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A REVIEW OF MONITORING, SAMPLING AND ANALYSIS OF REACTOR COOLANT, REACTOR CONTAINMENT ATMOSPHERE AND AIRBORNE REACTOR EFFLUENTS IN POST ACCIDENT CONCENTRATIONS*

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ABSTRACT

A post-implementation review has been made in NRC Region I of the post-accident sampling systems (PASS), the gaseous effluent monitors, and the provisions for sampling effluent particulates and radioiodines which were required by the NRC subsequent to the TMI-2 accident (NUREG-0737). Prefabricated PASS systems were predominant. Problems included insufficient purge times, inadequate separation of dissolved gases, excessive dilution and the accuracy of analytical techniques in the presence of interferences. Microprocessor-controlled high-range gas monitors with integral provisions for sampling particulates and radioiodines in high concentrations were widely used. Calibration information was generally insufficient for the unambiguous conversion of monitor readings to release rates for a varying postaccident mixture of radiogases. The referenced sampling guidance (ANSI-N 13.1-1969) was inappropriate for the long sampling lines customarily used. Generic research is needed to establish the behavior of particulates and radioiodines in these lines.

I. INTRODUCTION

The accident at Unit-2 of the Three Mile Island Nuclear Power Station (TMI) on March 28, 1979 disclosed numerous deficiencies in the installed system for the collection and analysis of primary coolant and containment atmosphere samples under post-accident conditions. This system was typical of those then installed at nuclear power stations in the U.S. The accident also disclosed limitations in the capability of its gaseous monitors and the adequacy of sampling systems to deal with the concentrations of airborne effluents that occurred under post-accident conditions. They were also typical of those being employed at the time of the accident.

Subsequently, the U.S. Nuclear Regulatory Commission (NRC) issued several short-term recommendations which were based on the lessons learned from the accident and which were described NUREG-0578 (Ref. 1). They included measures for the improvement of post-accident sampling capability and for the extension of the range of radiation monitors. These recommendations were developed into specific tasks in report NUREG-0660 (Ref. 2) and finalized for implementation in a clarification, NUREG-0737 (Ref. 3). Its specific requirement for Post Accident Sampling Capability were set forth in Item II.B.3. Those for High-Range Noble Gas Effluent Monitors were set forth in Item II.F.1, Attachment 1, and those for the Sampling and Analysis of High-Range Radioiodine and Particulate Effluents in Gaseous Streams were set forth in Item II.F.1, Attachment 2.

An implementation deadline of January 1, 1982 was specified in NUREG-0737. It was also indicated that these systems would be subject to a post-implementation review. Responsibility for this review was assigned by the NRC Office of Inspection and Enforcement to the NRC's regional offices. In mid-1983, Region I contracted with the Safety and Environmental Protection Division of Brookhaven National Laboratory for technical assistance in their performance. Each has required the identification and documentation of the licensee's commitments, clarifications, schedules and orders. A subsequent on-site inspection has included the physical verification and validation of the installation and operability of equipment, as well as the verification of the adequacy of the licensee's procedures and of the qualification and training of licensee's personnel.

Starting in late 1983, on-site reviews were completed at the rate of about one per month for the twenty-one operating licensee sites in Region I, which currently contain a total of twenty-seven operating reactors. They are located in five New England states: Maine, Vermont, Massachusetts, New Hampshire and Connecticut, New York, New Jersey, Pennsylvania and Maryland.

II. APPROACH

Before the on-site reviews commenced, the individual elements needed to determine the state of operational readiness were identified using a Management Oversight and Readiness Tree (MORT). The MORT Tree, as constructed, focused on the integrated ability of personnel, procedure and physical facilities to perform the acquired tasks within the time and dose constraints of Items II.B.3., II.F.1-1 and II.F.1-2. Following this, a specific set of instructions and/or questions related to each review component was prepared. These included sub-categories such as design, monitoring system, shielding, structures, hardware and support services, readout and recording, staffing and training.

III. FINDINGS

A. Post Accident Sampling System (II.B.3)

As indicated in NUREG-0578, the purpose of the requirement for the improved post-accident sampling capability was the prompt provision of information for the assessment and control of the course of an accident. In particular, the II.B.3 required chemical and radiological analyses are intended to provide information for the assessment of core damage and reactivity control. The required analyses of containment atmosphere are intended to establish the presence and concentration of hydrogen and airborne radioactivity, as well as to provide information for the assessment of core damage.

The principles of core damage assessment gases are based on the grouping of fission products according to their volatility. Thus, the fraction of each group that would be released would depend on the temperature that is reached and the extent of cladding damage and fuel fragmentation during an accident. An extended discussion of this subject was presented in the Rogevin Report (Ref. 4), from which the groupings shown in Table I are excerpted. An inventory of the major fission products in a reference 3651 Mw(t) BWR which has been in operation for three years, arranged according to release groups, is also shown in Table I.

In very broad terms, an accident in which only noble gases were released would be indicative of fuel cladding failure, one in which the volatile nuclides of I and Cs were also present in large amounts would be indicative of high fuel temperatures and one in which the non-volatiles were also present would be indicative of a fuel melting. In a more complex situation, the extent of core damage could be determined by a set of simultaneous equations which take into account the observed ratios of the release groups.

The licensees of the twenty-one operating power reactor sites in NRC Region I have installed a variety of systems to meet the requirements of NUREG-0737, Item II.B.3. As shown in a summary in Table II, they range from relatively simple licensee-designed systems which are intended solely to obtain samples of reactor coolant and of the containment atmosphere for subsequent laboratory analysis, to elaborate vendor- or architect/engineer-designed systems which are intended to perform most or all of the required analyses on line, with the laboratory serving only as a back-up. These systems are enumerated by licensee sites, since multi reactor sites either shared a common system or identical individual systems were installed for each reactor on the common site.

None of the reviewed PASS Systems were adjudged perfect in every respect. However, of the eighteen which could be fully tested at the time of the review, all met the basic requirements of Item II.B.3. Of the three that could not be tested, one was inoperative, one had an improperly installed valve which made it impossible to obtain a sample of the containment atmosphere and one could not conduct a test of the containment atmosphere sampling system due to its Technical Specifications, which did not permit the opening of the valves which maintain containment isolation during operation.

The representativeness of the PASS reactor coolant samples and the licensee's radiological analytical capability were tested by making a comparison of the results of their analysis with those from the plant's normal sample sink. The accuracy of the licensee's chemical analytical capability was tested by the use of standards of known content. In principle, the systems which were intended to perform all or most of the required analyses in-line should have demonstrated the greatest operational readiness and ability to provide prompt data. This was especially evident for the one system that was also used for the analysis of routine samples. However, their complexity and/or design deficiencies were found to be counter productive in this regard, including one system which required a long startup that the required sampling and analysis could not be completed within the stipulated three hours.

A schematic of the coolant sampling portion of the GE design system, which is a relatively simple PASS, is shown in Figure 1 and that for containment atmosphere sampling is shown in Figure 2. The principal features of the associated control panel are shown in Figure 3. The panel also contains a mimic diagram of the system, with pilot lights to indicate that the intended steps (i.e. valve closure and opening) have occurred. It is obvious that even this relatively simple system is in fact quite complex, so the detailed and lengthy procedures are required to guide the PASS operator through the sequence of steps necessary to obtain the desired samples.

The principal deficiencies that were identified during the review of the PASS systems are summarized in Table III. It should be noted that in many instances the findings of inadequacy of surveillance was made on the basis of the lack of a suitable schedule and/or the excessive time interval required to get a system fully back on line after a fault had been identified by the licensee. Although most purge times seemed adequate, in many instances the licensee had not conclusively established this by making calculations of the volume of the line(s) to be purged. Midway in the review, the Office of Inspection and Enforcement indicated that the containment atmosphere sample was primarily for fission gas measurements, so that sample line losses should not considered a significant factor unless the licensee intended to use measurements of airborne radioiodines in the containment atmosphere in the assessment of core damage (Ref. 6). Although their reliability for qualitative core damage assessment is questionable, these data could provide information of the release potential if the containment should leak or fail outright.

In most cases the shielding provided for PASS systems and sample transport appeared adequate, but many licensees had not conducted a formal study to establish that the GDC-19 criteria (5 rem whole body, 75 rem extremity dose) could be met.

The balance of the listed deficiencies and the measures necessary to address them should be self-explanatory.

B. Noble Gas Effluent Monitors

A summary of the installed high-range noble gas monitors, according to their location (on-line or off-line), type of detector, and vendor is shown in Table IV. They are enumerated by licensee sites, since at multiple reactor sites, the same vendor/type of monitors were installed. It is evident that the Region I licensees have chosen a variety of approaches to comply with the requirements of Item II.F.1-1. The typical Boiling Water Reactor (BWR) has either one monitored release point under accident conditions (the unit vent) or a second monitored release point (for the standby gas treatment system) as shown in Figure 4. The Pressurized Water Reactors (PWR) were more variable, with from one monitored unit vent and a main steam line monitor to three monitored vents and a steam relief line monitor, as shown in Figure 5.

Three licensees installed on-line monitors, using ion chambers which were located in or immediately adjacent to stacks or ducts, while eighteen installed off-line monitors. Of the latter, six installed "gas only" high-range monitors as additions to their pre-existing low-range monitors. A schematic of such a monitor which utilizes an ion chamber, is shown in Figure 6. Twelve licensees installed commercially available monitors with modules for both monitoring and sampling. A block diagram showing the principal features of one such system (the General Atomics WRGM) is shown in Figure 7. A view of a typical one (the Kaman KDGM-HR) is shown in Figure 8.

These installations have also incorporated a variety of approaches to the problem of achieving the required full-range sensitivity. Typically, three overlapping-range detectors have been provided, as shown in Figure 9 (for the General Atomics WRGM). In order to achieve the upper limit of 10^5 uCi/cm^3 (^{133}Xe equivalent), most of these monitors are designed so that their high-range detectors view a limited volume of gas, as compared to that viewed by their mid- or low-range detectors. An example, for the enhanced high-range detector of the Kaman HRH, is shown in Figure 10.

Although Item II.F.1-1 was not specific on the calibration of noble gas monitors up to the required upper range, the NRC has provided some guidance. It recognized the problem of the availability of suitable noble gases, i.e. ^{133}Xe in sufficient concentrations and of their utilization by licensees if they were available. Therefore, the Staff recommended that a one-time "type" calibration in the laboratory over the intended range be performed and that the transfer procedure of ANSI N323-1978 be utilized in conjunction with solid sources at appropriate energies for on-site calibrations (Ref. 7).

As suggested by Table V, most of the vendors appear to have performed only a "one point" primary calibration, utilizing ^{133}Xe and ^{85}Kr. They have then performed a number of transfer calibrations with solid sources with a range of activities and energies, to establish the energy response and/or range capability of a given detector.

A summary of the sampling arrangements which have been provided to achieve compliance with Item II.F.1-2 and which have been reviewed to date is shown in Table VI. Again, a variety of approaches is evident. Some licensees (including the five who utilized "gas only" monitors to comply with Item II.F.1-1) installed independent sampling facilities. One licensee wrote emergency sampling procedures which incorporated a pre-existing unshielded collector for routine sampling. Five others added additional shielded particulate and iodine sample positions which were connected to an existing low-range sample line, while one added a pre-fabricated multiple sample-position module.

Eleven licensees have installed integrated monitor/samplers which contain micro-processor modules that provide for the automatic or remote collection of a sample at one of three individual sample positions, as also shown in Figure 8.

Another licensee located its integrated unit in what would become a high-radiation field during post-accident conditions, so elected to create another more remote manual sampling station. These integrated monitor samplers typically provide for a much reduced flow of a few hundred cm^3/min, as compared to the 1-2 cfm flow that is typically provided for low- and mid-range sampling. The intent is to thereby limit the total amount of activity that would be collected at concentrations which approach the upper design criterion of 100 uCi/cm^3 for the stipulated 30-minute sampling period.

At PWRs, the NUREG-0737 requirements included the monitoring of secondary site steam effluents which might be released through safety and dump valve discharge lines. It specified that externally mounted monitors viewing the main steam line upstream of these valves were acceptable.

Of the fourteen PWR's (on ten licensee sites) which were reviewed, all but two had installed the required steam line monitors. Five utilized ion chambers and seven shielded GM detectors. Only a few licensees had performed the required analysis to account for pipe thickness in the attenuation of low-energy gamma radiation.

IV. LESSONS LEARNED

A. High-Range Noble Gas Monitors

Oversimplifications in the conversion of the direct indications of the installed gas monitor, typically in cpm or mR/hr, to effluent concentrations and/or rates of release were among the principal shortcomings encountered in the reviews.

The guidance in NUREG-0737, II.F.1-1 states "Design range values may be expressed in ^{133}Xe equivalent values for monitors employing gamma radiation detectors" (as most do). This concept has not been widely understood or employed by vendors or by the reviewed licensees. In some instances, they have employed uninterpreted actual calibration data for ^{133}Xe or ^{85}Kr to establish detector response, without a recognition of their limitations. The former emits low energy photons, with a mean energy of 0.045 MeV per disintegration. Thus, they may be significantly absorbed in the housing or walls of a detector. In contrast, ^{85}Kr is principally a beta emitter, with accompanying bremstrahlung gamma radiations and a 0.51 MeV photon with a yield of only 0.4%. This is apparent from Figure 11, which illustrates the direct response with distance of Eberline's high-range detector to each of these nuclides. When corrected respectively for absorption and bremstrahlung, the true energy response of this detector is about midway between the two curves, so using one point from either could lead to a factor of two error.

Beyond this, these uninterpreted calibration data were in some instances also employed to calculate release rates (in uCi/sec), without regard to the variable energy response characteristic of the detector. This characteristic may be close to linear with energy, as shown in Figure 12, for the Kaman KDGM-HR, or may be quite non-linear as shown in Figure 13, for the General Atomics WRGM. Beyond the inherent response of the detector itself, its energy response may also be dependent on the geometry in which it is installed and the type and thickness of the intervening duct or pipe walls which may absorb radiations before they reach the detector.

All of the reviewed licensees have installed monitors which in principle met the upper range criterion of 10^5 uCi/cm^3. However, only two had calibrated the installed high-range monitors on-site with radiogases in concentrations approaching 10^5 uCi/cm^3. The vendor calibration information supplied by Kaman, as shown in Figure 14, suggested that a test with actual radiogases approaching these concentrations had been performed with ^{133}Xe. However, on the basis of field testing which employed ^{85}Kr, it was found by another investigator that this monitor could not meet the specified upper range (Ref. 8). It is our understanding that since these tests, the Kaman high-range detector has been modified so that it can do so. A similar fall-off which appeared to be due to a large dead-time at high concentrations was reported by a consultant to a Region I licensee in a field calibration of the high-range detector (SA-9) of the Eberline SPING (Ref. 9).

Some licensees have recognized the variable energy response of high-range monitors by the provision of corrections in their software for making off-site dose assessments. However, this does not provide early guidance for a reactor operator or supervisor who may have to make manual calculations of effluent release rates before skilled post-accident dose assessors are likely to be available.

As indicated in Table V, three licensees selected the Eberline SPING-4 as a high-range monitor for effluent noble gasses. During the reviews, it was ascertained that the micro-processor of this monitor is not radiation hardened, thus making it doubtful that it would operate reliably in high-radiation fields. However, in one case the monitor was supplemented by the Eberline SA-10 and SA-9 mid- or high-range detectors, for which the sensitive components are remotely located. When the SPING-4 component of this unit senses high radiation fields, it is isolated from the sample stream, thus increasing its reliability of function throughout an accident sequence.

In several instances, licensees with installed micro-processor controlled high-range gas monitors were found to have a limited number of plant personnel with sufficient training to be able to retrieve data beyond that routinely displayed. The review also revealed that several of these monitors had experienced frequent and/or extended down time of their automatic features, due to the failure of their flow sensors which appear to be sensitive to entrained dust particles and which therefore call for frequent preventative maintenance.

Except for those with installed integrated units which function automatically, few licensees had incorporated provisions or procedures for the isolation and/or purging of their low-level gas monitors, should their range be exceeded. Thus their recovery and availability would be doubtful following an accident as effluent concentrations declined to within the low-range region.

While the steam line monitors at PWRs were relatively simple and straightforward devices, their detectors were of necessity installed in hostile environmenta where they were subject to heat and humidity. In some instances, they therefore required frequent maintenance (especially the GM detector devices). Most of the licensees had accepted the vendors calibrations and very few had analyzed the effect of the wall thickness of the steam line pipe to account for detector response to low-energy radiation.

B. Sampling and Analysis of Plant Effluents

The principal deficiency encountered in the review of arrangements for the sampling of radioiodines and particulates was the inability of licensees to document that their sampling systems could collect representative samples. This is particularly so for those with long sampling lines, in which considerable deposition losses of elemental radioiodines could occur even when installed in accordance with the design guidance of ANSI N13.1-1969.

The transmission of elemental iodines through long sampling lines has been measured under controlled conditions in the laboratory by Unrein et al (Ref. 10). Their studies suggest that it depends upon the relative rates of deposition and resuspension from their walls. Transmission factors greater than 50% were found for 1" sampling lines at flow rates of 2-3 cfm, for injection periods of several hours. However, these studies did not indicate how long it took to reach equilibrium between deposition and resuspension after an initial injection. Only a small fraction (<1%) of the injected elemental iodine was transmitted through the 1/4" sampling line with a 0.06 cfm flow rate as utilized in the General Atomics WRGM, which is shown schematically in Figure 15.

The NRC's proposed guidance suggests that the closest approximation to representativeness may be achieved at equilibrium, when deposition and reentrainment or re-suspension are equal. This could be expected to occur most rapidly in a continuously operated system, rather than one in which flow is initiated only upon the occurrence of higher-range concentrations. The Kaman and the Eberline AXM-1 monitors approximate this in that, upon an indication of abnormal gas concentrations, they isokinetically obtain a small local side-stream flow (of a few hundred cm^3/min) from the low-range monitoring/sampling line, in which a much greater flow (1-2 cfm) is maintained.

From the reviews, it was apparent that most architect/engineers and licensees have been aware of the need for the heat tracing of sampling lines when they are exposed to "outdoor" conditions. However, it was also apparent that some of them have not recognized a similar need for the heat tracing of long indoor horizontal sampling lines in which condensation could occur, especially under the high moisture loads of some accident sequences. In a few reviews condensation was found in the sampling medium of the "standby" sampling positions.

Although II.F.1-2 calls for continuous sampling, the procedures of five licensees called only for the analysis of a grab sample to be collected post-accident over a short period of time (to limit the amount collected to the capability of their laboratory Ge-Li analysis systems), with no indication of how they would evaluate the preceding sample to establish the total amount released from the onset of accident conditions.

In several instances, which included the three SPING-4s, the three SAI RAGEMS and one licensee devised installation, the filter assembly for the collection of particulates and iodines was either unshielded or inadequately shielded. None had conducted an analysis to assure that with such an arrangement, the samples could be collected, retained and transported within the GDC-19 dose limits (5 rem whole body and 75 rem to the extremities). It should be noted that by two successive 1/200 dilutions, the RAGEMS should collect only relatively low activity samples even under accident conditions.

All of the licensees had Ag-Zeolite collection media available for sampling under accident conditions. Almost all of the installations provided for isokinetic sampling at normal stack flow rates, but only a few could maintain it if large deviations from these flows were to occur under accident conditions. Of those that could not, none had developed correction factors, as called for in Item II.F.1-2.

Only a few licensees had developed adequate procedures for the analysis of high activity samples, in which the collected activity might considerably exceed the upper limit which could be analyzed by their GeLi counting and analysis systems. Although several had established procedures for counting samples with greater than normal activity in a geometry distant from the detector, only a few would be able to cope with samples approaching the 85-170 Ci of radioiodines which would be collected at a concentration of 100 uCi/cm^3 at normal flow rates of 1-2 cfm for the stipulated 30-minute sampling period.

VI. COMMENTS AND RECOMMENDATIONS

Except for the GE designed PASS, which was basically the same except for variations in sample line arrangements and the associated valves at individual facilities, a wide variety in PASS systems were encountered in the reviews which have been conducted over the past two years. Many required frequent and considerable attention to keep them fully operational and all required frequent retraining to maintain operator proficiency with their controls and their detailed operating procedures.

The example of the one in-line system which is also used for routine sampling suggests that the readiness and availability of the other systems could be enhanced if they were too were also periodically used for routine sampling, in between the infrequent occasions they are utilized for exercises or mandatory retraining.

A wide variety of approaches to the monitoring of noble gases and the sampling of particulates and radioiodines in high concentrations have also been encountered in the reviews.

If the monitoring requirements were solely those for the noble gases, ion chambers would seem the most straightforward detectors, in view of their simplicity, wide range capability, and linear energy response characteristics. However, they are relatively insensitive and therefore require a large volume of contained gas which is difficult to shield from extraneous radiations. An example of one such installation is shown in Figure 16. The 0.1" - thick steel wall in which the detector was housed would have a large absorption for low energy photons, such as those from ^{133}Xe, compared to a much smaller absorption of the higher energy photons from shorter-lived noble gases.

The integrated monitoring/sampling devices which incorporate microprocessor data handling and control accomplish the full range requirements of Item II.F-1.1 by routing the flow to more then one detector, each of which is designed to be sensitive to portions of the full range requirement. This permits the isolation of their low-range detectors during periods of high concentrations. It also facilitates the routing of flow to a selected shielded filter assembly at the same time. Their additional ability to store and to provide a history of release rates over time makes them attractive for both routine and accident monitoring. Additionally, the use of a monitor for every-day purposes adds to its reliability for accident monitoring. If not so utilized, these monitors require regular surveillance and maintenance to assure their availability.

Much of the confusion over the use of the ^{133}Xe equivalent concept in the calibration of high-range noble gas monitors could be elminated by the adoption of the "Ci-Mev" concept as described by Mourad (Ref. 11). A simplified version of the same concept, which utilizes the average noble gas energy as a function of time post-shut down is shown in Figure 17. Its use in dose calculations, was described by Lahti at the 1985 Annual Meeting of the Health Physics Society (Ref. 12).

To minimize the ambient post-accident radiation fields in their vicinity, most of the post-accident monitors and/or samplers have been located at considerable distances from the points of effluent release, thus necessitating long sampling lines (typically 1" x 100-250'). This creates a dilemma between the desirability of maintaining a high flow rate in the sample line so as to minimize deposition losses and the desirability of minimizing the amount of collected radioactivity on the sampler. It is solved in some monitors, by the provision of a second stage of isokinetic sampling with a probe situated within the high-flow line close to the sampling head, but with a much small flow (a few hundred cm^3/min) through the "high-concentration" sampler. This seems desirable on the grounds of both convenience in handling and analysis and of ALARA considerations.

TABLE I

INVENTORY OF MAJOR FISSION PRODUCTS IN A
REFERENCE PLANT OPERATED AT 3651 MWt FOR THREE YEARS

	Group (Rogevin Report)	Isotope*	Half-Life	Inventory** 10^6 Ci
Noble gases	I	Kr-85m	4.48h	24.6
		Kr-85	10.72y	1.1
		Kr-87	76.3m	47.1
		Kr-88	2.84h	66.8
		Xe-133	5.25d	202.0
		Xe-135	9.11h	26.1
Halogens	II	I-131	8.04d	96.0
		I-132	2.3h	140
		I-133	20.8h	201
		I-134	52.6m	221
		I-135	6.61h	189
Alkali Metals	III	Cs-134	2.06y	19.6
		Cs-137	30.17y	12.1
		Cs-138	32.2m	178.0
Tellurium Group	IV	Te-132	78.2h	138
Alkaline Earths	V	Sr-91	9.5h	115
		Sr-92	2.71h	123
		Ba-140	12.8d	173
Noble Metals	VI	Mo-99	66.02h	183
		Ru-103	39.4d	155
Rare Earths	VII	Y-92	3.54h	124
		La-140	40.2h	184
		Ce-141	32.5d	161
		Ce-144	284.3d	129
Refractories	VIII	Zr-95	64.0d	161
		Zr-97	16.9h	166

* Only the representative isotopes which have relatively large inventory and considered to be easy to measure are listed here.

** At the time of reactor shutdown.

TABLE II

SUMMARY OF INSTALLED POST-ACCIDENT SAMPLING SYSTEMS

Sample Collection (no on-line analysis capability)

Design	No.	Remarks
Licensee	4	
G.E.	9	

Sample collection (limited on-line analysis capability)

Design	No.	Remarks
General Dynamics	2	In-line-pH, Cond.
Quadrex	1	In-line-pH, B, Cl
Sentry	1	In-line-pH, Cond, Dis O, Dis H
	1	In-line-pH, Cond, DO, Dis H, Cl
Stone & Webster	1	In-line-isotopic analysis pH, B, Cl

Full in-line analysis capability (including isotopic)

Design	No.	Remarks
Sentry	1	
Combustion Eng.	1	

TABLE III

PRINCIPAL DEFICIENCIES IDENTIFIED IN REVIEW OF POST-ACCIDENT SAMPLING SYSTEMS

Frequency	Deficiency
12	Inadequate surveillance and maintenance program
11	Inadequate purge times
10	Non-representativeness of radioiodines in containment air sample
10	Inadequate time and motion studies to document that shielding in sample room and/or of sample during transport sufficient to enable operation within GDC-19 criteria.
7	Improper pressure and/or temperature corrections
7	Procedures inadequate or in need of revision to conform to actual operation of PASS
5	Dilution beyond the range capability of the analytical procedure
5	Moisture carry over into gas chamber during gas stripping
4	Inadequate assurance of sample flow (no flow meter installed)
4	Insufficient or no backup for one or more in-line analyses
3	Inadequate test of all features of system by licensee prior to on-site review
3	Inadequate training or insufficient number of trained personnel to assure ability to operate system during post-accident conditions.
3	Inadequate assurance that sample could be obtained when reactor depressurized (no pump in PASS).
3	Needle bent during attempt to perforate septum of sample collection vial
3	Improper interpretation of flow produced by critical orifice (or of pressure required to maintain design flow)
3	Unsuitable cask/shield vial for sample transport
3	Volume delivered by ball valve (for dilution) not established by actual measurement
3	Chemical analysis procedure not adequately tested for possible interferences
2	Sample not returned to containment

TABLE IV

SUMMARY OF INSTALLED MID- AND HIGH-RANGE NOBLE GAS MONITORS

No.	Range	Detector	Vendor	Model	Operating Mode	Data Processor	Background Subtraction
On-Line							
2	Mid/High	Ion Chamber	(1) GA (1) Victoreen	RD-2A 847	Continuous	No	No
Off-Line							
Gas Only							
1	Mid/High	Plastic	NMC	GA-270	High Alarm	No	No
1	Mid High	GM Ion Chamber	Victoreen Victoreen	847	Continuous	No	No
3	Mid/High	Ion Chamber	Victoreen	847	Continuous	No	No
1	Mid/High	Ion Chamber	Reuter-Stokes	C4-2510-101	High alarm	No	No
Integrated Gas Monitors and Particulate-Iodine Samplers							
6	Mid High	Cd-Te Cd-Te	GA	WRCM	High Alarm	Yes	No
3	Mid High	GM GM	Eberline	SPING-4	Continuous	Yes	Yes
2	Mid High	GM GM	Kaman	KGM-hRH	High Alarm	Yes	No
1	Mid/High	Ge-Li	SAI	RAGEMS	Continuous	Yes	NA
1	Mid High	GM GM	Eberline	AXM-1	High Alarm	Yes	Yes

TABLE V

CONCENTRATIONS FOR VENDOR CALIBRATIONS OF II F.1-1 HIGH RANGE MONITORS

	^{133}Xe Concentrations uCi/cm^3	^{85}Kr Concentrations uCi/cm^3
Eberline		
Mid-Range SPING NGD-1 (SA-13)	0.13	0.47
High-Range SPING AXM-1(SA-14)	0.26	1.47
SA-15, SA-9	1.75	9.98
General Atomics		
Mid/High Range-WRCM	0.65	11.1*
Kaman		
High-Range-HRH	$5x10^4$	$1.5x10^5$*

*Based on calibration data supplied by vendor, as inferred for NBS Reference Date.

TABLE VI

SAMPLING AND ANALYSIS OF PLANT EFFLUENTS, II.F.1-2

No.	Range	Vendor	Model	Sample Positions	Shielded	Filter Selection	Remarks
Independent Utility Design							
5	-	-	-	1	Yes		(In each instance)
Vendor Design							
1	-	NRC Ind.	MAP-5	3	Yes	Local/remote control	Timed sample
1	-	Kaman	HRH	1	Yes		
Integrated Units							
5	Mid/High	GA	WRGM	3	Yes	Local/remote control	Timed sample
3	Mid/High	Eberline	SPING-4	1	No	Fixed	
2	Mid/High	Kaman	KGM-HRH	3	Yes	Automatic (GM Monitor)	Automatically timed sample
3	All	SAI	RAGEMS	1*	Yes	Automatic	Note 1
1	Mid/High	Eberline	AXM-1	1	Yes	Fixed (GM Monitor)	

Note: One licensee has installed this system, but does not utilize its Ge-Li detection feature.

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Figure 1

PASS LIQUID SAMPLING SIMPLIFIED P&ID

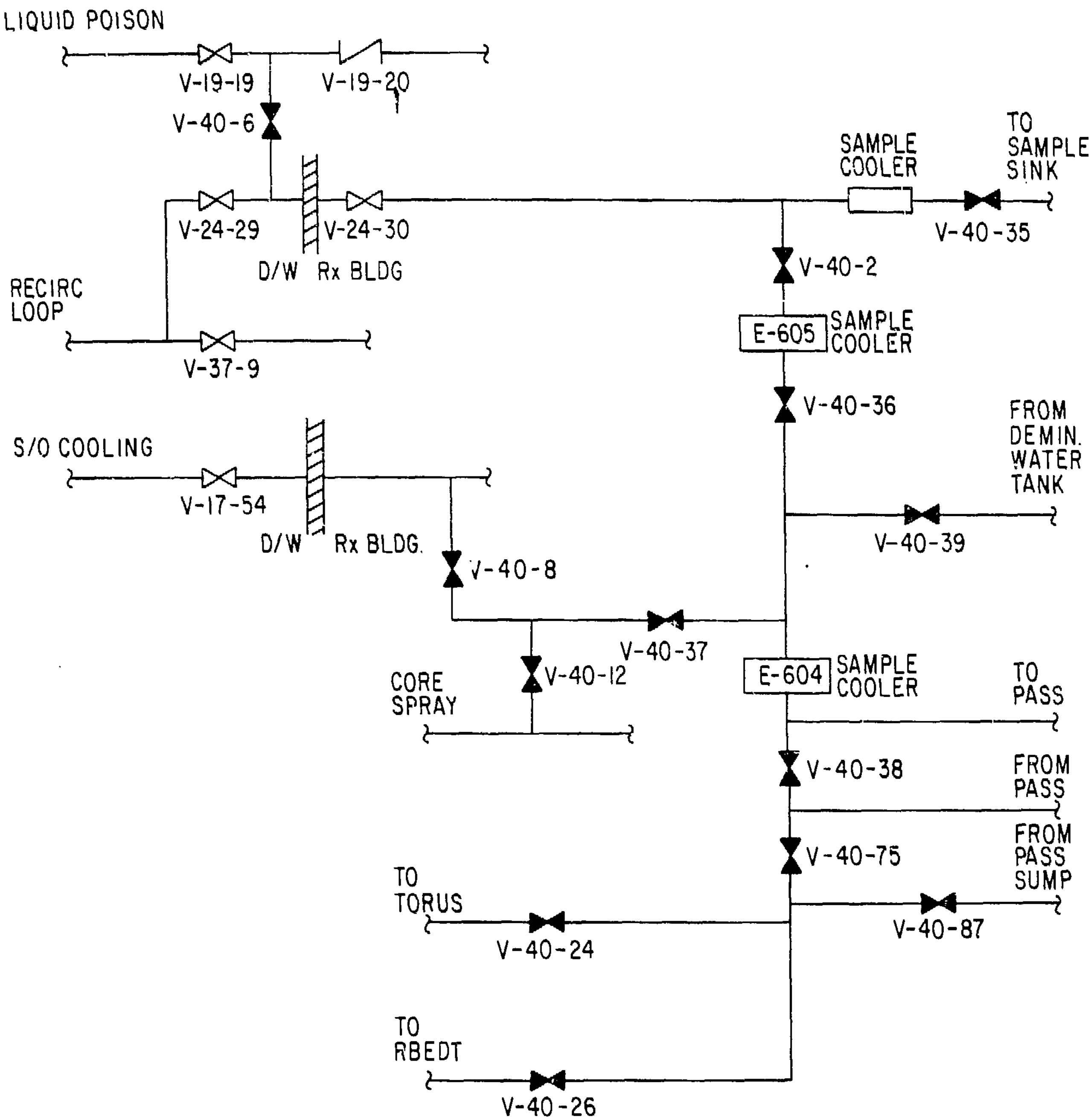


Figure 2

CONTAINMENT ATMOSPHERE PASS SAMPLING DIAGRAM
SIMPLIFIED P & ID

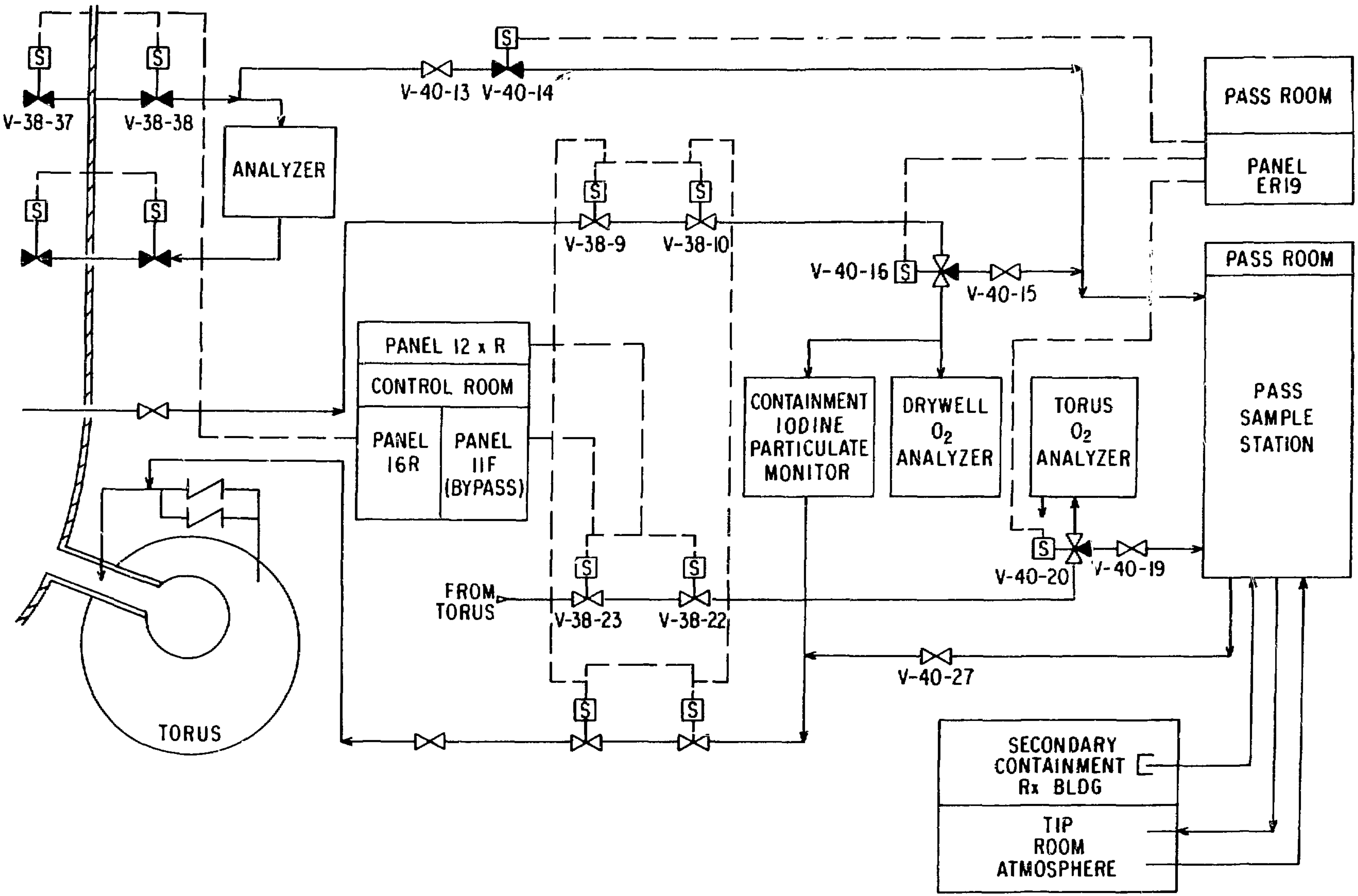
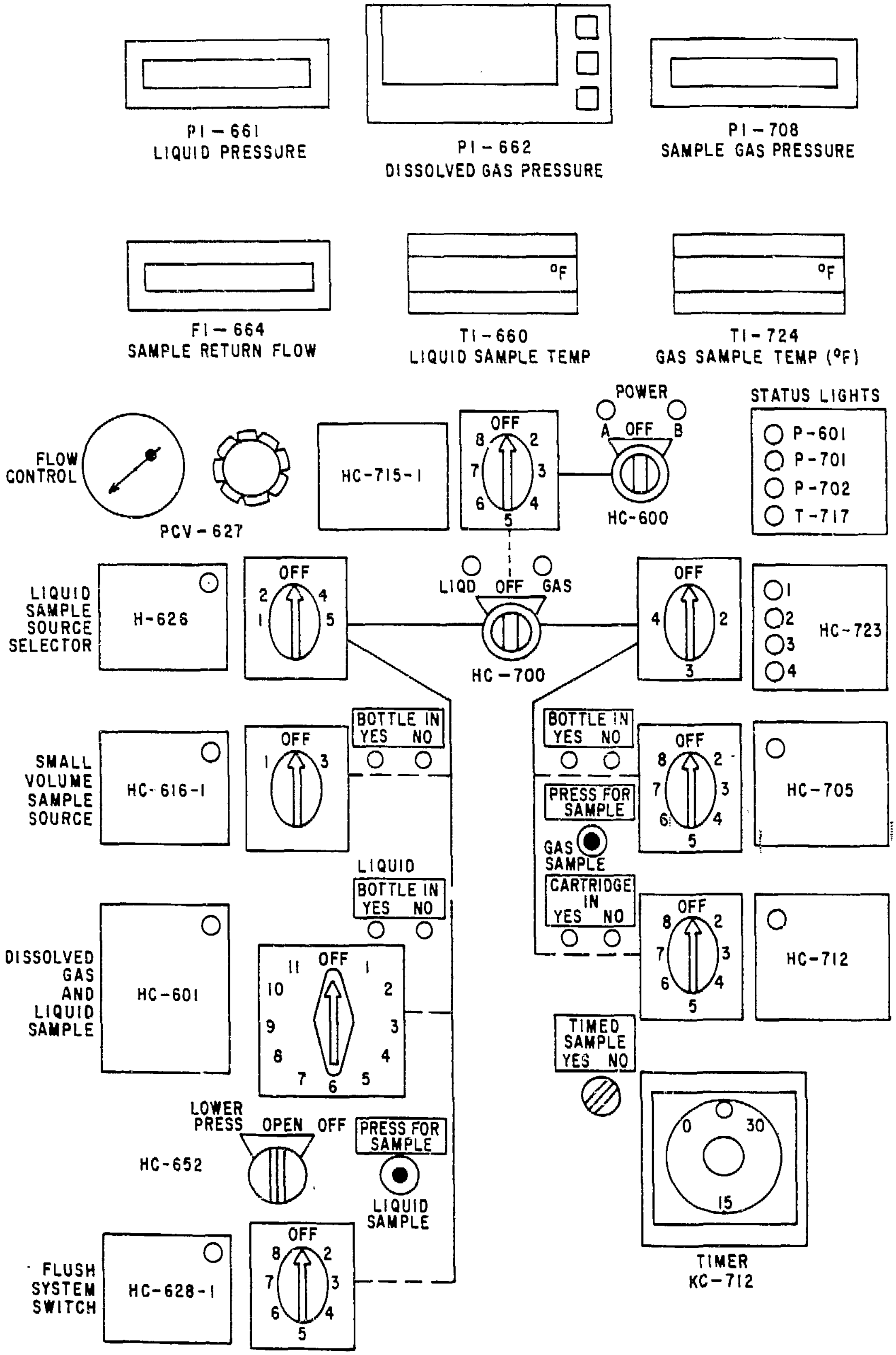


Figure 3

GE PASS CONTROL PANEL



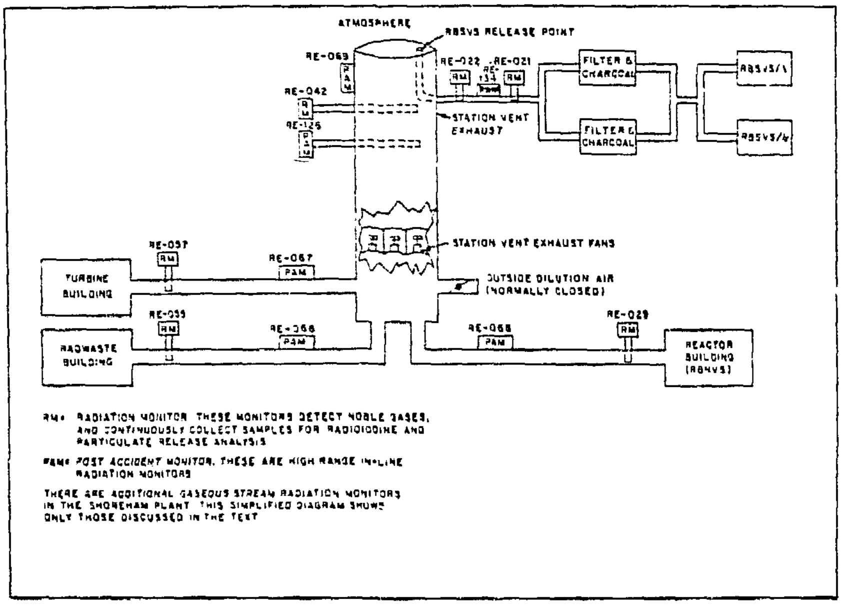


Figure 4. Gaseous effluent radiation monitors.

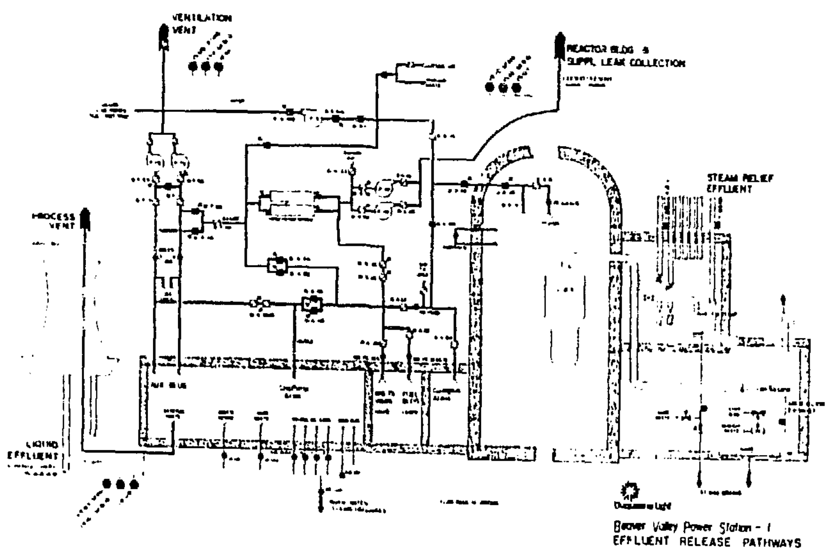


Figure 5. Effluent release pathways.

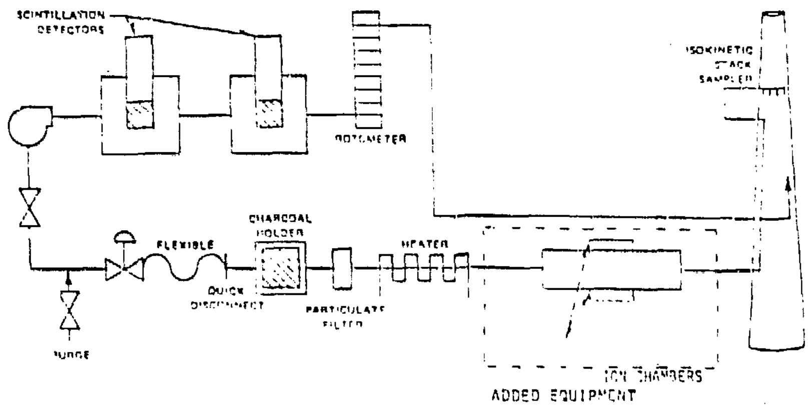


Figure 6. High-range effluent process radiation monitors.

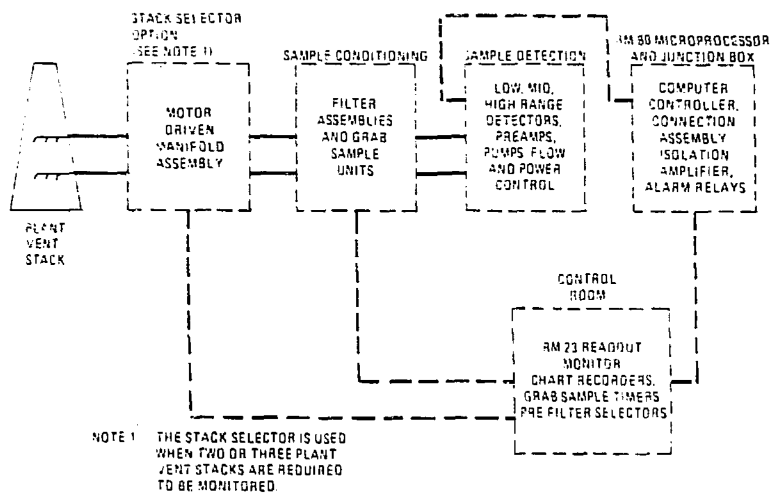


Figure 7. Wide-range gas monitor system block diagram.

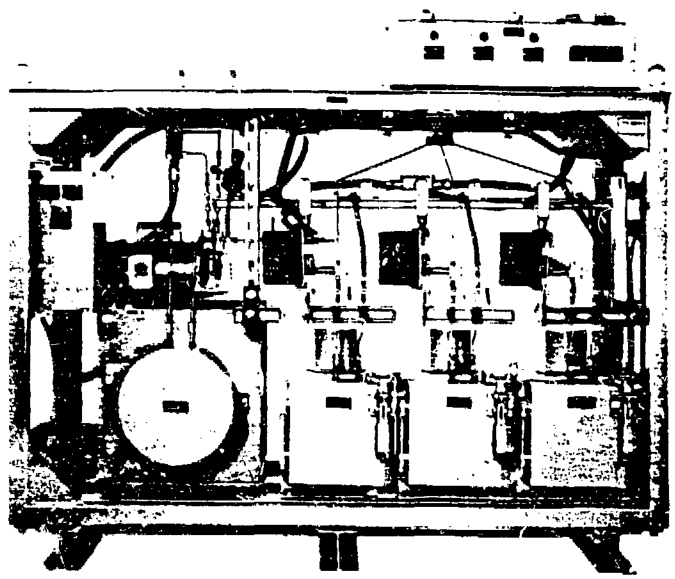


Figure 8. Kaman HRH high-range noble gas monitor and sampler.

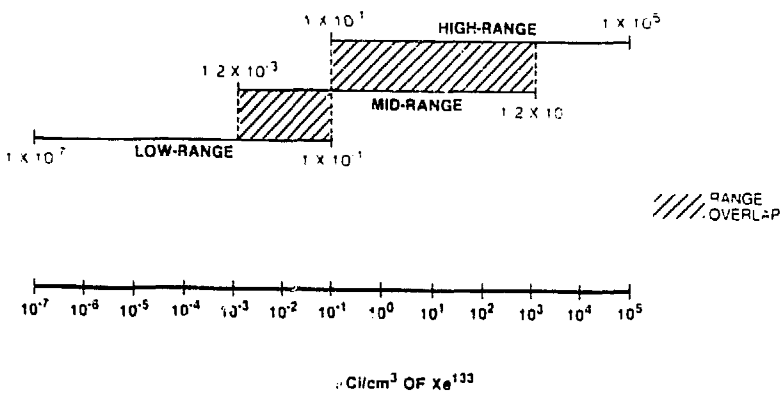


Figure 9. Ranges of General Atomics wide-range gas monitor.

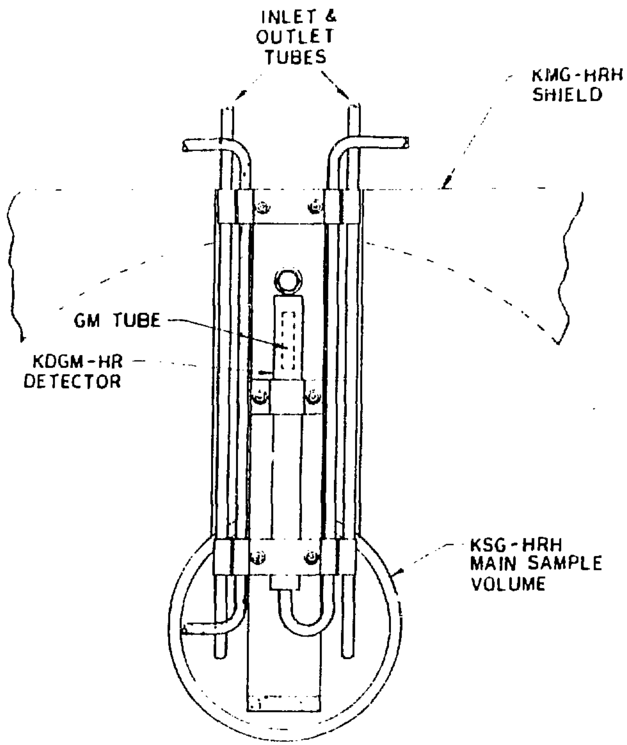


Figure 10. KMG-HRH-Enhanced high-range geometry.

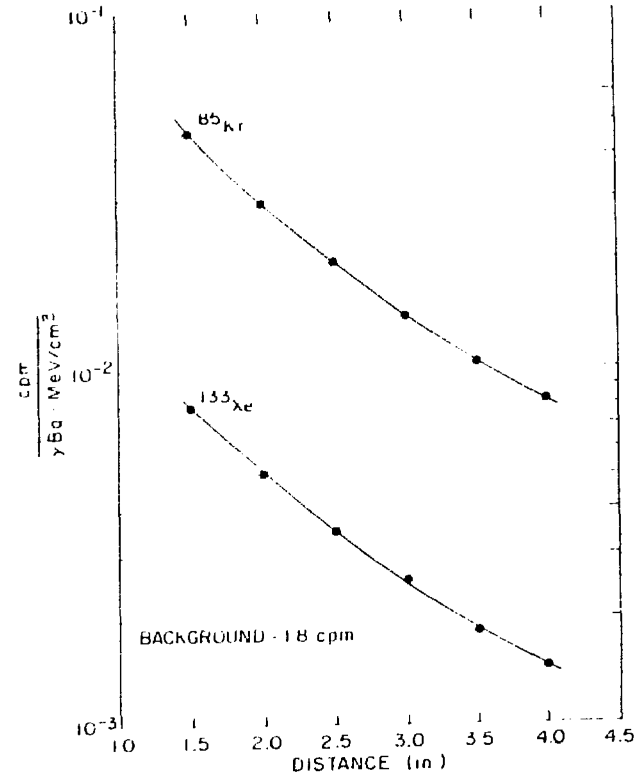


Figure 11. Response of Eberline SA-9 high-range detector to ^{85}Kr and ^{133}Xe.

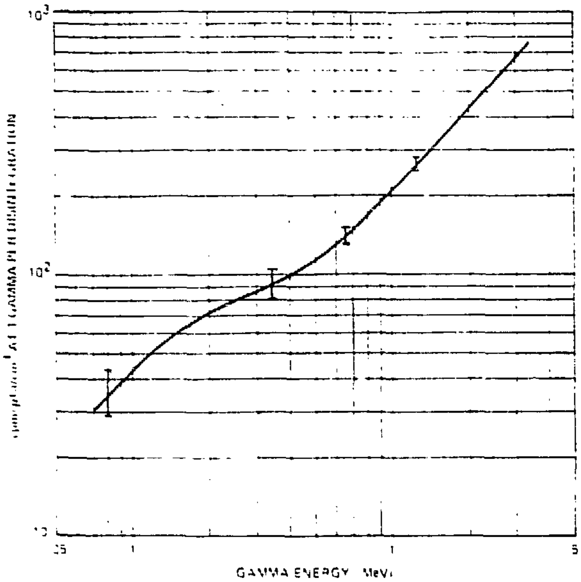


Figure 12. KDGM-HR enhanced detector in KSG-HRH sampler, enhanced high-range position energy dependence characteristic.

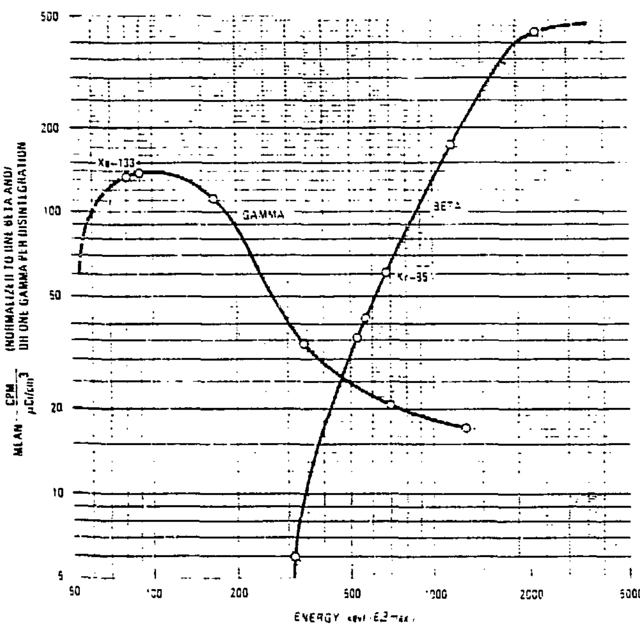


Figure 13. General Atomics wide-range gas monitor RD-72 high-range detector energy response curve.

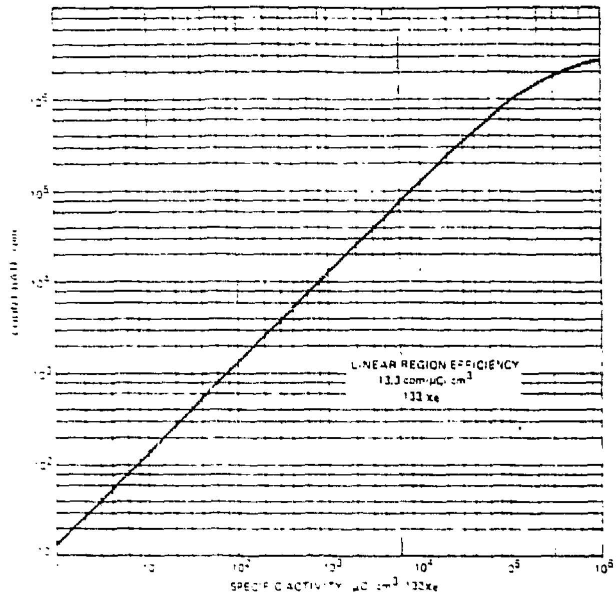


Figure 14. HDGM-HR Enhanced detector in KSG-HRH enhanced high-range position efficiency to Xenon-133.

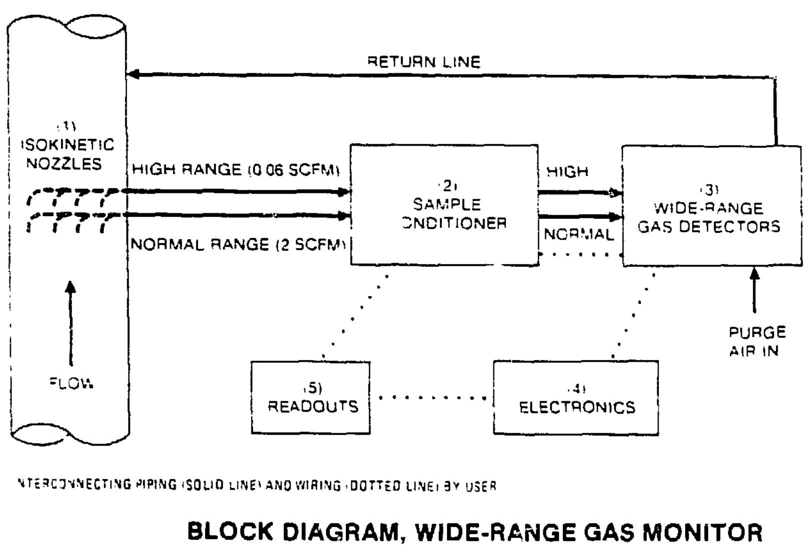


Figure 15. Block diagram, wide-range gas monitor.

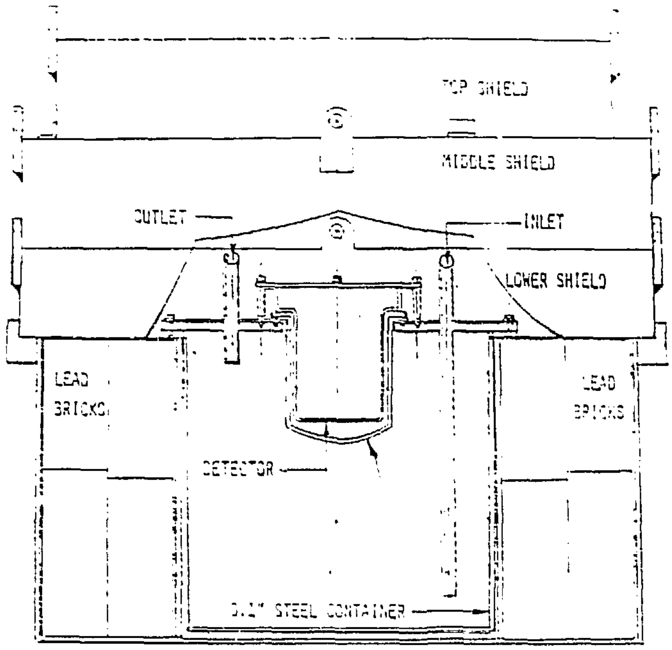


Figure 16. High-range noble gas monitor.

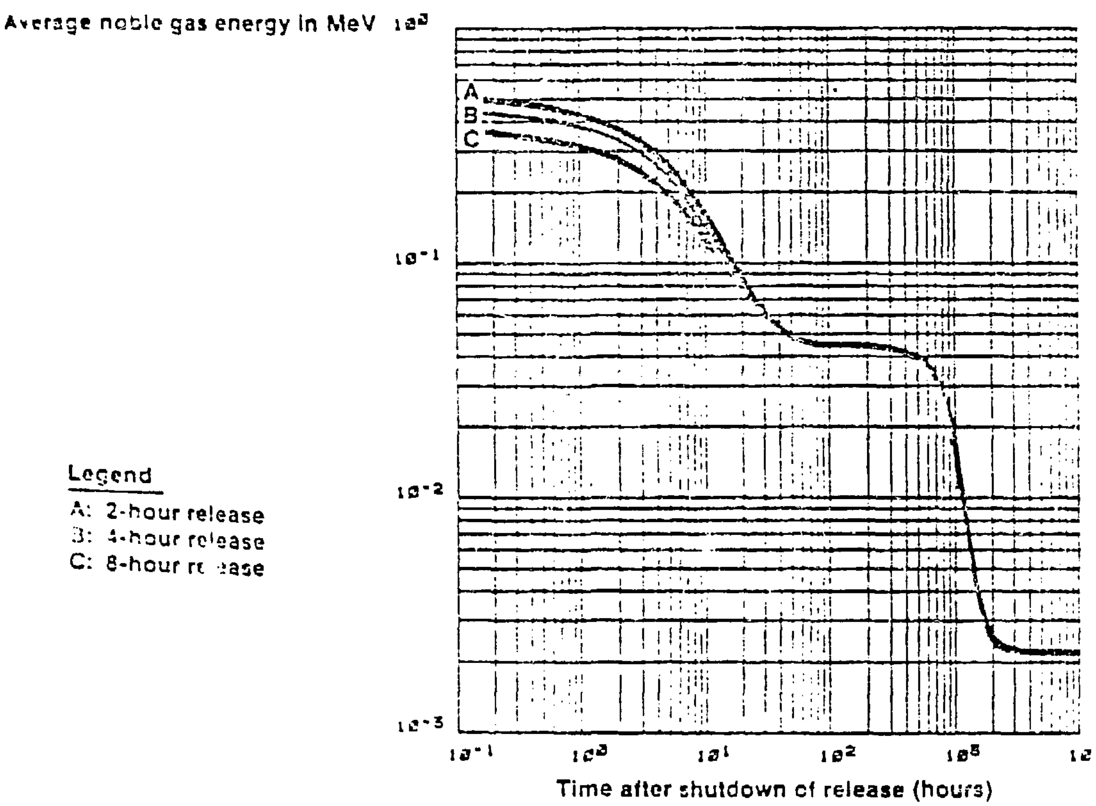


Figure 17. Average Noble Gas Energies of Total Releases.