylinders at 2000 psig. The internal volume of one standard gas cylinder is 1.54 cubic feet. The krypton activity in a cylinder will necessitate radiation shielding (approximately 1 inch of lead) and some cooling. The cylinders containing the waste gas could be stored onsite or shipped offsite. See Section 6.4.6 for a discussion of transportation and burial.

6.5.3 Occupational Exposure

The occupational radiation exposure at the Oak Ridge pilot plant has been negligible. It is anticipated that the exposure would increase slightly with a larger system. The feature which sets personnel exposure during system operation and maintenance is the volume of krypton which is contained within the process at any one time. Shielding would be provided for components having a high radiation field. For major maintenance activities, krypton can be completely removed from the absorber system to further reduce exposure. The storage system for concentrated krypton gas could be designed for remote and maintenance-free operation; however, it would be unrealistic to assume that the system would not require some maintenance during the long term storage while the Kr-85 decays. Occupational exposure would also be incurred during removal of the process filters. We estimate the occupational exposure which would result from the operation of the system, filter removal and long-term storage to be approximately 45 person-rem.

6.5.4 Environmental Impact

Selective absorption has zero release as a goal. Krypton is removed from the reactor building and stored in pressurized containers with only minimal release to the environment, although some leakage is expected. In addition, a few cubic centimeters would be released each time gas cylinders are changed. Subsequent long term storage of the pressurized containers on site will not affect the environment directly; however, the potential for accidental release would remain while the Kr-85 is stored on site.

6.5.5 Accident Analysis

For the purpose of analyzing potential accidents, the absorption process and compressed gas storage bottles will be reviewed separately.

(1) Absorption Process

The maximum curie content in the absorber system (12" column) at any one time would not exceed 200 curies. Process components will be housed in a confinement structure. Automatically activated isolation valves would be used to separate the absorber process from the reactor building and the gas storage system whenever a malfunction is detected. Assuming an accident which results in a release of the entire process inventory of krypton (200 curies) to the confinement structure and subsequently to the environment over a 2-hour period, the resulting total body gamma dose at the site boundary would be 0.1 mrem and a beta skin dose of 6 mrem assuming a X/Q of 6.8×10^{-4} sec/m^3.

(2) Gas Storage

The process product, concentrated krypton gas, could be stored on site in pressurized containers. Numerous container configurations can be designed. Assuming that all 57,000 curies of krypton are stored in one container and a container rupture results in a release of the krypton to the confinement structure with subsequent releases to the environment over a two-hour period, the resulting total body gamma dose at the site boundary would be 20 mrem and a beta skin dose of 1700 mrem assuming a X/Q of 6.8×10^{-4} sec/m^3. Precautions would be taken to assure safe long-term storage of Kr-85 in high pressure cylinders.

Summary

The selective absorption process has been studied and has had extensive development on a small scale. Large scale operation has not been proven but all indications are that the absorption system would perform satisfactorily and quantitatively remove krypton from the TMI gases. The absorption system is simple to operate and can be constructed with standard off-the-shelf equipment. The estimated time required to construct an absorption system at TMI is about 1-1/2 to 2 years, but may take longer, depending on regulatory requirements. The occupational exposure should be very low based on prior operating experience. Doses to the public would be negligible since only minimal leakage of Kr-85 from the system is expected. The resulting concentrated Kr-85, maintained under pressure in gas cylinders, does present a long-term storage hazard.

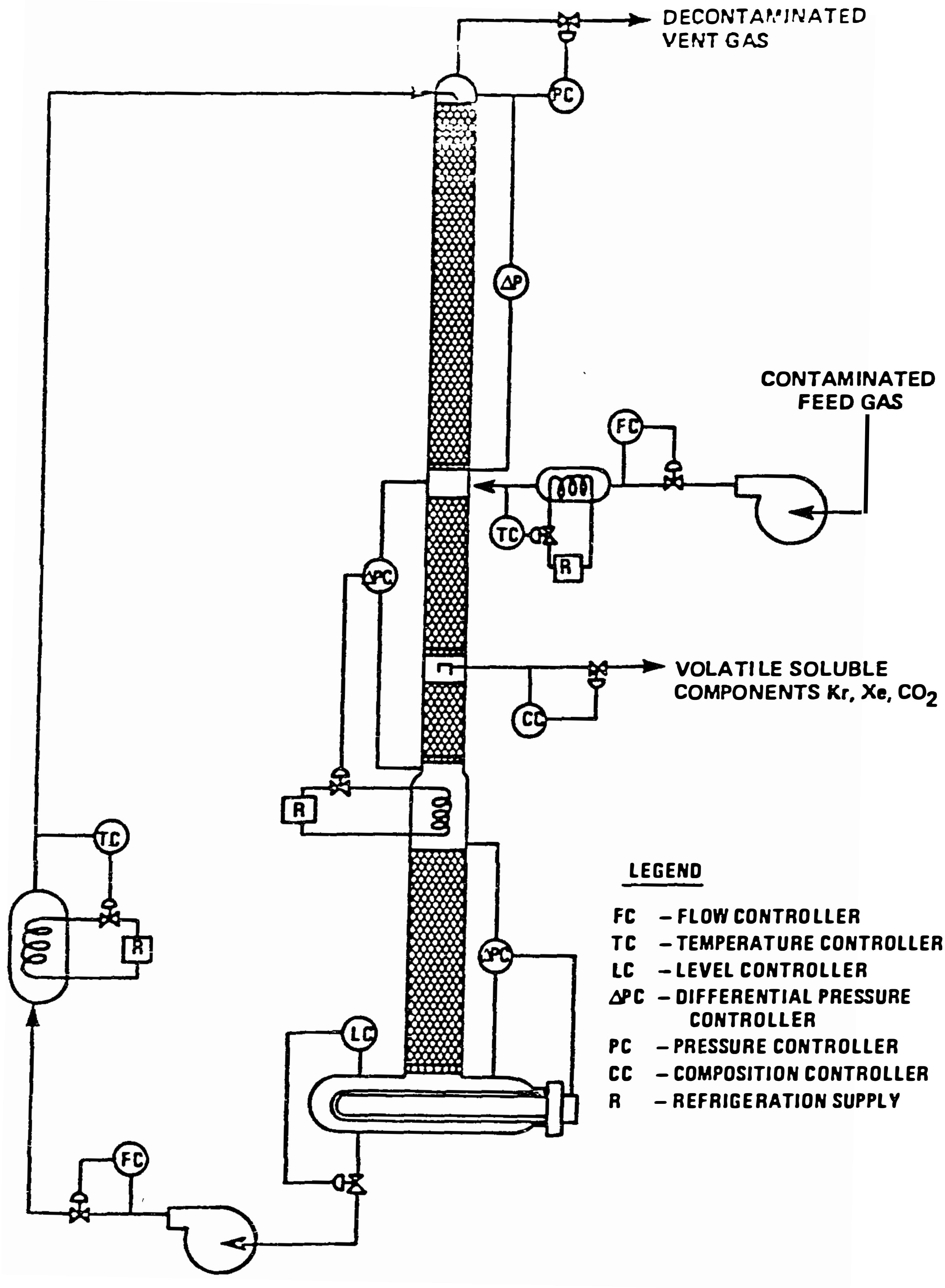

Figure 6.5-1. Schematic of the Combination Column

7.0 Radiological Environmental Monitoring Program

7.1 Introduction

The radiological environmental monitoring around the TMI site and nearby communities during decontamination of the reactor building atmosphere would be performed by (1) Metropolitan Edison Company (the licensee), (2) the Commonwealth of Pennsylvania, (3) the U.S. Environmental Protection Agency, (4) the Nuclear Regulatory Commission, and (5) the U.S. Department of Energy. Each program is described in the following subparagraphs.

7.2 Licensee's Radiological Environmental Monitoring Program

The licensee normally utilizes 72 radiological environmental monitoring locations to monitor plant releases with two thermoluminescent dosimeters (TLD) at each location. In addition to these required TLDs, four additional TLDs will be placed in each of these locations during controlled purge; two for periodic readouts (frequency depends upon purge duration and the influence of plume) and the remaining two for assessment of the integrated dose over the entire purge period. In anticipation of certain sectors coming under the influence of the plume for a greater duration of purge period, additional TLDs will be placed in selected areas.

In addition to the TLD monitoring, grab air samples will be obtained by an individual(s) dispatched via two-way communications to the projected plume touch-down area during the controlled purge. The air sampler will be placed and operated such that a grab sample will be obtained over a 15-20 minute period while immersed in the plume. Hourly update of plume direction and touch-down area utilizing real time monitoring and assessment program will be obtained and disseminated to field sampling teams.

7.3 Commonwealth of Pennsylvania Radiological Monitoring Program

The Department of Environmental Resources of the Commonwealth of Pennsylvania operates three continuous air sampling stations; one at the Evangelical Press Building in Harrisburg, one at the TMI Observation Building, and one in Goldsboro near the boatdock. Each air sampling station consists of a particulate filter followed by a charcoal cartridge. The filters and cartridges are changed weekly; the particulate air samples are gamma scanned and beta counted for reactor-related radionuclides. The particulate air samples are composited quarterly and analyzed for Sr-89 and Sr-90. The charcoal samples are gamma scanned for reactor-related radionuclides. They do not, however, have the capability to sample or analyze for Kr-85.

7.4 U. S. Environmental Protection Agency (EPA) Radiological Monitoring Program

EPA operates a network of eighteen continuous air monitoring stations at radial distances ranging from 0.5 miles to 7 miles from TMI. Each station includes an air sampler, a gamma rate recorder, and three TLDs. A list of sampling locations is shown in Table 7.1. The air sampler units sample at approximately 2 cfm and the samples are collected from each station and analyzed typically three times per week. All samples are analyzed by gamma spectroscopy at EPA's Harrisburg Laboratory using Ge(Li) detector with lower limit of detection for cesium-137 approximately 135 pCi (0.2 pCi/m^3 for a 48-hour sample).

Each monitoring station is equipped with a gamma rate recorder for measuring and recording external exposure. Recorder charts are read on the same schedule used for air sample collection and the charts removed weekly for review and stroage at EPA's laboratory in Las Vegas, Nevada.

Thermoluminescent dosimeters have been placed at each monitoring station and at 0.25 mile intervals along roads immediately parallel to the Susquehanna River near TMI out to a distance of about 2.5 miles from the Reactor. TLDs have also been placed on the islands located 0.5 miles to 1.5 miles west of the reactor site (Shelley, Hill, Henry, Kohr and Beech Islands). These dosimeters are read quarterly.

In addition to the above, a weekly compressed gas sample is taken at the Observation Center and sent to EPA Las Vegas for a determination of krypton and xenon.

7.5 U.S. Nuclear Regulatory Commission Radiological Monitoring Program

The Nuclear Regulatory Commission (NRC) will operate one air sampling station that is located in the middle of the reactor complex. The air samples will be changed weekly and be analyzed by gamma spectrometry. The NRC will place two sets of TLDs at 47 locations. Both sets will be read on a monthly basis; however, flexibility exists to read one set at more frequent intervals should conditions warrant.

7.6 U.S. Department of Energy Radiological Monitoring Program

The Department of Energy (DOE) has proposed an extensive program to be carried out if controlled purging of airbonre radioactivity is the option approved for decontaminating the reactor building atmosphere. One objective of the program is to improve the communication of accurate information to community leaders and the public near Three Mile Island, to alleviate community concerns regarding credibility of information, and to assist in providing citizens' understanding of amount and significance of radioactivity released. To meet this objective, DOE is offering citizens near Three Mile Island training and equipment to enable them to monitor radioactivity levels during purging activities. Another objective of the program will be the development of information on the atmospheric transport of radionuclides under well documented meteorological conditions in order to test and/or validate transport models; and to determine the adequacy of models and assumptions used in current regulatory guides, including an assessment of their margin of conservatism. Secondary objectives which will integrate directly into the coordinated Federal- State surveillance plan include the assessment of the effectiveness of field monitoring for low concentration of radionuclides, the testing/demonstration of advanced monitoring technology, and the characterization of the airborne material being released, including measurements before and after filtration and dilution.

The monitoring effort defined by DOE includes:

1. Collection of airborne samples to be analyzed specifically for Kr-85 at four fixed locations along the predominant wind directions.

2. Collection of airborne samples for Kr-85 analysis at four variable locations dependent upon meteorological conditions. (This portion of the program will be integrated with the EPA effort.)

3. Collection of samples for H-3 and C-14 at the same locations as the Kr-85 samplers.

4. Dose rate measurements using pressurized ion chambers or other devices will be made at both fixed and variable locations.

5. Beta sensitive dosimeters (TLDs) will be placed within each of six sectors at distances of 1, 2, 5, and 10 kilometers from the release point, at the location of each dose rate monitor, and at other locations as necessary to supplement current monitoring efforts.

Table 7.1

Three Mile Island

EPA Long-Term Surveillance Stations

Air Samplers, Gamma Rate Recorders, TIDS

STATION	AZ	DISTANCE (Miles)	ASSOCIATED TOWN
3	325	3.5	Meade Heights, PA - Harrisburg International Airport
4	360	3.0	*Middletown, PA - Elwoods' Sunoco Station
5	040	2.6	Royaltown, PA - Londonderry Township Building
9	100	3.0	Newville, PA - Brooks Farm (Earl Ninsley Residence)
11	130	2.9	Falmouth, PA - Charles Brooks Residence
13	150	3.0	Falmouth, PA - Dick Libhard Residence
14	145	5.3	*Bainbridge, PA - Bainbridge Fire Company
16	180	7.0	*Manchester, PA - Manchester Fire Dept.
17	180	3.0	*York Haven, PA - York Haven Fire Station
20	205	2.5	Woodside, PA - Zane Resner Residence
21	250	4.0	*Newberrytown, PA - Exxon Kwick Service Station
23	265	2.9	Goldsboro, PA - Muellar Residence
31	270	1.5	*Goldsboro, PA - Dusty Miller Residence
34	305	2.7	Plainfield, PA - Polites Residence
35	068	3.5	Royaltown, PA --George Hershberger Residence
36	095	0.5	TMI Observation Center
37	025	0.7	North Gate, TMI
38	175	0.8	South Gate, TMI

*Sampling stations located in indicated town. Other sampling stations are located near indicated towns.

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The Nuclear Regulatory Commission
Public Document Room (PDR) is located at
1717 H. St, N. W., Washington, DC 20555.

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2. U. S. Nuclear Regulatory Commission. Rules and Regulations, Title 10 Code of Federal Regulations Part 50, "Licensing of Production and Utilizations Facilities," March 1975, Appendix I, "Numerical guides for design objectives and limiting conditions for operation to meet the criterion' as low as practicable' for radioactive material in light-water-cooled nuclear power reactor effluents." Available in public libraries.

3. U. S. Environmental Protection Agency. Rules and Regulations, Title 40 Code of Federal Regulations Part 190, "Environmental Standards for the Uranium Fuel Cycle," January 1977. Available in public libraries.

4. U. S. Nuclear Regulatory Commission. Final Environmental Impact Statement on Three Mile Island, Unit 2" (Docket 50-320), Dec. 1972. Reissued as NUREG-0552, April 1979, and available from Publication Sales Manager, Division of Technical Information and Document Control, U. S. Nuclear Regulatory Commission, Washington, D. C. 20555.

5. Metropolitan Edison Company," Three Mile Island Unit 2 Reactor Building Purge Program Safety Analysis and Environmental Report," Docket 50-320, November 13, 1979. Available in NRC PDR for inspection and copying for a fee.

6. Letter from Richard H. Vollmer, NRC, to Robert C. Arnold, Metropolitan Edison Co., Subject: Reactor containment building atmosphere cleanup, Docket 50-320, December 18, 1979. Available in NRC PDR for inspecton and copying for a fee.

7. Letter from John T. Collins, NRC, to R. F. Wilson, Metropolitan Edison Co., Subject: Additional information request for preparation of environmental assessment, Docket 50-320, Dec. 18, 1979. Available in NRC PDR for inspection and copying for a fee.

8. Letter from R. F. Wilson, Metropolitan Edison Co. to John F. Collins, NRC, Subject: Response to 33 questions on reactor containment building atmosphere cleanup, Docket 50-320, January 4, 1980. Available in NRC PDR for inspection and copying for a fee.

9. U. S. Nuclear Regulatory Commission. "Order by the Director of the Office of Nuclear Reactor Regulation" (Docket 50-320), February 11, 1980. Available for inspection and copying for a fee at the NRC PDR.

10. U. S. Nuclear Regulatory Commission, Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors." Copies are available from the NRC PDR for inspections and copying for a fee and from U. S. Government Printing Office, Washington, D. C. 20402. ATTN: Regulatory Guide Account.

11. Metropolitan Edison Company, "Final Safety Analysis Report," April 1974. Docket 50-320. Available from the NRC PDR for inspection and copying for a fee.

12. Three Mile Island Nuclear Station, Unit 2, Environmental Technical Specifications, Appendix B to Operating License DPR-73, Feb. 8, 1978. Available for inspection and copying for a fee at the NRC PDR.

13. U. S. Nuclear Regulatory Commission. Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will be as Low as is Reasonably Achievable." Copies are available from the NRC PDR for inspection and copying for a fee and from the U. S. Government Printing Office, Washington, D. C. 20402. ATTN: Regulatory Guide Account.

14. U. S. Nuclear Regulatory Commission. Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I." Copies are available for inspection and copying for a fee from the NRC PDR and from the U. S. Government Printing Office, Washington, D. C. 20402. ATTN: Regulatory Guide Account.

15. U. S. Nuclear Regulatory Commission. Rules and Regulations, Title 10, Code of Federal Regulations Part 100, "Reactor Site Criteria," Sept. 1, 1978. Available at public libraries.

16. MPR Associates, Inc. "Three Mile Island Unit 2 Containment Atmosphere Cleanup Alternate Systems Evaluation," Docket 50-320, Sept. 14, 1979. Available in NRC PDR for inspection and copying for a fee.

Glossary

Background radiation - Radiation arising from natural radioactive materials always present in the environment, including solar and cosmic radiation and radioactive elements in the upper atmosphere, the ground, building materials, and the human body. In the Harrisburg area the background radiation level is about 125 mrem per year.

Beta particles - High-energy electrons; a form of ionizing radiation that normally is stopped by the skin, or a very thin sheet of metal.

Control rod - A rod containing material that absorbs neutrons; used to control or halt nuclear fission in a reactor.

Core - The central part of a nuclear reactor that contains the fuel and produces the heat.

Critical - Term used to describe a nuclear reactor that is sustaining a chain reaction.

Cryogenic - Low-temperature separation processes whereby materials that are normally gases are isolated and recovered from other gases by liquifying them at low temperatures.

Cubic Centimerter (cc) Unit for measuring volume. Approximately 947 cubic centimeters is equal to 1 U.S. quart.

Curie (Ci) - A unit of the intensity of radioactivity in a material. A curie is equal to 37 billion disintegrations each second.

Decay heat - Heat produced by the decay of radioactive particles; in a nuclear reactor this heat, resulting from materials left from the fission process, must be removed after reactor shutdown to prevent the core from overheating. See Radioactive decay.

Gamma rays - High-energy electromatic radiation; a form of ionizing radiation, of higher energy than X-rays, that penetrates very deep into body tissues. Gamma ray exposure results in total body dose.

Half-life - The time required for half of a given radioactive substance to decay.

Krypton-85 - A radioactive noble gas, with a half-life of 10.7 years, that is not absorbed by body tissues and is soon eliminated by the body if inhaled or ingested.

Meteorological dispersion factor (χ/Q)- Unit for measuring the rate at which effluents disperse between the source point and some downwind exposure point. It is the effluent concentration at the exposure point, χ, normalized by the source strength, Q, at the release point. Units are generally expressed in sec/m^3.

Microcurie (μCi) - Unit for measuring radioactivity. One Microcurie = that quantity of any radioactive isotope undergoing 3.7 x 10^4 disintegrations per second.

Millirem (mrem) - 1 one-thousandth of a rem; see rem.

Noble gases - Inert gases that do not react chemically and are not absorbed by body tissues, although they may enter the blood if inhaled into the lungs. These gases include helium, neon, krypton, xenon, and radon.

Nuclear Regulatory Commission (NRC) - U.S. agency responsible for the licensing and regulation of commercial, test, and research nuclear reactors.

Person-rems - The sum of the individual doses received by each member of a certain group or population. It is calculated by multiplying the average dose per person by the number of persons within a specific geographic area. Consequently, the collective dose is expressed in person-rems. For example, a thousand people each exposed to one mrem would have a collective dose of 1 person-rem.

rad - The basic unit of absorbed dose of ionizing radiation. A dose of one rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.

Radioactive decay - The spontaneous process by which an unstable radioactive nucleus releases energy or particles to become stable.

Radioactivity - The spontaneous decay of an unstable atom. During the decay process, ionizing radiation is usually given off.

Reactor building - The structure housing the nuclear reactor that contains the radioactive gas that was released during the March 28, 1979 accident.

Reactor (nuclear) - A device in which a fission chain reaction can be initiated, maintained, and controlled.

Reactor vessel - The steel tank containing the reactor core; also called the pressure vessel.

Rem - A standard unit of radiation dose. Frequently radiation dose is measured in millirems for low-level radiation; 1,000 millirems equal one rem.

Selective Absorbtion - A separation process whereby a liquid is used to selectively absorb (separate) a select (gas) from a source gas stream (air).

Thermoluminescent dosimeter (TLD) - A device to measure nuclear radiation.

χ/Q - See Meteorological Dispersion Factor

NOV 21 1979
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APPENDIX A

DOCKET NUMBER
PROD. & UTIL. FAC. 50-320

[7590-01]

STATEMENT OF POLICY AND NOTICE OF INTENT TO
PREPARE A PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

AGENCY: U.S. Nuclear Regulatory Commission

ACTION: Statement of Policy

SUMMARY: The Nuclear Regulatory Commission has decided to prepare a programmatic environmental impact statement on the decontamination and disposal of radioactive wastes resulting from the March 28, 1979 accident at Three Mile Island Unit 2. For some time the Commission's staff has been moving in this direction. In the Commission's judgment an overall study of the decontamination and disposal process will assist the Commission in carrying out its regulatory responsibilities under the Atomic Energy Act to protect the public health and safety as decontamination progresses. It will also be in keeping with the purposes of the National Environmental Policy Act to engage the public in the Commission's decision-making process, and to focus on environmental issues and alternatives before commitments to specific clean-up choices are made. Additionally, in light of the extraordinary nature of this action and the expressed interest of the President's Council on Environmental Quality in the TMI-2 clean-up, the Commission intends to co-ordinate its actions with CEQ. In particular, before determining the scope of the programmatic environmental impact statement the Commission will consult with CEQ.

The Commission recognizes that there are still areas of uncertainty regarding the clean-up operation. For example, the precise condition of the reactor core is not known at this time and cannot be known until the containment has been entered and the reactor vessel has been opened. For this reason, it is unrealistic to expect that the programmatic impact statement will serve as a blueprint, detailing each and every step to be taken over the coming months and years with their likely impacts. That the planned programmatic statement inevitably will have gaps and will not be a complete guide for all future actions does not invalidate its usefulness as a planning tool. As more information becomes available it will be incorporated into the decision-making process, and where appropriate supplements to the programmatic environmental impact statement will be issued. As the decontamination of TMI-2 progresses the Commission will make any new information available to the public and to the extent necessary will also prepare separate environmental statements or assessments for individual portions of the overall clean-up effort.

The development of a programmatic impact statement will not preclude prompt Commission action when needed. The Commission does recognize, however, that as with its Epicor-II approval action, any action taken in the absence of an overall impact statement will lead to arguments that there has been an inadequate environmental analysis, even where the Commission's action itself is supported by an environmental assessment. As in settling upon the scope of the programmatic impact statement, CEQ can lend assistance here. For example should the Commission before completing its programmatic statement decide that it is in the best interest of the public health and safety to decontaminate the high level waste water now in the containment building, or to purge that building of its radioactive gases, the Commission will consider CEQ's advice as to the Commission's NEPA responsibilities. Moreover, as stated in the Commission's May 25 statement, any action of this kind will not be taken until it has undergone an environmental review, and furthermore with opportunity for public comment provided.

However, consistent with our May 25 Statement, we recognize that there may be emergency situations, not now foreseen, which should they occur would require rapid action. To the extent practicable the Commission will consult with CEQ in these situations as well.

With the help of the public's comments on our proposals we intend to assure, pursuant to NEPA and the Atomic Energy Act, that the clean-up of TMI-2 is done consistently with the public health and safety, and with awareness of the choices ahead. We are directing our staff to include in the programmatic environmental impact statement on the decontamination and disposal of TMI-2 wastes an overall description of the planned activities and a schedule for their completion along with a discussion of alternatives considered and the rationale for choices made. We are also directing our staff to keep us advised of their progress in these matters.

Dated at Washington, D.C. this 21st day of November, 1979.

For the Commission

SAMUEL J. CHILK
Secretary of the Commission

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