

ENVIRONMENTAL MEASUREMENT REQUIREMENTS RESULTING FROM THE TMI-2 ACCIDENT*

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Summary

The "lessons learned" from the TMI-2 accident has resulted in expansion of the radiological monitoring requirements in and around nuclear power facilities. Additional instrument requirements, include expanded range of detection (10^{-6} to 10^5 $\mu\text{Ci/cc}$), broader energy response, and environs monitors are under consideration. Environs monitors are real-time exposure-rate monitors with a range of 10^{-6} to 10 R/hr. These monitors are supplemented by TLD's in the environment placed by the facility operator and supplemented by additional TLD's placed by the State and NRC. Present considerations indicate that both active and passive environmental monitoring will be required. Active monitoring including selected area monitoring can be useful in conjunction with emergency planning and evacuation measures and routes. Both active and passive systems can be used to assess the radiological impact on the population.

Introduction and Background

The accident at the Three Mile Island Unit 2 Nuclear Power Plant on March 28, 1979 has had a profound effect on the nuclear industry and the regulatory considerations of the NRC. This accident has removed much of the complacency that has developed over the past two decades. This attitude was largely due to the excellent safety record of the nuclear industry and to the installation of redundant safety and instrument systems required in each plant.

TMI demonstrated that the man-machine interface was indeed fallible and that in the presence of apparently conflicting information safety systems could be overridden contributing to the severity of an accident. Two factors were evident that required corrective actions: 1) that nuclear power plant operators or operational staffs required additional training and, 2) additional instrumentation was required to give an operator information to enable him to take necessary preplanned actions, inform him of the status and function of safety systems and to determine the potential for breaching of safety barriers. If the safety barriers (fuel clad, primary system and containment integrity) are breached, the operator must have information regarding the release of radioactive materials to the environment.

Following the accident at TMI, the NRC established a Lessons Learned Task Force to identify and evaluate the safety concerns originating from the accident that require licensing considerations for present and future power reactors. These recommendations are contained in NUREG-0578, "TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendations".¹ In a subsequent report, NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident,"² the specific tasks, anticipated research efforts, plans and schedules were promulgated.

*This paper has not been reviewed by the NRC management and therefore represents solely the views of the author.

Environmental and in-plant radiological monitoring requirements presently exist in NRC regulations. The

NRC regulations, Appendix A to 10 CFR Part 50,³ require that instrumentation be provided to monitor variables and systems over their anticipated ranges for accident conditions as appropriate to ensure adequate safety.

10 CFR Part 50, Appendix A,⁴ also includes a requirement that means be provided for monitoring the reactor containment atmosphere, effluent discharge paths and the plant environs for radioactivity that may be released from postulated accidents. However, the issuance of new, more definitive guidance and the addition of new licensee requirements was deemed necessary in view of TMI. This guidance will be contained in the revised Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions

During and Following an Accident".⁵ Further guidance regarding environmental monitoring requirements appear in the Radiological Assessment Branch, Branch Technical Position prepared as guidance for the revisions to Regulatory Guide 4.8, "Environmental Technical Specifications for Nuclear Power Plants".⁶ The post-TMI accident monitoring requirements being promulgated therefore specify methods that are acceptable to the NRC for complying with the existing regulations.

There is no single definition for postulated reactor accidents. A recent interim policy statement by the NRC,⁷ requires that Environmental Impact Statements include consideration of the site-specific impact attributable to releases of radioactive materials or radiation from accidents involving degraded fuel and melting of the reactor core. The only limitation to these accident scenarios is the human imagination, and many of the postulated scenarios and consequences challenge the fundamental laws of physics and chemistry. Within this range of possible accident scenarios, there are certain factors that are accepted and become the basis for monitoring requirements and instrument capabilities. The magnitude of the postulated accident radiological releases and the composition of these releases are the focus of current considerations for future siting, engineered safety features and degraded core cooling rulemakings.

Three Mile Island Accident

The TMI accident resulted in a release to the environment of several million curies of noble gases and relatively small quantities of the radioiodines. The best estimates of these releases are shown in Table I.⁸ The major constituent of the release was xenon-133. The presence of the noble gases created many problems for both in-plant instrumentation and for the off-site surveillance program.

An understanding of the nature of the release mechanism, pathway and radionuclides explains the problems that were encountered and thus many of the future monitoring requirements. The radionuclides released were transported to the auxiliary building via the primary coolant let-down, demineralizer flow. Degassing of the primary coolant occurred while in tanks in the

auxiliary building. The gases leaked into the building where normal ventilation flow carried them through the building before exhausting to the environment through the installed filter systems. The problems encountered with the installed monitor systems were:

- 1) They were saturated by the quantity of noble gases released and were off scale.
- 2) The noble gases diffused or leaked into the annular spaces in and around detector shields creating very high and continuing backgrounds.
- 3) The noble gases adsorbed on the installed in-line radioiodine charcoal filter belt monitors and gave rise to the false indication that large quantities of radioiodine were being released.
- 4) Early off-site radioiodine charcoal samplers adsorbed large quantities of xenon-133. When these charcoal samplers were counted on the portable single channel analyzer detector, set up for radioiodine monitoring, due to the amount of xenon and probably considerable pulse pile-up, quantities of iodine-131 were reported.
- 5) Off-site monitoring equipment consisted of installed environmental TLD's and the portable survey instruments carried by the monitoring personnel from the State, utility and government personnel.

Early in the morning of the accident, several of the radioiodine charcoal samples were sent to a nearby hospital for spectral analyses with a Ge(Li) detector to determine the amount of radioiodine. Spectral analysis established that the radionuclide present was xenon-133, and that radioiodine was below detectability.

The environmental TLD's in place at the time of the accident were used by Ad-Hoc Interagency Task Group,⁹ Kemeny Commission Staff,¹⁰ and the TMI Special Inquiry Group investigation (Rogovin)⁸ to determine the population dose, dose to the maximum exposed individual and to estimate the potential health effects. The TLD's were supplemented by additional TLD's placed by the NRC, and then by both EPA and HEW (BRH). The number of TLD's in place required extrapolation of their results to achieve a measure of the population dose. The majority of the TLD's were at, or just beyond, the site boundary and placed at these locations to cover all sectors where there was a possibility of getting readings from normal operations. However, it was realized that the area covered by the TLD's, particularly in view of the population's concern, was inadequate and that many additional detection stations are necessary for adequate monitoring. However, the TLD is an after the fact monitor and does not provide the ability to take rapid protective action.

Using the experience gained from the TMI accident, and defining the information necessary to enable an operator to take corrective action, to determine what off-site actions are necessary and to evaluate potential consequences the monitoring requirements can be defined.

NRC Monitoring Requirements

The experience gained from the TMI accident has resulted in the NRC expanding the guidance regarding accident instrumentation. The most recent version of this appears in Draft No. 3, Revision 2 to Regulatory Guide 1.97.⁵ Regulatory Guide 1.97 covers the spectrum of prospective accident instrumentation. The environmental instrumentation and the effluent monitor guidance are contained in Tables II thru VI.

The environs radiation monitors shown in Table II, approximately 16-20 locations per site, serve several functions. During normal operations as well as during accident conditions, these monitors provide a back-up capability to the installed effluent monitors and monitor to detect and determine release rates for unidentified release paths. In the event of a breach of containment they would provide the only external indication of external radiation levels. This notification would occur in real-time. The presence of these monitors could also be used as a rapid means for determining potential off-site doses and other radiological consequences, and should protective action be required, such as evacuation or sheltering of any population, an indication of available time and direction of radiation plume will be immediately available. However, this does require remote readout capability. The data from these monitors should be available both in the control room and at the emergency response center, wherever this is established.

The range of the monitors was selected to be capable of use during normal operations as well as during an accident situation. The lowest range 1 μ R/hr will be exceeded by the natural background in most locations. However, by having a monitor whose response is at the upper end of the first decade, or even onto the second decade will generally provide positive indication that the system is operable. In addition the very small fluctuations of fractions of a μ R/hr from normal operation should be discernible. This will depend on the duration of the signal and the time constant of the instrument.

Other required environmental instrument capabilities are portable, manually used instruments. Particulate and radioiodine sampling generally requires long sampling periods through selected filter matrices. As experienced at TMI, noble gases also adhere to existing filter materials, and spectral analyses would generally be required to determine what is present.

Tables III and IV contain the required monitor release points for a BWR, and Tables V and VI contain the required monitored release points for a PWR. In essence, since any radioactive materials leaving a plant from these vents is directly to the environment, they can be considered as part of the environmental monitoring program. The requirement is that provisions be made to monitor all identified pathways for release of gaseous radioactive materials to the environs. Liquid effluent pathways are generally combined into a single release source which is monitored independently.

The requirements for the gaseous effluent monitors are as follows:

- 1) Monitors should be capable of detecting and measuring radioactive gaseous effluent concentrations with compositions ranging from fresh equilibrium noble gas fission product mixtures to 10-day old mixtures with overall system accuracies of $\pm\frac{1}{2}$ decade. Effluent concentrations may be expressed in terms of xenon-133

equivalents or in terms of any noble gas nuclide(s). It is not expected that a single monitoring device will have sufficient range to encompass the entire range provided in this guide and that multiple components or systems will be needed. Existing equipment may be utilized to monitor any portion of the stated range within the equipment design rating. Additional extended range instrumentation should overlap the range of existing instrumentation by at least a factor of 2.

- 2) Detectors should respond to gamma radiation photons within any energy range from 60 keV to 3 MeV with an accuracy of $\pm 20\%$ at any specific photon energy from 0.1 MeV to 3 MeV. Overall system accuracy should be within $\pm \frac{1}{2}$ decade over the entire range.

In response to the TMI accident, the NRC staff¹¹ has added an additional requirement on the operational radiological environmental monitoring program that 40 (site dependent) monitoring stations be used. In stated: "Two or more dosimeters or one instrument for measuring and recording dose rate continuously to be placed as follows: 1) an inner ring of stations in the general area of the site boundary and an outer ring in the 4 to 5 mile range from the site with a station in each sector of each ring. (16 sectors x 2 rings = 32 stations). The balance of the stations, 8, should be placed in special interest areas such as population centers, nearby residences, schools and in 2 or 3 areas to serve as control stations."

In addition to these stations, NRC is placing TLD's in two concentric rings around power plants, one inside the 2-3 mile ring and the other beyond the 5 mile monitor ring placed by the utility. However, the TLD's are after the fact instrumentation, useful for determining population exposure, but not for knowing or responding to accident conditions.

Conclusion

The TMI-2 accident will have many regulatory consequences that are far reaching and will be felt for some time to come. There were positive aspects to the TMI accident which are generally ignored in view of the desire for self-flagellation. Safety systems such as the containment building, containment sprays and emergency core cooling systems worked as designed. Operational defeat of some of these systems resulted in increasing the severity of the accident.

Requirements upgrading effluent and environmental monitoring instrumentation is long overdue. The addition of expanded detection range, and I trust, better designed equipment is long overdue and will serve to better characterize effluents and perhaps inform the public that it is their health and safety that the NRC is attempting to protect.

References

1. NUREG-0578, "TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendations," Office of Nuclear Reactor Regulation, U. S. NRC, Washington, D. C., July, 1979.
2. NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," U. S. NRC, Washington, D. C., May, 1980.
3. 10 CFR Part 50, Appendix A, Criterion 13
4. 10 CFR Part 50, Appendix A, Criterion 64
5. Regulatory Guide 1.97, Draft No. 3, Revision No. 2, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following An Accident," U. S. NRC, Washington, D. C., October 15, 1980.
6. Regulatory Guide 4.8, "Environmental Technical Specifications for Nuclear Power Plants," U. S. NRC, Washington, D. C.
7. 45 FR 40101, 10 CFR Parts 50 and 51, "Nuclear Power Plant Accident Considerations Under the National Environmental Policy Act of 1969," June 13, 1980.
8. M. Rogovin and G. Frampton, "Three Mile Island," A Report to the Commission and the Public, Vol. II, Part 2, p. 344, U. S. NRC Special Inquiry Group, January 1980, Washington, D. C.
9. L. Battist, et. al., Ad-Hoc Interagency Dose Assessment Group, "Population Dose and Health Impact of the Accident at the Three Mile Island Nuclear Station," U. S. NRC, NUREG-0558, May, 1979, Washington, D. C.
10. J. Auxier, et. al., "Report of the Task Group on Health Physics and Dosimetry to the President's Commission on the Accident at TMI, October 31, 1980.
11. Radiological Assessment Branch, Branch Technical Position, Revision 1, November, 1979, U. S. NRC, Washington, D. C.

TABLE I

Radionuclides Released to the Environment as a Result of TMI-2 Accident.

RADIONUCLIDE	HALF-LIFE	QUANTITY IN CORE AT TIME OF SHUTDOWN (Curies)	QUANTITY RELEASED ESTIMATED (Curies)	ESTIMATED FRACTION OF TOTAL RELEASED
Kr-88	2.8 hours	6.92×10^7	3.75×10^5	0.15
Xe-133	5.2 days	1.42×10^8	1.58×10^6	0.63
Xe-133m	2.2 days	2.11×10^7	2.25×10^5	0.09
Xe-135	9.1	3.31×10^7	3.0×10^5	0.12
Xe-135m	15.3 min.	2.60×10^7	2.5×10^4	0.01
I-131	8.0 days	6.55×10^7	15	*

*On an estimated fractional basis of total nuclides released, iodine-131 was very small.

TABLE II

VARIABLE	RANGE	PURPOSE
ENVIRONS RADIATION AND RADIOACTIVITY		
RADIATION EXPOSURE RATE (INSTALLED INSTRUMENTATION)	10^{-6} R/HR TO 10 R/HR	DETECTION OF SIGNIFICANT RELEASES; VERIFICATION; RELEASE ASSESSMENT; LONG-TERM SURVEILLANCE
AIRBORNE RADIOALOGENS AND PARTICULATES (SAMPLING, WITH ON-SITE ANALYSIS CAPABILITY)	10^{-9} TO 10^{-3} $\mu\text{Ci/cc}$	RELEASE ASSESSMENT; ANALYSIS
PLANT AND ENVIRONS RADIATION (PORTABLE INSTRUMENTATION)	0.1 TO 10^3 R/HR, PHOTONS 0.1 TO 10^4 RADS/HR, BETA RADIATIONS AND LOW-ENERGY PHOTONS	RELEASE ASSESSMENT; ANALYSIS
PLANT AND ENVIRONS RADIOACTIVITY (PORTABLE INSTRUMENTATION)	MULTI-CHANNEL GAMMA-RAY SPECTROMETER	RELEASES ASSESSMENT; ANALYSIS

TABLE IV

VARIABLE	RANGE	PURPOSE
AIRBORNE RADIOACTIVE MATERIALS RELEASED FROM THE PLANT		
NOBLE GASES AND VENT FLOW RATE		
o CONDENSER AIR REMOVAL SYSTEM EXHAUST	10^{-6} TO 10^5 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW (NOT NEEDED IF EFFLUENT DISCHARGES THRU COMMON PLANT VENT)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT
o COMMON PLANT VENT OR MULTI-PURPOSE VENT DISCHARGING ANY OF THE ABOVE RELEASES	10^{-6} TO 10^3 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT; LONG-TERM SURVEILLANCE
o VENT FROM STEAM GENERATOR SAFETY RELIEF VALVES OR ATMOSPHERIC DUMP VALVES	10^{-1} TO 10^3 $\mu\text{Ci/cc}$ (DURATION OF RELEASES IN SECONDS, AND PMS OF STEAM PER UNIT TIME)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT
o ALL OTHER IDENTIFIED RELEASE POINTS	10^{-6} TO 10^2 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW (NOT NEEDED IF EFFLUENT DISCHARGES THRU OTHER MONITORED PLANT VENTS)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT; LONG-TERM SURVEILLANCE

TABLE III

PWR VARIABLES
TYPE E VARIABLES - THOSE VARIABLES TO BE MONITORED AS REQUIRED FOR USE IN DETERMINING THE MAGNITUDE OF THE RELEASE OF RADIOACTIVE MATERIALS AND CONTINUALLY ASSESSING SUCH RELEASES.

VARIABLE	RANGE	PURPOSE
AIRBORNE RADIOACTIVE MATERIALS RELEASED FROM THE PLANT		
NOBLE GASES AND VENT FLOW RATE		
o DRYWELL PURGE, STANDBY GAS TREATMENT SYSTEM PURGE (FOR MARK I, II, III PLANTS) & SECONDARY CONTAINMENT PURGE (FOR MARK I PLANTS)	10^{-6} TO 10^5 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW (NOT NEEDED IF EFFLUENT DISCHARGES THRU COMMON PLANT VENT)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT
o SECONDARY CONTAINMENT PURGE (FOR MARK I, II, III PLANTS)	10^{-6} TO 10^4 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW (NOT NEEDED IF EFFLUENT DISCHARGES THRU COMMON PLANT VENT)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT

TABLE V

PWR VARIABLES
TYPE E VARIABLES - THOSE VARIABLES TO BE MONITORED AS REQUIRED FOR USE IN DETERMINING THE MAGNITUDE OF THE RELEASE OF RADIOACTIVE MATERIALS AND CONTINUALLY ASSESSING SUCH RELEASES.

VARIABLE	RANGE	PURPOSE
AIRBORNE RADIOACTIVE MATERIALS RELEASED FROM THE PLANT		
NOBLE GASES AND VENT FLOW RATE		
o CONTAINMENT OR PURGE EFFLUENT	10^{-6} TO 10^5 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW (NOT NEEDED IF EFFLUENT DISCHARGES THRU COMMON PLANT VENT)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT
o SECONDARY CONTAINMENT (REACTOR SHIELD BLDG ANNULUS, IF IN DESIGN)	10^{-6} TO 10^4 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN (NOT NEEDED IF EFFLUENT DISCHARGES THRU COMMON PLANT VENT)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT
o AUXILIARY BLDG (INCLUDING ANY BLDG CONTAINING PRIMARY SYSTEM GASES, E.G., WASTE GAS DECAY TANK)	10^{-6} TO 10^4 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW (NOT NEEDED IF EFFLUENT DISCHARGES THRU COMMON PLANT VENT)	DETECTION OF SIGNIFICANT RELEASES; RELEASE ASSESSMENT; LONG-TERM SURVEILLANCE

TABLE VI

VARIABLES	RANGE	PURPOSE
AIRBORNE RADIOACTIVE MATERIALS RELEASED FROM THE PLANT		
ARTICULATES AND HALOGENS		
<ul style="list-style-type: none"> ALL IDENTIFIED PLANT RELEASE POINTS (EXCEPT STEAM GENERATOR SAFETY RELIEF VALVES OR ATMOSPHERIC STEAM DUMP VALVES AND CONDENSOR AIR REMOVAL SYSTEM EXHAUST) SAMPLING, WITH ON-SITE ANALYSIS CAPABILITY	10^{-3} TO 10^2 $\mu\text{Ci/cc}$ 0 TO 110% VENT DESIGN FLOW	DETECTION OF SIGNIFICANT RELEASES, RELEASE ASSESSMENT, LONG-TERM SURVEILLANCE