MOISTURE MONITOR INJECTION TESTS IN COMPLIANCE WITH FORT ST. VRAIN TECHNICAL SPECIFICATION LCO 4.9.2

SUMMARY

Fort St. Vrain Technical Specification LCO 4.9.2 - "Plant Protection System Dew Point Moisture Monitor Tests During Phase 2" require the performance of response time tests on the Plant Protective System dew point moisture monitor system. The tests were to be conducted at 5%, 25% and 100% of rated reactor thermal power. The tests at 5% and 25% of rated power were previously completed as tests T-5A and T-6C, respectively. The results of these tests were reported to the NRC in Reference 2. Justification for performing the moisture injection tests at 70% reactor power rather than at 100% reactor power was provided in Reference 3. This same reference also provides the acceptance criterion with regard to response times for 70% power testing. NRC, Reference 4, concurred that satisfactory tests conducted at 70% power will fulfill this commitment (in lieu of moisture injection tests at 100% power).

Moisture monitor injection test T-159 performed at 70% reactor power verifies the performance of the dew point moisture monitor (DPMM) system at high reactor powers. The tests for T-159 were performed for each of the high and low level detectors with an unrestricted sample flow and for several of the high and low level detectors with a restricted sample flow.

Tables 1-3 show the results of the T-159 test. Because of low moisture concentrations in the helium samples, the test response times are adjusted for sample-to-mirror concentration difference. The adjusted response times given in Tables 1-3 show that all adjusted response times lie within or below the acceptance criterion times of Ref. 3. Figure 3 shows the adjusted response time for the unrestricted sample tests plotted as response time versus circulator ΔP. This figure is a duplicate of Fig. 3 from Ref. 1. The figure includes curves of the expected response times for unrestricted sample flows for the high and low level monitors up to 100% reactor power. The acceptance bands for test T-159 from Ref. 3 are also included in Fig. 3. The T-159 test data fall within or below the acceptance bands indicating satisfactory DPMM response times.

Table 5 provides a summary of the 5%, 25% and 70% of rated reactor thermal power moisture monitor injection response time tests. Also included in this table is an evaluation of unrestricted versus restricted monitor sample flow. Of concern regarding the latter is the coolant loop containing the leaking steam generator has low level moisture monitors with unrestricted flow. Primary coolant with a partial mixture of moisture in the subsequent pass around the primary coolant circuit could potentially trip the monitors in the non-leaking loop prior to the trip of the monitors in the leaking loop. It is concluded that 15 scc/sec minimum monitor sample flow rate evaluated

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for the 5% and 25% reactor power moisture injection response time tests is satisfactory. It is further concluded based on testing at 70% reactor power the monitor minimum sample flow rate of 40 scc/second used during the testing be increased to 50 scc/second in the revised Technical Specification for minimum sample flow for reactor powers from 30 to 100% of rated. Note (t) to Technical Specification LCO 4.4.1 currently specifies 50 scc/sec minimum sample flow for 70% reactor power operation.

INTRODUCTION

The dew point moisture monitor (DPMM) test RT-355C (Ref. 1), conducted in 1975, was an extensive checkout of the DPMM system at prestartup conditions. As part of this test, response times were measured under simulated 5-100% reactor operating conditions. The results of this test indicated the DPMM system would have satisfactory response times for actual 5-100% reactor operating conditions. Moisture injection test T-5A (Ref. 2), performed in 1976 at 5% reactor power, did demonstrate satisfactory response times at actual 5% reactor power, and similarly with test T-6C (Ref. 2) performed in 1977 at 25% reactor power.

Moisture injection tests were to be performed at 100% reactor operating conditions. Reference 3 provides a basis for performing such tests at 70% reactor power. NRC (Ref. 4) concurred that satisfactory tests conducted at 70% reactor power would fulfill the Technical Specification LCO 4.9.2 requirement for moisture injection tests at 100% reactor power. The current test T-159 is the moisture injection tests at 70% reactor power and were performed in early 1981.

The objective of test T-159 is to show satisfactory performance regarding the response times of the DPMM system at 70% reactor power. Satisfactory response times at 70% reactor established in Ref. 3 are also listed on Tables 1, 2 and 3 and in Figure 3. Overall system performance is to be demonstrated by showing adequate response times for the following individual tests:

a. Base test: test each of the six low-level and two high-level monitors.

b. Show repeatability: test each of the two high-level monitors twice more. (The base time of the six low levels will demonstrate repeatability.)

c. Restricted flow test: Test separately one low level monitor from each loop and one high level monitor with a detector flow of 40 scc/sec and the bypass valve at the minimum stop position.

Important in each test is to have the correct inlet supply flow from the rake pickup to the bypass valve junction, the correct sample flow from the bypass valve junction to the detector, and a reasonable sample-to-mirror moisture concentration difference. The inlet supply flow and sample flow govern the transit times from the rake to the detector head. The sample-to-mirror moisture concentration difference governs the mass transfer to the detector mirror and thus the mirror fogging time. The transit time plus the fogging time constitute the DPMM response time. (See Ref. 1, Appendix A3 for a description of these part times and the total response time.)

TEST ARRANGEMENT

The schematic diagram of the DPMM and moisture injection piping arrangement is illustrated in Figure 1. The injection apparatus, which has been used in previous DPMM response testing, is illustrated in Figure 2.

In the 5% and 25% reactor power tests, one test difficulty was to achieve satisfactorily high moisture concentrations in the helium at the injection rake. This difficulty would be augmented in the 70% reactor power tests due to the higher helium flow rates through the DPMM system. To achieve high moisture concentrations in the helium DPMM supply flow, the test procedure was defined as:

1. Test only one detector at a time.

2. Inject only into one rake for a given detector test.

3. Valve off the supply lines from the injected rake to all other detectors excluding the test detector.

4. Valve off the other supply lines of the test detector from rakes other than the injected rake.

5. Set the trip setting for all instruments to 0°F to increase the sample-to-mirror concentration difference. (The normal settings are 27°F for the low-level instruments and 67°F for the high-level instruments.)

Using the valve arrangement as described above, the moist helium from the bubbler flows to the test detector only and the test detector receives supply helium from only the injection rake. (Valving off all but one supply line to a test detector does not appreciably alter the inlet line transit time nor the sample flow to the detector relative to the conditions when there is flow in all of the supply lines. Since the flow resistance of the inlet line dominates the total inlet-bypass-return line flow resistance, the supply flow in the open supply line is essentially unchanged whether other supply lines to the detector are open or valved off. The test response times are adjusted for the change in the supply flow and inlet transit time due to valving off all but one supply line.)

TEST PROCEDURE

The details of the test procedure are given in the Request for Test T-159 (Ref. 5). A brief description of the test procedure is given here.

The tests were run at nominally 70% reactor power. As long as this power was indicated, all other reactor conditions (primary system pressure and temperature and circulator pressure rise) were accepted as typical 70% reactor power operating conditions.

To prepare a detector for test, it was first placed in the trip/indicate mode, and its mirror setting was lowered to 0°F. In the trip/indicate mode the detector trips at the specified mirror setting and then switches to the indicate mode to track the moisture concentration in the helium sample. The trip signal and tracking signal were recorded on a strip chart recorder. The sample-to-mirror concentration difference could then be calculated from this recorded data. The valving line-up specified in T-159 was followed to isolate the test detector and to isolate the one supply line from the injection rake. The proper sample flow and bypass valve setting were insured. For a nominal unrestricted test the bypass valve was set to achieve a sample flow of 62.5 scc/sec. For a restricted flow test the bypass valve was closed to the minimum stop position. The sample line block valve labeled V-11XXX-1 in Fig. 1 was then closed until a sample flow of 40 scc/sec was achieved.

Just prior to initiating an injection test the data measurements indicated on the Data Sheet of T-159 were taken. These measurements included primary system pressure, reactor inlet temperature, circulator speeds and ΔP, and detector sample flow. The injection supply line from the helium bubbler to the isolation valve (Fig. 2) was then flushed with moist helium (isolation valve closed). Closing the injection valve and the flush line valve and opening the isolation valve prepared the system for start of injection. The strip chart recorder was turned on. At a signal to indicate start of injection the injection valve was opened and a tick mark was made on the moving strip chart. A detector trip was indicated by the pen movement on the strip chart and a switch to indicate mode. The moisture injection and strip chart were continued until a peak indicating temperature was achieved on the chart recording or for a maximum of 2 minutes. The injection flow was secured and the detector was prepared for another test or returned to its nominal operating status.

TEST RESULTS

The measured response times are given in Tables 1, 2 and 3. Tables 1-3 also give the sample-to-mirror concentration differences, adjusted response times, and a range of acceptance response times from Ref. 3. The adjusted response times lie within the acceptance range or slightly below the lower limit of the acceptance range indicating satisfactory performance of the DPMM system.

Tables 1-3 show sample-to-mirror concentration differences generally between 50 vpm and 1600 vpm. The acceptance response times of Ref. 3 assume concentration differences of 1300 vpm for the low level detectors and 1000 vpm for the high level detectors. The difficulty experience in past injection tests in achieving consistently high sample concentrations was also experienced in this test. Note in particular that the test runs 6, 22 and 24 have very low sample-to-mirror concentrations; i.e. less than 50 vpm. Detector MT-1118, which corresponds to Run 6 and the concentration difference of 8 vpm, also had two runs with concentration differences greater than 1000 vpm. This illustrates the erratic behavior of the moisture bubbler system.

Because of the low sample-to-mirror concentrations during the tests, the measured response times given in Tables 1-3 were adjusted for concentration. The method for adjustment is described in Appendix A.3 of Ref. 1. Essentially the method consists of first calculating the inlet line and sample line transit times using the reactor test conditions and the known line flow-resistance characteristics (Ref. 1). These transit times are subtracted from the measured response time to obtain a fogging time. Since the fogging time is inversely proportional to the sample-to-mirror concentration difference (Ref. 1), the fogging time is corrected according to the ratio:

$$\frac{\text{actual sample-to-mirror concentration difference}}{\text{criteria sample-to-mirror concentration difference}}$$

The adjusted response time is determined by adding the adjusted fogging time to the inlet transit times. (In calculating the inlet line transit time, the helium supply flow rate from the injected rake to the bypass junction was adjusted slightly because of valving off all but one of the inlet supply lines.)

The measured response times for Runs 22 and 24 were not adjusted since the measured response time was less than the calculated inlet transit times. (This condition would yield a negative fogging time.)

The response data for the unrestricted runs are also plotted in Fig. 3 as a function of response time versus circulator ΔP. This figure is a duplicate of Fig. 3 from Ref. 1. The curves in Fig. 3 represent the expected response of the high level and low level DPMM's due to a design basis steam leak accident where the sample-to-mirror concentration difference would be in the range of 2000-5000 vpm at 70% reactor power. The data plotted from T-159 are adjusted only to the 1000-1300 vpm range. The acceptance bands from Ref. 3 are also shown in the figure. As illustrated by the figure, the T-159 data fall within or lower than the acceptance bands indicating good response.

For record purposes the response data are given in Table 4 along with the primary system pressure, the core inlet temperature, the circulator ΔP and the sample flow rate.

EVALUATION OF 70, 25 AND 5% REACTOR POWER MOISTURE INJECTION TEST RESULTS AND MINIMUM DETECTOR SAMPLE FLOW RATE

Table 5 shows a summary comparison of the response time moisture monitor injection testing at 70, 25 and 5% reactor thermal power. There are three requirements which establish the upper limit response times for the dew point moisture monitor system. These are discussed in Reference 6 and are (1) not lifting the PCRV pressure relief valve, (2) limiting oxidation of the hottest fuel element to 1%, and (3) initiating the trip by the moisture monitoring system before the trip would occur by the diverse backup high PCRV pressure trip thus best assuring isolation and dump of the correct (leaking) loop. The required moisture monitor response time to prevent the PCRV relief valve from lifting assuming a design basis leak is 207 seconds at 100% power, 320 seconds at 70% power, and 590 seconds at 25% power. The valve will not lift at less than 13% power operation. To limit the hottest fuel element oxidation to 1% with a design basis steam leak, the required response time is 850 seconds at 100% power, 1,550 seconds at 70% power, 4,250 seconds at 25% power. Graphite oxidation is insignificant at the lower temperatures which occur at 5% power. The high PCRV pressure trip assuming a design basis steam leak is 95 seconds at 100% power, 112 seconds at 70% power, and 113 seconds at 60% and lesser reactor power levels. The measured response times during testing, including restricted monitor sample flows, satisfy all the above response time requirements.

Another purpose of the response time moisture injection tests was to establish minimum dew point moisture monitor sample flow rates. The sample flow rate is a function of the circulator pressure rise, the proper operation of the bypass regulating valve and the degree of filter clogging which increases flow resistance to the monitor. The concern is that the coolant loop with the leaking steam generator module has one or more low level moisture monitors with restricted sample flow rate (slower response) while the low level moisture monitors in the non-leaking loop have normal unrestricted sample flow rates (faster response).

Table 5 presents a conservative evaluation of obtaining correct identification of the leaking steam generator loop. It is conservative in that it assumes the low level monitors in the non-leaking loop will be sampling primary coolant with the same moisture content as being sampled by the low level monitors with restricted sample flow in the leaking loop. At worst with total mixing, the moisture concentration would be one half that being sampled in the leaking loop. Specifically the evaluation is made by adding the primary coolant loop transit time to the range of response time test results obtained for low level monitors with unrestricted sample flow rate. This establishes the range of time in which the low level monitors in the non-leaking loop could trip. These times are then compared to the range of response time tests obtained for low level monitors with restricted sample flow. This comparison is judged to support the adequacy of 15 scc/sec minimum sample flow evaluated for the 5 and 25% reactor power response time moisture monitor injection testing. The restricted sample flow rate of 40 scc/sec employed for the 70% reactor power tests resulted in an

upper value of 16 seconds for the moisture monitors in the leaking loop to trip as opposed to a lower value of 14 seconds for moisture monitors in the non-leaking loop to trip. The minimum monitor sample flow rate of 40 scc/sec is thus judged not to be adequate at high reactor power levels. Increasing the minimum sample flow rate to 50 scc/sec reduces the response time at 70% reactor power for restricted sample flow monitors by 2.2 seconds. It is concluded that the minimum sample flow of 50 scc/sec currently specified for 70% reactor power in Note (t) of LCO 4.4.1 be retained.

MOISTURE MONITOR TECHNICAL SPECIFICATION REVISION

Minimum moisture monitor sample flow rates are specified dependent upon reactor power level in Note (t) of Technical Specification LCO 4.4.1. The proposed revision to Note (t) of LCO 4.4.1 for minimum sample flow are:

Reactor Power Range	Minimum Sample Flow
2 - 5%	1 scc/sec
5 - 30%	15 scc/sec
30 - 40%	30 scc/sec
40 - 50%	40 scc/sec
50 - 100%	50 scc/sec

The 1 scc/sec minimum flow for reactor powers between 2 and 5% is consistent with prior submittals, References 7 and 8. The 15 scc/sec minimum flow for reactor powers between 5 and 30% is supported by moisture monitor injection tests conducted at 5 and 25% reactor power. The 30 and 40 scc/sec minimum flow for reactor powers between 30 and 50% provides a transition to the minimum sample flow determined by testing to be required at higher power levels. The 50 scc/sec minimum sample flow for reactor powers between 50 and 100% is supported by the moisture injection testing conducted at 70% power.

REFERENCES

1. Del Bene, J. V., et. al., "Fort St. Vrain Dew Point Moisture Monitor System Post-Modification Test Results (RT-355C)," General Atomic Report GA-A13823, February 9, 1976.

2. J. K. Fuller to R. P. Denise, PSC letter P-77144 dated June 30, 1977, subject - DPMM H_2O Injection Tests.

3. F. E. Swart to R. P. Denise, PSC letter P-78092 dated June 2, 1978, subject - Dewpoint Moisture Monitor Response Testing.

4. T. P. Speis to J. K. Fuller, NRC letter (G-78080) dated July 25, 1978, subject - FSV Dewpoint Moisture Monitor Response Testing.

5. PSC Request for Test T-159, "Testing the Dew Point Moisture Response at a Reactor Power Level of 70% Instead of 100%."

6. Project Staff, "Test and Evaluation of the Fort St. Vrain Dew Point Moisture Monitor System," General Atomic Report GA-A13677, October 10, 1975.

7. C. K. Millen to R. P. Denise, PSC letter P-77192 dated September 13, 1977, subject - DPMM Technical Specification.

8. C. K. Millen to R. P. Denise, PSC letter P-77228 dated November 16, 1977, subject - Proposed Changes to Technical Specifications.

Table 1

Response Times for Loop I Low Level Moisture Monitors

T-159 70% Power	MT-1116						MT-1117	MT-1118		
	Unrestricted Flow ($\sim$62 scc/sec)					Restricted Flow ($\sim$40 scc/sec)	Unrestricted Flow ($\sim$62 scc/sec)	Unrestricted Flow ($\sim$62 scc/sec)		Restricted Flow ($\sim$40 scc/sec)
Run Number	1	2	3	16	17	18	4	5	6	7
Sample-to-Mirror Concentration Difference, vpm	69	72	94	92	55	106	1639	1636	8	1066
Measurement Response Times, sec.	33.3	17.4	29.5	10.6	20.0	40.0	7.0	8.2	148.1	17.0
Adjusted Response Time, sec.	6.3	5.6	6.6	5.2	5.3	11.1	7.6	9.2	5.6	15.7
Criteria Response Time, sec.	7.0-13.0					10.0-18.5	7.0-13.0	7.0-13.0		10.0-18.5

Table 2

Response Times for Loop II Low Level Moisture Monitors

T-159 70% Power	MT-1120	MT-1121	MT-1122				
	Unrestricted Flow ($\sim$62 scc/sec)	Unrestricted Flow ($\sim$62 scc/sec)	Unrestricted Flow ($\sim$62 scc/sec)			Restricted Flow ($\sim$40 scc/sec)	
Run Number	8	22	9	10	23	24	25
Sample-to-Mirror Concentration Difference, vpm	62.3	45	89	182	92	92	93
Measured Response Time, Sec.	7.8	4.6	11.4	21.2	16.4	5.2	17.1
Adjusted Response Time, Sec.	5.9	4.6[1]	5.1	7.1	5.4	5.2[1]	8.0
Criteria Response Time, Sec.	7.0-13.0					10-18.5	

1. Measured response time not adjusted since measured value is less than calculated sample transit time.

Table 3

Response Times for High Level Moisture Monitors

T-159 70% Power	MT-1115					MT-1119		
	Unrestricted Flow (~62 scc/sec)			Restricted Flow (~40 scc/sec)		Unrestricted Flow (~62 scc/sec)		
Run Number	11	12	13	14	15	19	20	21
Sample-to-Mirror Concentration Difference, vpm	147	162	122	91	140	59	16	15
Measured Response Time, sec	44.0	20.6	29.4	66.1	27.6	13.6	51.5	76
Adjusted Response Time, sec.	10.9	7.7	8.1	13.4	11.5	5.8	5.9	6.3
Criteria Response Time, sec.	8.5-16.0			13.0-24		8.5-16.0		

Table 4

Tabulation of T-159 Test Data

DETECTOR	FILTER	RUN	PRIMARY SYS PRESS (PSIA)	CORE INLET TEMP (DEGF)	CIRC DP (PSID)	SAMPLE FLOW (SCC/SEC)	SAMPLE-TO-MIRROR CONC DIFF (UPM)	MEAS RESP TIME (SEC)	ADJUSTED TIME (SEC)	CRITERIA RESP. TIME RANGE (SEC)
1116	UNRESTRICTED	1	661.	687.	4.5	62.0	69.	33.3	6.3	7.0-13.0
1116	UNRESTRICTED	2	673.	678.	4.4	62.0	72.	17.4	5.8	7.0-13.0
1116	UNRESTRICTED	3	681.	674.	4.5	62.0	94.	29.5	6.6	7.0-13.0
1117	UNRESTRICTED	4	661.	674.	4.4	68.5	1639.	7.0	7.6	7.0-13.0
1118	UNRESTRICTED	5	662.	693.	4.7	62.0	1636.	8.2	9.2	7.0-13.0
1118	UNRESTRICTED	6	670.	679.	4.4	62.5	8.	148.1	5.6	7.0-13.0
1118	RESTRICTED	7	680.	694.	4.7	40.0	1066.	17.0	15.7	10.0-18.5
1120	UNRESTRICTED	8	669.	693.	4.7	62.0	623.	7.2	5.9	7.0-13.0
1122	UNRESTRICTED	9	661.	678.	4.5	62.0	89.	11.4	5.1	7.0-13.0
1122	UNRESTRICTED	10	680.	679.	4.4	62.0	182.	21.2	7.1	7.0-13.0
1115	UNRESTRICTED	11	680.	685.	4.8	62.0	147.	44.0	10.9	8.5-16.0
1115	UNRESTRICTED	12	677.	700.	4.8	62.0	162.	20.6	7.7	8.5-16.0
1115	UNRESTRICTED	13	678.	685.	5.0	62.0	122.	29.4	8.1	8.5-16.0
1115	RESTRICTED	14	665.	685.	4.9	35.0	91.	66.1	13.4	13.0-24.0
1115	RESTRICTED	15	673.	685.	5.0	40.0	140.	27.6	11.5	13.0-24.0
1116	UNRESTRICTED	16	680.	685.	4.8	62.0	92.	10.6	5.2	7.0-13.0
1116	UNRESTRICTED	17	657.	675.	4.7	61.0	55.	20.0	5.3	7.0-13.0
1116	RESTRICTED	18	681.	700.	5.0	62.5	186.	40.0	11.1	10.0-18.5
1119	UNRESTRICTED	19	676.	685.	4.8	62.0	59.	13.6	5.8	8.5-16.0
1119	UNRESTRICTED	20	670.	685.	5.3	62.0	16.	51.5	5.9	8.5-16.0
1119	UNRESTRICTED	21	674.	686.	4.7	60.0	15.	76.0	6.3	8.5-16.0
1121	UNRESTRICTED	22	669.	685.	4.9	62.0	45.	4.6	5.0	7.0-13.0
1122	UNRESTRICTED	23	678.	685.	5.1	62.0	92.	16.4	5.4	7.0-13.0
1122	RESTRICTED	24	676.	685.	5.1	40.0	92.	5.2	7.0	10.0-18.5
1122	RESTRICTED	25	669.	700.	4.7	40.0	93.	17.1	8.0	10.0-18.5

TABLE 5

RANGE OF RESPONSE TIMES FROM MOISTURE MONITOR INJECTION TESTING

	Time-Seconds Reactor Power (Test Sequence)		
	70% (T-159)(1)	25% (T-6C)(2)	5% (T-5A)(2)
Unrestricted Monitor Sample Flow			
Low Level Monitors Trip	5-9	8-12	18-24
High Level Monitors Trip	6-11	9-10	23-33
Restricted Monitor Sample Flow(3)			
Low Level Monitors Trip	5-16	29-32	29-38
High Level Monitors Trip	11-13	30-39	32-53
Primary Coolant Loop Transit	9	24	38
Non-Leaking Loop Low Level Monitor Trip (Unrestricted monitor flow trip plus primary coolant transit)	14-18	32-36	56-62

(1) Monitors tested individually. Range of response times are for all monitors.
(2) Monitors tested as a system. Range of response times for low level monitors are based upon first two of three monitors in a loop to trip. Response time for high level monitors are based on first of the two monitors to trip.
(3) Restricted detector flows are 40 scc/sec for 70% power test and 15 scc/sec for 25 and 5% power tests.

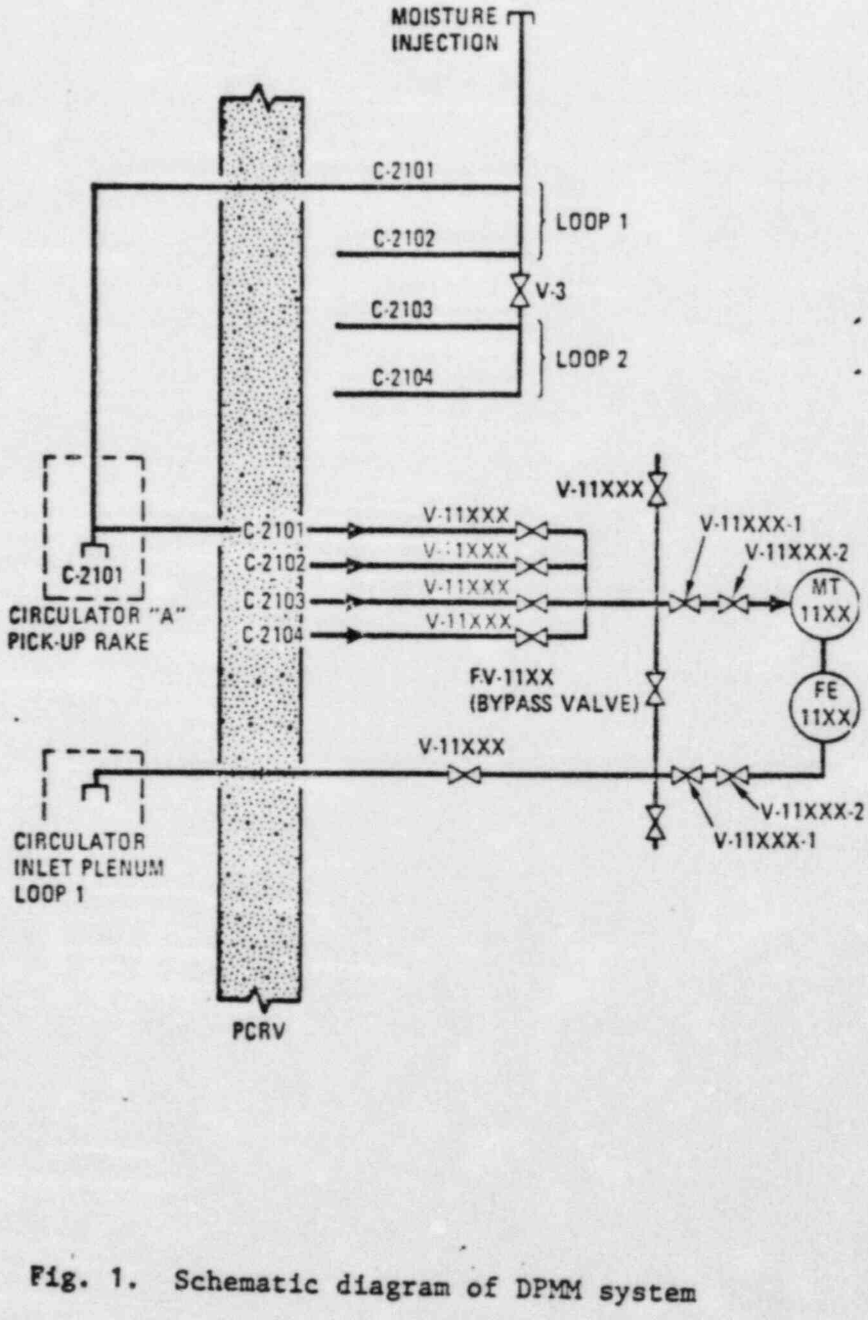


Fig. 1. Schematic diagram of DPMM system

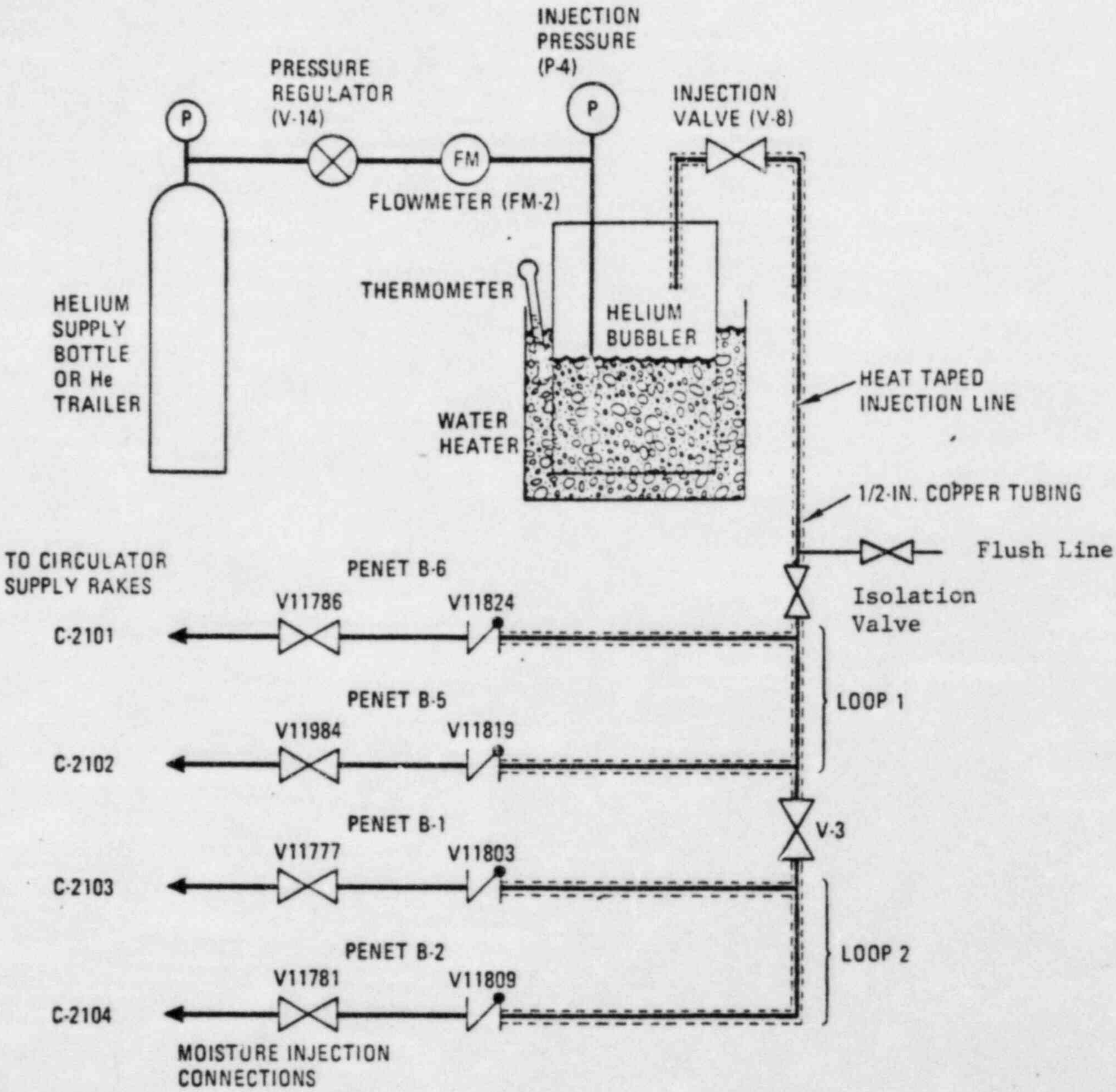
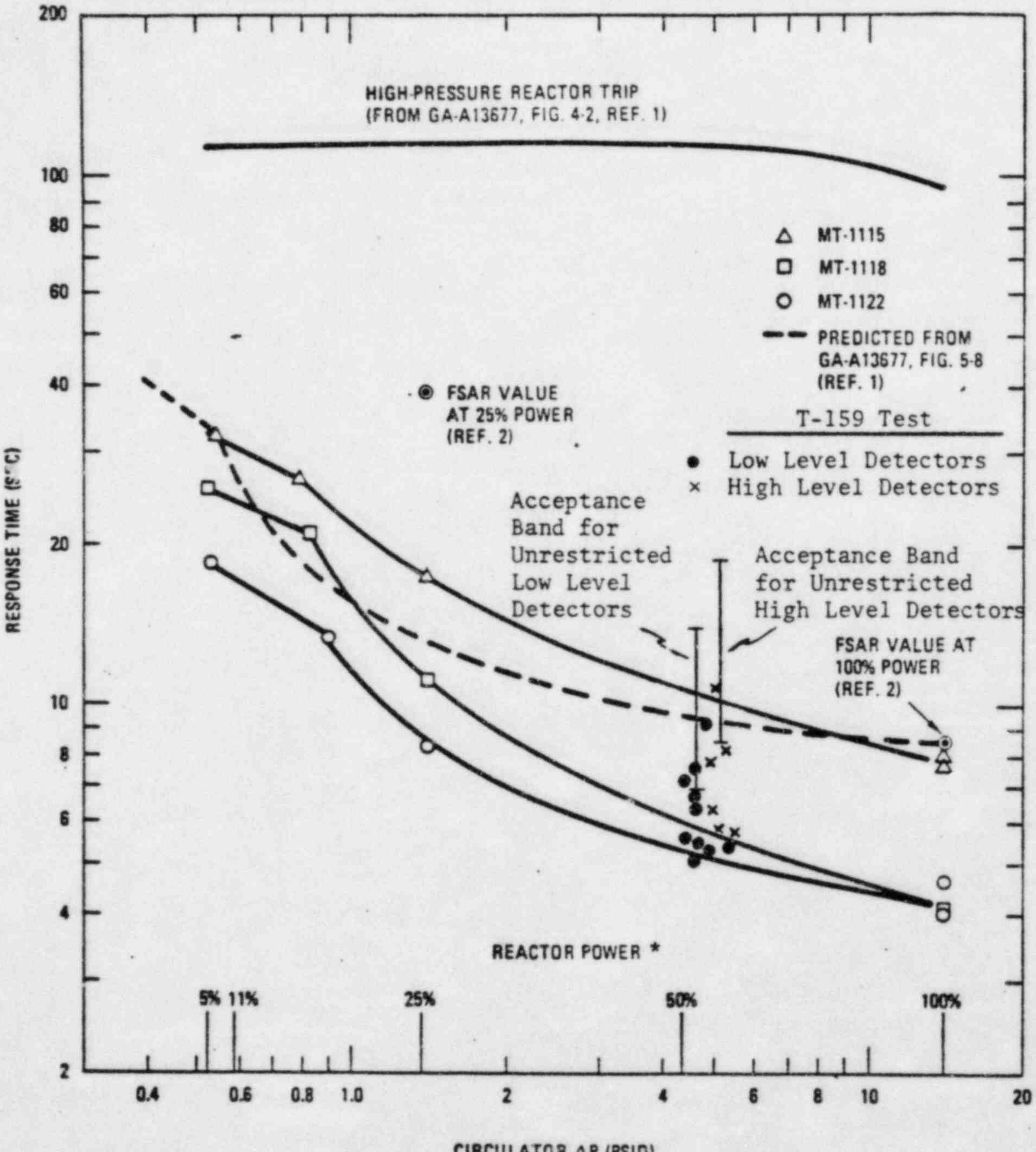


Fig. 2. Schematic diagram of moisture injection arrangement



*Reactor powers are for a higher flow resistance equilibrium core.

Fig. 3. Adjusted total response times from test data