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FINAL REPORT: DEVELOPMENT TEST NO.
105-609-A, SLUG RUPTURE DETECTION EXPERIMENTS
AT 105-C

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FINAL REPORT: DEVELOPMENT TEST NO. 105-609-A -
SLUG RUPTURE DETECTION EXPERIMENTS AT 105-C

INTRODUCTION

The experimental work authorized by Development Test No. 105-609-A⁽¹⁾ has been terminated and all related equipment has been removed from the "Y" sample room of 105-C.

Principle objectives of this test were:

1. To obtain additional data comparing the gamma spectrometer monitor with the C and K Type Beta Monitor.
2. To determine if charging and discharging during operation interferes with rupture detection by the gamma system.
3. To obtain data on water flow stability in sample lines from process tubes operating at elevated temperatures.
4. To further study the feasibility of using ion-exchange resins in rupture detection systems.

(1) HW-38071 - Development Test No. 105-609-A, Test of the Prototype Gamma Monitor Slug Rupture Detection Equipment at 105-C, R. S. Paul and M. C. Greene - 6-15-55 (Secret).

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SUMMARY

The prototype Gamma Monitor system demonstrated more sensitivity for rupture detection than the C Beta Monitor in agreement with earlier tests at H pile. In one instance a rupture was indicated several hours earlier by the experimental gamma installation.

Discharging and charging ball-valve tubes during operation has occasionally knocked loose film or corrosion material which caused up-scale signals on the effluent beta monitor. No "false" signals from this cause were registered by the Gamma system during this test. It is not believed that charge-discharge during pile operation will handicap rupture detection by the Gamma system.

Water was sampled directly from one tube which operated with outlet water temperatures up to 105°C. The flow stability in this sample line was as good as that in other lines with water temperatures below 100°C. However, it is believed that sampling effluent at high temperatures ($> 120^{\circ}\text{C}$) may pose some difficulties, and this problem should receive some attention in support of future programs.

A number of ruptures were detected with several versions of ion-exchange resin monitors. At the present time these offer no significant advantages as additions or alternates to the differential Gamma system. However, they may offer improvements in monitors for recirculating coolant systems and should be further studied in this regard.

DISCUSSION

A. The Gamma Spectrometer Monitor

A production model water sampling turret⁽²⁾ and prototype spectrometer⁽³⁾ instruments were installed in the Y sample room of 105-C. This system monitored samples from far side headers 20 through 30 and one from an individual tube which operated at high outlet water temperatures. After leaving the turret, all the lines entered a common drain which was monitored with several ion-exchange resin detectors. Unfortunately, the only piping from the rear face available for these lines were some small pressure-drop lines. These restricted the flow so that the holdup (decay) time at the turret ranged from 60 to 75 seconds rather than the 55 seconds desired. Because the water holdup time could not be adjusted to that used in the production Gamma Monitor, this installation was not used to train the pile operators as had originally been planned.

The longer holdup time handicapped comparison of the Gamma rupture sensitivity with that of the C-Pile Beta System. The reduced flow rates also contributed to several cases of severe contamination of the Gamma water chamber following a slug rupture. These chambers were readily decontaminated by flushing with oxalic acid and a strong flow of clean water. In one case of chamber contamination gamma spectra were taken several days after the rupture. The bulk of the activity in the 2 to 3.5 Mev signal channel (at this decay time) was identified as the fission product lanthanum-140.

- (2) HW-41412 - Operation and Maintenance of the Hanford Effluent Water Gamma Monitor, M. C. Greene, R. S. Paul, and M. R. Wood (Confidential).
- (3) HW-32166 - Dual Channel Pulse Analyzer and Count-Rate Meter for Gamma Spectrometer Monitor, R. S. Paul and M. R. Wood, June 17, 1954 (Unclassified).

Several rupture records were missed with the Gamma Monitor because of a faulty chart recorder. As judged from the resulting chamber contamination these would have given off-scale indications. Good records were obtained on three ruptures.

Rupture 2679 on January 8, 1956 was indicated on the Gamma Monitor about seven hours before the pile was shut down for the rupture. A smaller, but distinguishable, signal began showing on the C Beta system at about the same time. The two systems actually monitor separate sample lines so the fission product concentration is not necessarily the same for both. One of the major difficulties with the C and K type Beta systems was then observed. Although the header 26 point was well outside the pattern because of the rupture signal, several other headers also began deviating from the normal pattern. This recurrence of "false" or unexplained signals on the Beta system has fostered by necessity an operating philosophy of waiting until there is a real strong signal. Usually this means an increase in gross activity of the total effluent where the rupture signal is roughly 100 times more diluted than in the crossheader sample.

The progress of this particular rupture signal as shown by both the Gamma and Beta systems is of interest. The signal intensity or rupture release rate increased gradually for about five hours. There was then a small reduction in intensity for about an hour and then an increasing release again. Finally, about seven hours after the Gamma signal exceeded the usual alarm trip level, there was a large burst of activity. The magnitude of the burst is not known as both Beta and Gamma recorders went off-scale. At this time the total effluent activity monitors indicated and the pile was shutdown. The ruptured slug was found stuck.

One is tempted to speculate that the rupture was likely not stuck in its early stages and perhaps not until the burst of activity release. It is apparent that reliability and absence of false signals is as important in a practical rupture detection system as outright sensitivity.

Rupture 2073-C gave a nearly full-scale Gamma signal shortly after pile startup on January 10, 1956. The pile was quickly shutdown. Details of the responses of other detectors are incomplete for this case.

At about 5:00 pm on February 11, 1956 Operations Supervisor, J. R. Pierce, noted that the experimental Gamma Monitor was showing an increasing signal on header 21 far. About two hours later the same header began indicating on the Beta system. However, seven or eight other headers were giving similar deflections on the same Beta recorder. Readings on water samples drawn from the Beta sample lines during the next several hours gave inconclusive results. The Gamma signal continued to increase steadily to near full scale. At about 10:00 pm the Gamma Monitor registered a very large signal. So much rupture material was released that the monitor went off-scale from radiation leakage through the turret shielding when the porthole was viewing the other water lines. At the same time the riser and retention basin total activity monitors doubled their reading and the tube inlet pressure increased ten pounds. The reactor was quickly shutdown.

This rupture was detected significantly sooner and with more sensitivity by the Gamma Monitor. An exact sensitivity comparison with the Beta system is not justified because they were on different sample lines. However, the results are compatible with comparisons made several years ago with simulated ruptures.⁽⁴⁾ This rupture again

(4) HW-27629 - Methods for Detecting Uranium Slug Jacket Failures, R. S. Paul, April 3, 1953 (Secret).

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emphasized how severely the erratic signals of the Beta Monitor handicap rupture detection with that system. The erratic behavior is principally caused by inherent difficulties in switching low-level ionization chamber currents, power level and holdup time dependence, and residual radioactive contamination of the detection chambers.

B. Effect of Charging and Discharging During Operation

The experimental Gamma system monitored headers which included the experimental charge-discharge system ball valve tubes. No "false" signals were observed on the monitor due to operation of these ball valves. Additional Gamma spectrometer equipment was set up for the Discharge of November 30, 1955 to attempt identification of any activity released into the water. None was detected. The riser Beta monitor recorder showed two spikes corresponding to discharge of the two tubes. However, inspection of the time showed that they were caused by direct radiation through the shielding wall from the intensely radioactive slugs (zero decay) as they dropped to the basin, rather than from activity in the water. The latter would be delayed by the holdup in the sample line.

On other occasions operation of the ball valves has apparently released active material which indicated on the Beta system. This film or corrosion product material could register on the Gamma system if it emitted gamma rays with energies greater than 2 Mev. The main offenders would be manganese-56 or sodium-24. Even if some of this material is released it should not be a serious problem since the time duration will be short and the location can be correlated with the tubes being charged.

C. Monitoring High Temperature Water

No conclusive data were obtained from this phase of the experiment. Flow in the sample line directly from a tube with outlet temperatures in the order of 105°C was as stable as that in other sample lines. However, the line was run wide open and it may have behaved differently if throttled with a valve. Other facilities will be required to adequately study the problem of sampling 120°C or higher temperature effluent.

D. Ion-Exchange Resins for Rupture Detection

In some applications it may be possible to increase rupture detection efficiency by using the ion exchange mechanism to select fission products from the effluent stream.^(5,6) Some experiments at HAP0 by R. R. Bloomstrand⁽⁷⁾ gave encouraging results but didn't permit a direct evaluation of the efficiency of the ion exchange resin. Considerable development of this idea has been done at the MTR and good success is claimed in applying a version of the ion exchange method to fission product detection in recirculating coolant systems.⁽⁸⁾

(5) ANL-5002 - Removal of Slug Rupture Products from a Water-Cycling System (CP-6). M. Divetz, C. H. Scheibelhut, and E. S. Sowa, July 1, 1953 (Secret).

(6) IDO-16209- MTR Technical Branch Quarterly Report, J. R. Huffman, 12-21-54 (Secret).

(7) HW-36298 - Slug Rupture Detection Utilizing Ion Exchange Resins, R. R. Bloomstrand, 4-25-55 (Secret).

(8) IDO-16213- Fission Product Monitoring in Reactor Coolant Streams, R. L. Heath, 1-1-56 (Unclassified).

Assuming the ion exchange effect is capable of collecting fission products from the water, there are two major problems which may limit its application. First, the ion exchange resin (or any similar filtering or collection system) will also collect material from the normal effluent stream, increasing the level of the background radiation. There will be an increase in the overall detection sensitivity only if the fission product concentration is proportionately higher, since the sensitivity criterion in any system is the signal-to-background (S/B) ratio. Secondly, the regeneration or replacement of highly radioactive ion-exchange or filter elements could become an operational nuisance where large numbers of sample lines must be monitored. The first problem is dependent on the water impurities in a particular reactor coolant. In some cases selective absorption may be obtained by proper choice of ion-exchange resin. The second problem may be minor if a very few monitors are required.

The first Physics Development ion-exchange tests were made to determine if ion-exchange resins should be added to the Gamma Monitor water chambers. A water sample line from the far riser supplied effluent which flowed first through a normal water chamber and then a second chamber of the same size containing Dowex 50 cation resin as used by Bloomstrand. A scintillation counter was moved from one chamber to the other once a minute. Both the total gamma activity and the differential 2.0 to 3.5 Mev fission-product channel activity were recorded. The following relative bare and resin reading were obtained from four ruptures.

<u>Date</u>	<u>Relative Total Gamma Signal/Background</u>		<u>Relative 2-3.5 Mev Gamma Signal/Background</u>	
	<u>Bare H₂O</u>	<u>Cation Resin</u>	<u>Bare H₂O</u>	<u>Cation Resin</u>
5-7-55	1.0	0.4	1.0	0.7
5-9-55			1.0	1.2
5-10-55	1.0	0.9	1.0	0.6
5-14-55	1.0	1.0	1.0	0.9

Used in this way the resin showed no advantage over the normal water chamber. The actual loss of sensitivity being due to the buildup of background activities on the resin. At this holdup time the principal activities concentrated by the cation exchangers were Al²⁸ and Mn⁵⁶.

From these results, further study of the properties of ion exchange resins, and preliminary information from the MTR work, it was concluded that anionic exchange resins might be more effective in Hanford effluent. The cationic resin collects metallic positive ions like Al, Na, Cu, Mn, which are present in the normal effluent. It would also be expected to collect fission products like Cs and Ru. An anionic exchanger would not be expected to collect most of the normal background activities but should collect high yield fission products like iodine.

For these reasons, the cation resin chamber was installed upstream as a background remover. This was followed by a normal water chamber and then a chamber with Dowex (1) anion resin. The latter two were monitored with one scintillation counter as before. Three ruptures gave the following results:

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<u>Date</u>	<u>Relative Total Gamma Signal/Background</u>		<u>Relative 2.0-3.5 Mev Gamma Signal/Background</u>	
	<u>Bare H₂O</u>	<u>Anion Resin</u>	<u>Bare H₂O</u>	<u>Anion Resin</u>
5-23-55	1.0	2.3	1.0	4.4
5-27-55	1.0	1.4	1.0	2.1
6-2-55	1.0	1.2	1.0	1.3

This arrangement showed more promise than the cation resin above, but no remarkable improvement. There was also indication that the efficiency decreased with time either from continually increasing background on the anion resin or decreasing affinity for fission product collection. No measurement on the effectiveness of the cation background remover could be obtained from this run.

Resin chambers were next installed on the drain line of the prototype Gamma Monitor described in Section A. Four chambers of the same size were used in series; first water, second cation resin, third anion resin, and fourth water. The resins were contained in wire mesh cups so the water was forced to flow through the resin. Each chamber was monitored by identical small Raytheon CK-1034 geiger tubes sensitive to total gamma. These were switched cyclically to a recorder. The geiger tube detectors were used for convenience and to obtain operating experience with a possible simple monitor system. It was reasoned that if improvements in S/B could be obtained from resins in this fashion, more gains could be obtained later with energy discriminating detectors.

Results on three ruptures were:

<u>Date</u>	<u>Relative Total Gamma Signal/Background</u>			
	<u>#1 H₂O</u>	<u>#2 Cation</u>	<u>#3 Anion</u>	<u>#4 H₂O</u>
11-26-55	1.0	1.7	3.9	0.7
12-11-55	1.0	0.4	0.7	0.6
2-11-56	1.0	1.0	1.0	

Again it appears that some gain may be realized with fresh resins but the efficiency is lost as they continue to operate. The decay of resin activity at pile shutdown and buildup again at subsequent pile startup did not change much with time. Perhaps this is more a mechanical filtering action than a chemical effect. Heath⁽⁸⁾ has not observed this decrease in effectiveness with time.

On the basis of these somewhat limited tests⁹, there is no incentive now for adding the ion-exchange principle to the Gamma Monitors. The increase in sensitivity is small and its possible economic gains very small compared to the costs of installation and maintenance. Likewise if considered as a total activity monitor, the sensitivity increase of the resin over the Beta type monitor is not as large as can be obtained with the differential Gamma system on bare water. Nor does it afford power level independence.

⁽⁸⁾ Ibid.

However, there is still interest in exploring the ion-exchange principle at Hanford for recirculating system monitors. In recirculating systems the background activity problem is more severe and a selective absorption or background reduction technique may be a real help. The more refined ion-exchange systems developed at the MTR are promising in this regard but have not yet been compared to other recirculating system monitors we are studying. This should be done.

Incidental to the main purpose of these tests, good performance was obtained from the small, inexpensive, geiger type radiation detectors. The high current output (micro-amperes) from these tubes may make them useful in a number of plant applications. More details and prototype applications will be reported separately.

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