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WCAP-14443

AP600 CORE MAKEUP TANK LEVEL INSTRUMENT TEST DATA AND EVALUATION REPORT

July 1995

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TABLE OF CONTENTS

Section	Title	Page
1.0	Introduction	1-1
1.1	Background	1-1
1.2	CMT Level Instrument	1-3
2.0	CMT Level Instrument Description	2-1
3.0	Test Data	3-1
3.1	CMT Test Numbering	3-1
3.2	CMT Level Instrument Data	3-1
4.0	Evaluation	4-1
4.1	Discussion	4-1
4.2	Results	4-3
5.0	Conclusions	5-1
6.0	References	6-1

Appendix A - Drawing 93-388951, Multi-Point Level System, Model ML89HT

Sheet 1		A-1
Sheet 2		A-2
Sheet 3		A-3
Sheet 4		A-4

LIST OF TABLES

Table No.	Title	Page
3-1	Post-Test Measurements of CMT Level Instrument Heater Circuits	3-5
4-1	Level Instrument Performance, Tests C037301 and C025302	4-5
4-2	Level Instrument Performance, Tests C036302 and C038303	4-6
4-3	Level Instrument Performance, Tests C027304 and C028305	4-7
4-4	Level Instrument Performance, Tests C080305 and C029306	4-8
4-5	Level Instrument Performance, Tests C031307 and C034308	4-9
4-6	Level Instrument Performance, Tests C039309 and C032310	4-10
4-7	Level Instrument Performance, Tests C033311 and C004315	4-11
4-8	Level Instrument Performance, Tests C005316 and C048317	4-12
4-9	Level Instrument Performance, Tests C049318 and C050319	4-13
4-10	Level Instrument Performance, Tests C051320 and C052321	4-14
4-11	Level Instrument Performance, Tests C053322 and C054323	4-15
4-12	Level Instrument Performance, Tests C055401 and C056402	4-16
4-13	Level Instrument Performance, Tests C057403 and C058404	4-17
4-14	Level Instrument Performance, Tests C067501 and C069503	4-18
4-15	Level Instrument Performance, Tests C071505 and C065506	4-19
4-16	Level Instrument Performance, Tests C077507 and C075508	4-20
4-17	Level Instrument Performance, Test C073509	4-21
4-18	Level Instrument Performance, Recirculation Tests C066501 and C059502	4-22
4-19	Level Instrument Performance, Recirculation Tests C068503 and C061504	4-23
4-20	Level Instrument Performance, Recirculation Tests C070505 and C064506	4-24
4-21	Level Instrument Performance, Recirculation Tests C076507 and C074508	4-25
4-22	Level Instrument Performance, Recirculation Test C072509	4-26
4-23	CMT 300-Series Matrix Test Runs	4-27
4-24	CMT 400-Series Matrix Test Runs	4-28
4-25	CMT 500-Series Matrix Test Runs	4-28

LIST OF FIGURES

Figure No.	Title	Page
3-1	Test C076507, Active RTD Temperature, Sensor Head 1	3-6
3-2	Test C076507, Reference RTD Temperature, Sensor Head 1	3-6
3-3	Test C076507, Active RTD Temperature, Sensor Head 2	3-7
3-4	Test C076507, Reference RTD Temperature, Sensor Head 2	3-7
3-5	Test C076507, Active RTD Temperature, Sensor Head 3	3-8
3-6	Test C076507, Reference RTD Temperature, Sensor Head 3	3-8
3-7	Test C076507, Active RTD Temperature, Sensor Head 4	3-9
3-8	Test C076507, Reference RTD Temperature, Sensor Head 4	3-9
3-9	Test C076507, CMT Water Temperature at Elevation of Sensor Head 1	3-10
3-10	Test C076507, CMT Water Temperature at Elevation of Sensor Head 2	3-10
3-11	Test C076507, CMT Water Temperature at Elevation of Sensor Head 3	3-11
3-12	Test C076507, CMT Water Temperature at Elevation of Sensor Head 4	3-11
3-13	Test C076507, Reference RTD Compared to Test Facility T/C, Sensor Head 1	3-12
3-14	Test C076507, Reference RTD Compared to Test Facility T/C, Sensor Head 2	3-12
3-15	Test C076507, Reference RTD Compared to Test Facility T/C, Sensor Head 3	3-13
3-16	Test C076507, Reference RTD Compared to Test Facility T/C, Sensor Head 4	3-13
3-17	Test C076507, Delta-T, Sensor Head 1	3-14
3-18	Test C076507, Delta-T, Sensor Head 2	3-14
3-19	Test C076507, Delta-T, Sensor Head 3	3-15
3-20	Test C076507, Delta-T, Sensor Head 4	3-15
3-21	Test C077507, Active RTD Temperature, Sensor Head 1	3-16
3-22	Test C077507, Reference RTD Temperature, Sensor Head 1	3-16
3-23	Test C077507, Active RTD Temperature, Sensor Head 2	3-17
3-24	Test C077507, Reference RTD Temperature, Sensor Head 2	3-17
3-25	Test C077507, Active RTD Temperature, Sensor Head 3	3-18
3-26	Test C077507, Reference RTD Temperature, Sensor Head 3	3-18
3-27	Test C077507, Delta-T, Sensor Head 1	3-19
3-28	Test C077507, Delta-T, Sensor Head 2	3-19
3-29	Test C077507, Delta-T, Sensor Head 3	3-20
3-30	Test C077507, CMT Pressure	3-20
3-31	Test C076507, Water Level from Top of CMT	3-21
3-32	Test C077507, Water Level from Top of CMT	3-21
4-1	Effect of Setpoint Filter Length, Recirculation Test	4-29
4-2	Effect of Data Filter Length, Recirculation Test	4-29
4-3	Trip Algorithm, Recirculation Test, 15 Second Data Filter	4-30
4-4	Trip Algorithm, Recirculation Test, 35 Second Data Filter	4-30
4-5	Effect of Setpoint Filter Length, Draindown Test	4-31
4-6	Effect of Data Filter Length, Draindown Test	4-31
4-7	Trip Algorithm, Draindown Test, 15 Second Data Filter	4-32
4-8	Trip Algorithm, Draindown Test, 35 Second Data Filter	4-32

LIST OF ACRONYMS AND ABBREVIATIONS

ADS	Automatic depressurization system
CMT	Core makeup tank
RCS	Reactor coolant system
DAS	Data acquisition system
RTD	Resistance temperature detector
LOCA	Loss-of-coolant accident
T/C	Thermocouple
IRWST	In-containment refueling water storage tank
FCI	Fluid Components International
SFL	Setpoint filter length
DFL	Data filter length
psig	Pounds per square inch, gauge
psia	Pounds per square inch, absolute
gpm	Gallons per minute
vdc	Volts, direct-current
ma	Milliamps
ΔT	Delta-T

1.0 INTRODUCTION

This report discusses results from the AP600 core makeup tank (CMT) test program relevant to performance of the CMT level instrument.

1.1 Background

A unique feature of the AP600 design is the use of passive safety systems to protect the reactor core following postulated accidents. One component of the AP600 passive safety systems is the CMT. Each of the two CMTs in the AP600 stores cold borated water at reactor coolant system (RCS) pressure that can be gravity-injected into the RCS to provide reactivity control and core cooling.

The CMTs have a safety function in addition to adding coolant and boron to the reactor systems. Continued draining of a CMT indicates a loss-of-coolant accident (LOCA). The CMTs provide the indication of low RCS inventory, which actuates the automatic depressurization system (ADS). When the tank water level reaches approximately 67 percent, level instruments in the CMT actuate the first stage of ADS, and the plant begins a controlled blowdown through the ADS valves into the in-containment refueling water storage tank (IRWST). The second- and third-stage ADS valves open based on timers that are started with the opening of ADS stage 1. If the CMTs continue to drain and the volume reaches 20 percent, the fourth-stage ADS valves open, providing a large vent path directly to containment to further depressurize the RCS. As the RCS depressurizes, the CMTs continue to add coolant to the RCS to maintain core cooling.

There are two modes of operation for the CMTs: recirculation and draindown. During the initial phase of a small-break LOCA, steam line break, or steam generator tube rupture event, the RCS inventory remains at or near its steady-state value. During this period, flow from the CMT to the reactor vessel is balanced by return flow from the cold leg to the top of the CMT. This is referred to as the recirculation mode of CMT operation. The colder, denser CMT water drives flow into the reactor vessel because of the density difference between the CMT water and the cold leg balance line. This flow will decrease as the colder CMT water is replaced by hotter water from the balance line, decreasing the thermal driving head.

During non-LOCA events (steam line break or steam generator tube rupture), the CMT will heat-up due to recirculation of water but will not draindown and ADS will not be actuated; however, during LOCA events, the CMT will eventually drain. As the LOCA continues to drain the RCS, the cold leg balance line begins to void and the recirculation path is broken. The CMT then drains as the water volume is replaced by steam from the cold leg, beginning the draindown mode of CMT operation. As the CMT drains, the ADS will be actuated at the appropriate level setpoints

The AP600 CMT test program is part of the test program developed to support the AP600 design certification. The test facility CMT is half-scale in height and 1/7.77-scale in diameter. The purpose of the test program is to simulate CMT operation over a wide range of prototypic pressures and

temperatures and to obtain data to support development and verification of computer models to be used in safety analyses and licensing of AP600. The test is also intended to obtain data to show the feasibility of the CMT level instrument.

The CMT test program is designed to obtain thermal-hydraulic data on:

- Convective condensation on cold, thick steel walls
- Transient conduction through thick steel walls
- Direct condensation on the CMT water surface
- Dynamic effects of steam injection and mixing with CMT liquid and condensate
- Thermal stratification and mixing of the warmer condensate and colder CMT water
- Natural circulation between the cold CMT and RCS hot legs
- Flashing effects of CMT during depressurization

The CMT test program is a series of tests designed to observe and record the effects of these thermal-hydraulic conditions. Cold pre-operational tests were performed to determine tank volumes and system line resistances and to show the operability of system instrumentation, the data acquisition system (DAS), and the control and isolation valves. Hot pre-operational tests measured pertinent facility parameters and characterized the test facility response under hot conditions with measurements of steam condensation and steam jet/CMT water interactions.

There are four series of matrix tests: 100, 300, 400, and 500. In 100-series tests, the rate at which steam condenses on the CMT walls was measured with no water initially in the CMT. The test series included steam addition into an evacuated (no air) CMT and tests with the CMT initially containing some noncondensible gas. The 100-series tests provide direct measurement of the heat flow through the CMT wall versus time and measurement of the resulting steam condensation rate versus time. Two sets of CMT draindown tests were performed with no recirculation heat-up of the CMT water prior to draindown initiation. The 300-series tests were draindown tests at constant pressure. The 400-series tests were draindowns performed while the steam supply pressure was decreased, similar to the expected plant depressurization with the ADS operating. The 500-series tests simulated the heat-up of the CMT water during recirculation, with subsequent draindown and depressurization.

The test facility, testing, and data collection associated with the CMT test program is described in Reference 1. The test data obtained during the performance of the AP600 CMT test is evaluated in Reference 2. The data analysis in Reference 2 focuses on analysis of the test data to support safety analysis computer code model development and verification. An initial evaluation of the performance of the CMT level instrument can be found in Section 4.5 of Reference 1.

This report completes the feasibility evaluation of the CMT level instrument performance. This report presents data and evaluates CMT level instrument for detecting the decreased CMT water levels during a range of CMT operating conditions.

Performance evaluation of the CMT level instrument is limited to the test conditions established by the test matrix, which was developed to support the computer code model development and verification efforts and was not designed specifically for level instrument evaluation. The evaluation of the CMT level instrument is an additional benefit of the CMT test program but was not a principle driver in the design of the test facility. Test facility scaling did not consider potential effects of the scaled CMT geometry on the performance of the CMT level instrument. Direct application of the level instrument test results to the plant configuration is not intended. The specific instrument selected for an AP600 plant will be qualified during the procurement process.

1.2 CMT Level Instrument

The CMT level instruments are used to initiate automatic depressurization of the RCS when the CMT water level reaches predefined levels. Drawing 93-388951 in Appendix A is an illustration of the level instrument. Each CMT level instrument consists of multiple sensing points or sensor heads, mounted in a single probe. Each sensor head is made up of two pairs of thermowells. One thermowell pair consists of a heater thermowell and a platinum resistance temperature detector (RTD) thermowell. The other thermowell pair consists of an RTD thermowell and a dummy thermowell. The dummy thermowell provides for mass balance between the two thermowell pairs.

The heater thermowell contains a heater that preferentially heats its adjacent RTD, that is, the active RTD. The other RTD (the reference RTD) measures the temperature of the surrounding fluid. A difference between the temperatures measured by the active and reference RTDs will occur due to the heater output. The magnitude of the difference (ΔT) will depend on the heat transfer rate from the heater thermowell to the surrounding fluid.

When a sensor head is covered by the CMT water level, the heat transfer coefficient is relatively large, causing the temperature difference between the active RTD and the reference RTD to be small. When the CMT water level decreases to uncover the sensor head, the heat transfer coefficient changes as a result of the change in surrounding fluid from liquid to vapor and the temperature difference between the active RTD and the reference RTD will increase. By detecting this increase in the temperature difference, the water level inside the CMT can be inferred since the elevation of the sensor heads are known.

The CMT level instrument experiences a wide range of conditions. The water temperature may vary from 50°F to 550°F. At the higher temperature, the relative difference in the heat transfer coefficients of the liquid and vapor is smaller. This affects the detection of the CMT water level. In addition, heat transfer may be affected by splashing, condensation, and fluid velocity effects. These may affect the ability of the CMT level instrument to accurately detect CMT water level changes.

The level instrument used in the CMT test program was factory-calibrated in dry air and room temperature water. Under these conditions, the heat transfer coefficient change is over 400 to 1. At

higher temperatures and pressures characteristic of certain CMT operating conditions, the heat transfer coefficient change decreases to less than 7 to 1.

The CMT test program includes a single, level instrument with four sets of RTDs (sensor heads) from which data are obtained. The data are analyzed to assess the performance of the level instrument under a wide range of controlled conditions and to evaluate an algorithm that can be used to detect the change in ΔT associated with the uncovering of a level instrument sensor head.

2.0 CMT LEVEL INSTRUMENT DESCRIPTION

The level instrument used in the CMT test program is manufactured by Fluid Components International (FCI) of San Diego California. Drawing 93-388951 in Appendix A illustrates this level instrument. The level probe has four discrete sensor heads numbered 1 through 4, with sensor head number 1 being the highest sensed level and sensor head number 4 being the lowest sensed level. As shown in the drawing, the level probe used in the CMT test program is inserted from the bottom of the tank. The instrument consists of a level probe with an integral electrical junction box and a separate remote electronics enclosure. Interconnecting cable is used to connect the level probe to the remote electronics enclosure.

The remote electronics enclosure contains terminal strips and four electronic circuit boards. A separate electronic circuit board is associated with each of the four sensor heads located in the level probe. Each electronic circuit board outputs a constant current to the RTD heater and measures the resistance of the active and reference RTDs. Each electronic circuit board outputs two, 4 milliamp to 20 milliamp signals. One signal is scaled to provide an indication of the temperature measured by the reference RTD. The second signal is used to detect the status of the liquid level with respect to the sensor head. If the sensor head is uncovered, the current output is low. If the sensor head is covered, the current output is high.

The level instrument was factory-calibrated at atmospheric pressure conditions using room temperature water. The reference temperature output was calibrated so that the 4-milliamp to 20-milliamp signal indicates temperature from 0°F to 650°F. The level output was calibrated so that a dry air condition corresponds to 4 milliamps while a submerged wet condition corresponds to 20 milliamps.

During the pre-operational tests of the CMT facility, it was determined that the measurement of the output signals by the original remote electronics enclosure would not provide data that would facilitate a good evaluation of the CMT level instrument. To obtain data that would facilitate a better evaluation of the level instrument, modifications were made to provide for the separate measurement and recording of the temperatures measured by the active and reference RTDs at each of the four sensor heads.

Eight Omega TX64 programmable two-wire temperature transmitters were procured. One was wired to each of the eight (four active and four reference) RTDs of the level probe. Each of the temperature transmitters was programmed to provide a 4-milliamp to 20-milliamp output for measured temperature between 0°F and 800°F. The current output was converted to a voltage signal by precision resistors. The voltage signal was then input to the AP600 CMT test DAS described in Section 2.4 of Reference 1. These eight measurement channels are identified as LT1A, LT2A, LT3A, LT4A, LT1T, LT2T, LT3T, and LT4T in Table 2.3-1 of Reference 1. For the remainder of this report, the channels used to measure the temperatures of the reference RTDs are referred to as LT1R, LT2R, LT3R and LT4R instead of LT1T, LT2T, LT3T, and LT4T.

The electronic circuit boards contained in the remote electronics enclosure supplied the constant current power to the RTD heaters during the performance of the tests.

3.0 TEST DATA

3.1 CMT Test Numbering

A unique seven-character identification is assigned to each of the AP600 CMT matrix tests in accordance with the following guidelines:

- The letter C assigned to the first character designates the test as an AP600 CMT test.
- The sequential CMT test run number assigned to the second to fourth characters signifies the consecutive number of CMT test runs, including repeats and/or invalid tests, so the run number agrees with the number automatically assigned to data files created by the data system during a test run.
- The matrix test number from the published test matrix is assigned to the fifth to seventh characters, where:

  The fifth character represents the matrix test type or series; 1 = CMT wall condensation tests with and without noncondensible gases (series 100), 3 = CMT wall and water surface condensation tests with CMT draindown (series 300), and so on.

  The sixth and seventh characters represent the number of a test within in a specific matrix test series. For each test series, the matrix test number corresponds to a unique set of test conditions (steam supply pressure, drain line resistance, initial CMT level, and so on.)

The first CMT wall condensation test is identified by the matrix test number 101. The fourth CMT test involving draindown during depressurization is identified as 504.

Example:

C045107 represents the 45th chronological test run, and matrix test number 107 is the seventh test in test series 100 (steam supply pressure = 10 psig, CMT pressurized with air to 1.13 psia).

3.2 CMT Level Instrument Data

This section discusses the data that was recorded and analyzed to evaluate the performance of the CMT level instrument. Data from the CMT 500-series tests are used to focus this discussion. Figures 3-1 through 3-32 are data plots that were obtained during the performance of test numbers C076507 and C077507. The 500-series tests simulated the heat-up of the CMT water during recirculation, with subsequent draindown and depressurization. Data obtained during test number C076507 were collected during the simulated recirculation mode of CMT operation. During this test,

hot water from the simulated hot leg entered the top of the CMT while the colder CMT water exited out the bottom. The system pressure was maintained at 1835 psig, while recirculation continued until approximately 20 percent of the CMT depth was replaced with hot water. Data obtained during test number C077507 were collected during the simulated draindown mode of CMT operation. This test was started at the temperature and pressure conditions reached at the conclusion of recirculation mode. The CMT was drained with the drain valve fully open to produce a target drain rate of 16 gpm. During the draining of the CMT, the pressure remained constant during the early portion of the test followed by a constant depressurization rate. The CMT draindown was continued until the CMT was completely empty.

Figures 3-1 through 3-8 are plots of the temperatures measured by the active and reference RTDs of the CMT level instrument for sensor heads 1 through 4 during the recirculation heat-up test, C076507. The plots for sensor heads 1 through 3 show a steep temperature rise as the hot CMT water reaches each subsequent sensor head during CMT recirculation. The temperatures associated with sensor head 4 do not show the same steep rapid temperature increase since the recirculation was terminated before the hot water reached this sensor head.

Figures 3-9 through 3-12 are plots of the temperature obtained by thermocouples measuring CMT water temperature at elevations corresponding to the four sensor heads during the recirculation test, C076507. Comparisons of the water temperature measured by the thermocouples with the water temperature measured by the reference RTDs are provided in Figures 3-13 through 3-16. These plots illustrate that the temperatures are similar except for a portion of the test interval associated with LT2R, the reference RTD temperature measured at the second sensor head. The 3°F or 4°F smear in the data is the result of measuring the temperatures to a 1°F resolution.

The sharp reduction of the temperature measured on LT2R is observed on a number of test plots and assumed to be anomalous. To determine the reason for this behavior, a post-test evaluation was made on the CMT level instrument wiring and data channels at the conclusion of all CMT testing. During this evaluation, it was noted that the input impedance of the data acquisition channel associated with the recording of LT2R would decrease to such an extent that the resulting voltage produced across the precision resistor would not represent a correct temperature. This was determined by measuring the voltage across the current loop resistor during intervals in which the anomalous channel behavior was observed. When the DAS was disconnected from the current loop resistor, the voltage measured across the resistor would return to the proper value. This voltage would decrease when the DAS was again reconnected. Based on these observations and subsequent technical discussions with the manufacturer of the DAS, it is concluded that the voltage input channel associated with the measurement of LT2R is defective. This defect clearly results in an intermittent sharp reduction of the temperature recorded for LT2R on many of the tests; however, the effect of this defect on the measurement of LT2R when sharp temperature reductions are not observed cannot be determined.

Figures 3-17 through 3-20 are plots of the temperature differences measured by the active and reference RTDs (ΔT) at each of the four sensor heads during the recirculation test. Under ideal

conditions, ΔT measured at each of the four sensor heads should remain constant since the four sensor heads were covered by water during all portions of the recirculation test.

Figure 3-17 is a plot of ΔT for sensor head number 1, the highest sensor head. As indicated in the figure, ΔT is approximately [ ]^{a,b,c} while the sensor head is submerged in the cold [ ]^{a,b,c} water. When the hot [ ]^{a,b,c} water reaches this sensor head, ΔT decreases to approximately [ ]^{a,b,c}. This is consistent with the operating principle of the CMT level instrument. The viscosity change associated with heating the water produces an increase to the effective heat transfer coefficient of the water, resulting in a lower ΔT. A velocity effect of the circulating CMT water may also be partially responsible for the observed reduction of ΔT.

Figure 3-18 is a similar plot for sensor head number 2. Except for the anomalous behavior discussed previously, this figure shows little change in ΔT. Although sensor head 2 displayed anomalous behavior during some tests, its data has been treated as valid in this report.

The response of sensor head 3, as illustrated in Figure 3-19, is similar to that observed for sensor head 1. ΔT decreases approximately [ ]^{a,b} as the hot water reaches this sensor head.

Figure 3-20 is the plot of ΔT for sensor head 4. This plot does not indicate any change in ΔT. This is expected during this test. However, a change in ΔT was not observed for sensor head 4 during any of the tests considered in this evaluation. During the post-test evaluation, it was determined that the level instrument heater had failed in this sensor head. This determination was made by measuring the current and voltage that was output from the electronic circuit boards located in the remote electronics enclosure. These measurements are summarized in Table 3-1. The measurements are characteristics of a burned-out heater element or an open heater circuit. Since the location of the failure is within the level probe, no additional evaluation of this failure was performed. The loss of the heater for sensor head 4 invalidates the ΔT measurements for this sensor head. Therefore, this report does not provide any additional evaluation of sensor head number 4.

Figures 3-21 through 3-30 are plots made during the CMT draindown test, C077507. The initial CMT conditions for this test are the conditions that existed at the termination of the recirculation test, C076507.

Figures 3-21 through 3-26 are temperature plots measured by the active and reference RTDs located at sensor heads 1, 2, and 3. The difference between the temperature measured by the active and referenced RTD at each sensor head, ΔT, is plotted in Figures 3-27 through 3-29. These plots show that for each sensor head, ΔT remains constant until the hotter water, associated with the water/steam surface boundary, reaches the elevation of the sensor head. At this point, ΔT decreases slightly. This decrease occurs for the same reason that ΔT decreased during the recirculation phase. The viscosity of the hotter water provides enhanced heat transfer resulting in a lower ΔT. This slight ΔT decrease is followed by an increase in ΔT due to the decrease in heat transfer capability as the sensor head is

uncovered. It is this increase in ΔT that is characteristic of the CMT water level reaching the elevation of a sensor head.

Figure 3-30 is a plot of CMT pressure during the draindown test, C077507. Figures 3-31 and 3-32 are plots of the differential pressure measurement used to determine the water level in the CMT. These plots show an increasing differential pressure as the CMT water level decreases due to the configuration of the test facility. This configuration results in the differential pressure instrument reference leg remaining filled with water as the pressure of the reference leg decreases due to the decreasing CMT water level. The small differential pressure increase illustrated in Figure 3-31 is due to density changes that occurred in the CMT water as it was heated during recirculation, not due to an actual water level change.

TABLE 3-1
POST-TEST MEASUREMENTS OF CMT LEVEL INSTRUMENT HEATER CIRCUITS

Measurement	Sensor Head 1	Sensor Head 2	Sensor Head 3	Sensor Head 4
Output Heater Voltage Measured at Circuit Board				
Heater Voltage Measured at Level Probe Leads				
Measured Heater Current				
Measured Heater Resistance				

a,b,c

The plots on pages 3-6 through 3-21 are not included in this nonproprietary document.

4.0 EVALUATION

This section discusses the evaluation of the CMT level instrument data obtained during the CMT test program.

4.1 Discussion

The safety-related function of the CMT level instrument is to detect the CMT water level to initiate actuation of the ADS at the appropriate CMT levels. Each of the two CMTs in the AP600 plant has four independent sets of level instruments, each one powered by and feeding a separate safety division. The first stage of the ADS is initiated during CMT injection when any two of the four safety divisions in either of the two tanks indicate that the CMT water level has decreased below a predefined level. The fourth stage of the automatic depressurization also uses CMT water level as one of its initiating inputs. The evaluation of the CMT level instrument is concerned with two separate performance considerations: (1) how quickly and reliably can it be determined that the CMT water level has decreased to a level that requires actuation of the ADS, and (2) could the CMT level instrument indicate that the CMT level has reached the ADS setpoint when it really has not. Item (1) is related to operation of the CMT level instrument to ensure safety-limits are achieved, while item (2) is related to minimizing the false (spurious) operation of the ADS.

To perform an evaluation of this type, some assumptions must be made as to what type of algorithm will be used to distinguish the uncovering of a CMT level instrument sensor head based on the temperature measurements made by the reference and active RTDs. The most simple algorithm would be based on the instantaneous measurement of these temperatures, a computation of ΔT, and a comparison against a fixed setpoint. However, observation of the test data indicates that the normal variations of ΔT, which occurs as a result of pressure and temperature changes, are difficult to distinguish from variations of ΔT that occur as a result of actual level changes. If the setpoint is too small, normal variations of ΔT may initiate a spurious signal. If the setpoint is too large, the potential for delaying or not generating a required safety signal increases. While it may be possible to enhance the performance of such an algorithm by providing a setpoint correction or bias based on AP600 plant parameters such as pressure or temperature, the evaluation of such an algorithm, in conjunction with the test data obtained during the performance of the CMT tests, has not been performed.

Another alternative is to develop an algorithm that is based on the change (past history) of the measured ΔT. The most simple form of this algorithm would be based on the measurement of the temperatures detected by the active and reference RTDs, a computation of ΔT, and a comparison against a setpoint that is based on an average of the ΔT with some additional bias. The mathematical form of this algorithm becomes:

$$\Delta T_n > \frac{\sum_{n-SFL}^{n} \Delta T_n}{SFL} + BIAS$$

where a trip occurs when this inequality is true. *SFL* (setpoint filter length) is the number of samples that are used to compute the average ΔT. If the data sample rate is one sample per second, *SFL* is the number of seconds over which the average ΔT is computed. For nonchanging ΔT samples, the average ΔT will be equal to each sampled ΔT, and the inequality will always be false for positive bias values. The sampled ΔT must increase greater than the bias amount for the inequality to be true.

This inequality can be modified slightly and rearranged into the following form:

$$\frac{\sum_{n-DFL}^{n} \Delta T_n}{DFL} - \frac{\sum_{n-SFL}^{n} \Delta T_n}{SFL} > SETPOINT$$

where as in the previous equation, a trip occurs when this inequality is true. In this form, the average ΔT has been moved from the right side of the inequality to the left side. In addition, a digital filtering function has been applied to the ΔT samples. The filter value is given by *DFL* (data filter length), which is the number of samples (number of seconds) over which the data are averaged. In this new form of the inequality, the bias can now be considered to be a fixed setpoint value. By making *SFL* larger than *DFL*, this algorithm can detect changes in ΔT that occur more rapidly than those that are biased out by the computation of average ΔT.

Figure 4-1 illustrates the effect of setpoint filtering on data obtained from recirculation test C076507. The unfiltered data, ΔT, is identical to that shown in Figure 3-17, except that the horizontal (time) axis has been expanded to focus on the fluctuation that occurs when the hot water reaches the sensor head. This figure also shows the unfiltered data plotted after filtering using setpoint filter lengths of 200, 300, and 500 seconds.

Figure 4-2 illustrates the effect of data filtering on the same data. Plots using data filter lengths of 5, 15, 25, and 35 seconds are shown. As would be expected, the data filter reduces the sharp data extremes without losing the information on the basic data fluctuations.

Figures 4-3 and 4-4 plot the left side of the trip algorithm inequality using the same data. Figure 4-3 uses a 15-second data filter and setpoint filters of 200, 300, and 500 seconds. Figure 4-4 is a set of similar plots using a 35-second data filter. As illustrated in these figures, the left side of the trip algorithm inequality is nominally zero. As ΔT fluctuates as a result of the hot water reaching the elevation of the sensor head, the fluctuations are reflected in the trip algorithm. Once the large ΔT fluctuations have ended and ΔT stabilizes at a new value, the left side of the trip algorithm inequality returns to zero.

Figures 4-5 through 4-8 provide similar plots of data that were obtained during a CMT draindown 400-series test (C055401). Additional information and plots of other data obtained during this test are provided in Reference 2. Figure 4-5 illustrates the effect of setpoint filtering while Figure 4-6 illustrates the effect of data filtering. Figures 4-7 and 4-8 plot the left side of the trip algorithm inequality using the same data. Figure 4-7 uses a 15-second data filter and setpoint filters of 200, 300, and 500 seconds. Figure 4-8 uses a 35-second data filter and setpoint filters of 200, 300, and 500 seconds. Similar to the plots illustrating performance during the recirculation test, these plots of the left side of the trip algorithm inequality illustrate that the initial value is nominally zero. However, as ΔT begins to steadily increase as a result of the water level decreasing below the elevation of the sensor head. the left side of the trip inequality becomes positive and tends to level out at a positive value. The left side of the trip algorithm inequality will remain positive as long as ΔT steadily increases.

Using the data plotted in Figures 4-7 and 4-8 along with CMT water level data obtained by narrow range differential pressure instruments, it is possible to generate a table that characterizes the performance of the level instrument. The data for the test plotted in Figures 4-7 and 4-8 is included in Table 4-12. This table shows that the actual time at which the CMT water level reached the elevation of sensor head 1 during test C055401 is [ ]^{a,b,c} seconds. This was obtained from the narrow-range CMT water level data. The time delay associated with the detection of this CMT water level by the level instrument is provided parametrically as a function of data filter length, setpoint filter length, and setpoint value.

For example, looking at the time delays associated with a data filter length (DFL) of 15 seconds, all time delays are negative. This means that the trip algorithm detected that the CMT level was at the elevation of sensor head 1 before the actual water level had reached that elevation. This is consistent with the plots of Figure 4-7. For all cases of setpoint filter length (SFL), the left side of the trip algorithm inequality peaks at a value of [ ]^{a,b,c} at approximately [ ]^{a,b,c} seconds. By comparison, the values listed in Table 4-12 are all positive when the DFL is increased to 35 seconds. This can be observed by looking at the plots of Figure 4-8. For a 35-second DFL, the peak, previously observed at [ ]^{a,b,c} seconds, is reduced to a value of less than [ ]^{a,b,c}. The filtered value of ΔT again increases after this peak and exceeds [ ]^{a,b,c} at approximately [ ]^{a,b,c} seconds. The value exceeds a setpoint of 4°F, at approximately [ ]^{a,b,c} seconds. The actual time delay is provided in the table for each parametric condition. For a DFL of 25 seconds, the time delay is negative for all cases using a 1°F setpoint. If the setpoint is increased to 2°F, the time delay is negative for a SFL of 200 seconds; however, the delay is positive when a SFL of 300 or 500 seconds is used.

4.2 Results

Tables 4-1 through 4-22 document the results of the parametric study of trip algorithm parameters. Each table contains performance characteristics for the three operating sensor heads of the level instrument. Time delay between the occurrence of a CMT level measured by the level instrument and

the actual CMT level as measured by narrow-range differential pressure instruments are provided as a function of setpoint value, digital filter length, and setpoint filter length.

Tables 4-1 through 4-11 document the results of the 300-series CMT tests. During these tests, the CMT was drained while the CMT pressure was held constant. Table 4-23 documents the nominal CMT pressure and draindown rate associated with each of these tests. During test C038303 (Table 4-2), the anomalous behavior of the LT2R data acquisition channel produced results that are clearly invalid. During this test, data acquisition channel LT2R recorded values of [ ][a,b,c] for the time interval between [ ][a,b,c] and [ ][a,b,c] seconds.

Tables 4-12 and 4-13 document the results of the 400-series CMT tests. During these tests, the CMT was drained while the CMT pressure was decreased to simulate the conditions that would occur in the plant for accidents. Table 4-24 documents the initial CMT pressure, draindown rate, and depressurization rate associated with each of these tests.

Tables 4-14 through 4-17 document the results of the 500-series CMT tests during draindown. During these tests, the CMT was first operated in the recirculation mode until the CMT water was partially heated. The CMT was then drained while the CMT pressure was decreased. Table 4-25 documents the initial CMT pressure, draindown rate, and depressurization rate associated with each of these tests.

Tables 4-18 through 4-21 document the results of the 500-series CMT tests during recirculation. During these tests, the cold water from the CMT was drained while hot water was injected to simulate conditions that occur during CMT recirculation. Table 4-25 documents the CMT pressure and drain rate associated with each of these tests. The tables for these tests appear different because the CMT level did not significantly change during the recirculation tests. A blank entry in the table indicates that the trip algorithm did not indicate that a trip should occur. A time entry in the table indicates the time at which a trip condition was determined based on the test data and the parametric conditions. The anomalous behavior of the LT2R data acquisition channel produced invalid results for sensor head 2 during tests C068503 (Table 4-19), C064506 (Table 4-20), and C076507 (Table 4-21).

TABLE 4-1
LEVEL INSTRUMENT PERFORMANCE, TESTS C037301 AND C025302

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C037301	Sensor Head 1 373 sec	15												
		25												
		35												
	Sensor Head 2 612 sec	15												
		25												
		35												
	Sensor Head 3 1050 sec	15												
		25												
		35												
C025302	Sensor Head 1 378 sec	15												
		25												
		35												
	Sensor Head 2 586 sec	15												
		25												
		35												
	Sensor Head 3 973 sec	15												
		25												
		35												

TABLE 4-2
LEVEL INSTRUMENT PERFORMANCE, TESTS C036302 AND C038303

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C036302	Sensor Head 1 425 sec	15												
		25												
		35												
	Sensor Head 2 610 sec	15												
		25												
		35												
	Sensor Head 3 960 sec	15												
		25												
		35												
C038303	Sensor Head 1 347 sec	15												
		25												
		35												
	Sensor Head 2 605 sec	15												
		25												
		35												
	Sensor Head 3 1065 sec	15												
		25												
		35												

TABLE 4-3
LEVEL INSTRUMENT PERFORMANCE, TESTS C027304 AND C028305

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C027304	Sensor Head 1 266 sec	15												
		25												
		35												
	Sensor Head 2 404 sec	15												
		25												
		35												
	Sensor Head 3 667 sec	15												
		25												
		35												
C028305	Sensor Head 1 234 sec	15												
		25												
		35												
	Sensor Head 2 344 sec	15												
		25												
		35												
	Sensor Head 3 564 sec	15												
		25												
		35												

a,b,c

TABLE 4-4
LEVEL INSTRUMENT PERFORMANCE, TESTS C080305 AND C029306

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C080305	Sensor Head 1 320 sec	15												
		25												
		35												
	Sensor Head 2 449 sec	15												
		25												
		35												
	Sensor Head 3 700 sec	15												
		25												
		35												
C029306	Sensor Head 1 249 sec	15												
		25												
		35												
	Sensor Head 2 378 sec	15												
		25												
		35												
	Sensor Head 3 632 sec	15												
		25												
		35												

TABLE 4-5
LEVEL INSTRUMENT PERFORMANCE, TESTS C031307 AND C034398

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C031307	Sensor Head 1 271 sec	15												
		25												
		35												
	Sensor Head 2 361 sec	15												
		25												
		35												
	Sensor Head 3 535 sec	15												
		25												
		35												
C034308	Sensor Head 1 367 sec	15												
		25												
		35												
	Sensor Head 2 450 sec	15												
		25												
		35												
	Sensor Head 3 618 sec	15												
		25												
		35												

a,b,c

TABLE 4-6
LEVEL INSTRUMENT PERFORMANCE, TESTS C039309 AND C032310

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C039309	Sensor Head 1 284 sec	15												
		25												
		35												
	Sensor Head 2 377 sec	15												
		25												
		35												
	Sensor Head 3 568 sec	15												
		25												
		35												
C032310	Sensor Head 1 303 sec	15												
		25												
		35												
	Sensor Head 2 375 sec	15												
		25												
		35												
	Sensor Head 3 523 sec	15												
		25												
		35												

a,b,c

TABLE 4-7
LEVEL INSTRUMENT PERFORMANCE, TESTS C033311 AND C004315

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C033311	Sensor Head 1 314 sec	15												
		25												
		35												
	Sensor Head 2 378 sec	15												
		25												
		35												
	Sensor Head 3 514 sec	15												
		25												
		35												
C004315	Sensor Head 1 1039 sec	15												
		25												
		35												
	Sensor Head 2 1974 sec	15												
		25												
		35												
	Sensor Head 3 3878 sec	15												
		25												
		35												

TABLE 4-8
LEVEL INSTRUMENT PERFORMANCE, TESTS C005316 AND C048317

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C005316	Sensor Head 1 1033 sec	15												
		25												
		35												
	Sensor Head 2 1962 sec	15												
		25												
		35												
	Sensor Head 3 3700 sec	15												
		25												
		35												
C048317	Sensor Head 1 411 sec	15												
		25												
		35												
	Sensor Head 2 634 sec	15												
		25												
		35												
	Sensor Head 3 1057 sec	15												
		25												
		35												

a,b,c

TABLE 4-9
LEVEL INSTRUMENT PERFORMANCE, TESTS C049318 AND C050319

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C049318	Sensor Head 1 416 sec	15												
		25												
		35												
	Sensor Head 2 529 sec	15												
		25												
		35												
	Sensor Head 3 760 sec	15												
		25												
		35												
C050319	Sensor Head 1 423 sec	15												
		25												
		35												
	Sensor Head 2 504 sec	15												
		25												
		35												
	Sensor Head 3 665 sec	15												
		25												
		35												

a,b,c

TABLE 4-10
LEVEL INSTRUMENT PERFORMANCE, TESTS C051320 AND C052321

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C051320	Sensor Head 1 379 sec	15												
		25												
		35												
	Sensor Head 2 628 sec	15												
		25												
		35												
	Sensor Head 3 1100 sec	15												
		25												
		35												
C052321	Sensor Head 1 306 sec	15												
		25												
		35												
	Sensor Head 2 426 sec	15												
		25												
		35												
	Sensor Head 3 669 sec	15												
		25												
		35												

TABLE 4-11
LEVEL INSTRUMENT PERFORMANCE, TESTS C053322 AND C054323

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C053322	Sensor Head 1 300 sec	15												
		25												
		35												
	Sensor Head 2 384 sec	15												
		25												
		35												
	Sensor Head 3 555 sec	15												
		25												
		35												
C054323	Sensor Head 1 289 sec	15												
		25												
		35												
	Sensor Head 2 335 sec	15												
		25												
		35												
	Sensor Head 3 455 sec	15												
		25												
		35												

TABLE 4-12
LEVEL INSTRUMENT PERFORMANCE, TESTS C055401 AND C056402

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C055401	Sensor Head 1 233 sec	15												
		25												
		35												
	Sensor Head 2 320 sec	15												
		25												
		35												
	Sensor Head 3 485 sec	15												
		25												
		35												
C056402	Sensor Head 1 246 sec	15												
		25												
		35												
	Sensor Head 2 334 sec	15												
		25												
		35												
	Sensor Head 3 500 sec	15												
		25												
		35												

a,b,c

TABLE 4-13
LEVEL INSTRUMENT PERFORMANCE, TESTS C057403 AND C058404

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C057403	Sensor Head 1 282 sec	15												
		25												
		35												
	Sensor Head 2 366 sec	15												
		25												
		35												
	Sensor Head 3 530 sec	15												
		25												
		35												
C058404	Sensor Head 1 280 sec	15												
		25												
		35												
	Sensor Head 2 362 sec	15												
		25												
		35												
	Sensor Head 3 528 sec	15												
		25												
		35												

TABLE 4-14
LEVEL INSTRUMENT PERFORMANCE, TESTS C067501 AND C069503

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C067501	Sensor Head 1 249 sec	15												
		25												
		35												
	Sensor Head 2 485 sec	15												
		25												
		35												
	Sensor Head 3 880 sec	15												
		25												
		35												
C069503	Sensor Head 1 224 sec	15												
		25												
		35												
	Sensor Head 2 415 sec	15												
		25												
		35												
	Sensor Head 3 707 sec	15												
		25												
		35												

a,b,c

TABLE 4-15
LEVEL INSTRUMENT PERFORMANCE, TESTS C071505 AND C065506

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C071505	Sensor Head 1 227 sec	15												
		25												
		35												
	Sensor Head 2 435 sec	15												
		25												
		35												
	Sensor Head 3 745 sec	15												
		25												
		35												
C065506	Sensor Head 1 214 sec	15												
		25												
		35												
	Sensor Head 2 286 sec	15												
		25												
		35												
	Sensor Head 3 420 sec	15												
		25												
		35												

a,b,c

TABLE 4-16
LEVEL INSTRUMENT PERFORMANCE, TESTS C077507 AND C075508

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C077507	Sensor Head 1	15												
		25												
	207 sec	35												
	Sensor Head 2	15												
		25												
	285 sec	35												
	Sensor Head 3	15												
		25												
	420 sec	35												
C075508	Sensor Head 1	15												
		25												
	150 sec	35												
	Sensor Head 2	15												
		25												
	218 sec	35												
	Sensor Head 3	15												
		25												
	349 sec	35												

a,b,c

TABLE 4-17
LEVEL INSTRUMENT PERFORMANCE, TEST C073509

a,b,c

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
073509	Sensor Head 1 154 sec	15												
		25												
		35												
	Sensor Head 2 228 sec	15												
		25												
		35												
	Sensor Head 3 355 sec	15												
		25												
		35												

TABLE 4-18
LEVEL INSTRUMENT PERFORMANCE, RECIRCULATION TESTS C066501 AND C059502

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 360 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C066501	Sensor Head 1	15												
		25												
	NO TRIP	35												
	Sensor Head 2	15												
		25												
	NO TRIP	35												
	Sensor Head 3	15												
		25												
	NO TRIP	35												
C059502	Sensor Head 1	15												
		25												
	NO TRIP	35												
	Sensor Head 2	15												
		25												
	NO TRIP	35												
	Sensor Head 3	15												
		25												
	NO TRIP	35												

a,b,c

TABLE 4-19
LEVEL INSTRUMENT PERFORMANCE, RECIRCULATION TESTS C068503 AND C061504

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C068503	Sensor Head 1 NO TRIP	15												
		25												
		35												
	Sensor Head 2 NO TRIP	15												
		25												
		35												
	Sensor Head 3 NO TRIP	15												
		25												
		35												
C061504	Sensor Head 1 NO TRIP	15												
		25												
		35												
	Sensor Head 2 NO TRIP	15												
		25												
		35												
	Sensor Head 3 NO TRIP	15												
		25												
		35												

a,b,c

TABLE 4-20
LEVEL INSTRUMENT PERFORMANCE, RECIRCULATION TESTS C070505 AND C064506

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C070505	Sensor Head 1 NO TRIP	15												
		25												
		35												
	Sensor Head 2 NO TRIP	15												
		25												
		35												
	Sensor Head 3 NO TRIP	15												
		25												
		35												
C064506	Sensor Head 1 NO TRIP	15												
		25												
		35												
	Sensor Head 2 NO TRIP	15												
		25												
		35												
	Sensor Head 3 NO TRIP	15												
		25												
		35												

a,b,c

TABLE 4-21
LEVEL INSTRUMENT PERFORMANCE, RECIRCULATION TESTS C076507 AND C074508

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C076507	Sensor Head 1	15												
		25												
	NO TRIP	35												
	Sensor Head 2	15												
		25												
	NO TRIP	35												
	Sensor Head 3	15												
		25												
	NO TRIP	35												
C074508	Sensor Head 1	15												
		25												
	NO TRIP	35												
	Sensor Head 2	15												
		25												
	NO TRIP	35												
	Sensor Head 3	15												
		25												
	NO TRIP	35												

a,b,c

u:\ap600\2240w-1.non-081595

TABLE 4-22
LEVEL INSTRUMENT PERFORMANCE, RECIRCULATION TEST C072509

CMT Test Number	Sensor Head and Actual Trip Time	DFL (sec)	Setpoint, F (SFL: 200 sec)				Setpoint, F (SFL: 300 sec)				Setpoint, F (SFL: 500 sec)			
			1	2	3	4	1	2	3	4	1	2	3	4
C072509	Sensor Head 1 NO TRIP	15												
		25												
		35												
	Sensor Head 2 NO TRIP	15												
		25												
		35												
	Sensor Head 3 NO TRIP	15												
		25												
		35												

a,b,c

TABLE 4-23 CMT 300-SERIES MATRIX TEST RUNS			
Test Run Number	**Test Date**	**Pressure (psig)**	**Drain Rate (gpm)**
C004315	3/24/94	2235	6
C005316	3/25/94	2235	16
C025302	5/25/94	135	6
C027304	5/27/94	10	11
C028305	5/31/94	135	11
C029306	6/1/94	1085	11
C031307	6/3/94	10	16
C032310	6/30/94	10	Max
C033311	7/1/94	135	Max
C034308	7/7/94	135	16
C036302	7/11/94	135	6
C037301	7/12/94	10	6
C038303	7/13/94	1085	6
C039309	7/15/94	1085	16
C048317	8/5/94	45	6
C049318	8/8/94	45	11
C050319	8/9/94	45	16
C051320	8/10/94	685	6
C052321	8/12/94	685	11
C053322	8/15/94	685	16
C054323	8/17/94	685	max
C080305	9/22/94	135	11

TABLE 4-24 CMT 400-SERIES MATRIX TEST RUNS				
Test Run Number	**Test Date**	**Pressure (psig)**	**Drain Rate (gpm)**	**Depressurization Rate (psi/sec)**
C055401	8/19/94	1085	16	1
C056402	8/22/94	685	16	1
C057403	8/23/94	685	16	2 to 3
C058404	8/24/94	685	16	0.5

TABLE 4-25 CMT 500-SERIES MATRIX TEST RUNS				
Test Run Number	**Test Date**	**Pressure (psig)**	**Drain Rate (gpm)**	**Depressurization Rate (psi/sec)**
C059502	8/26/94	1085	16	N/A
C061504	8/29/94	1085	16	N/A
C064506	8/31/94	1085	16	N/A
C065506	8/31/94	1085/685	16	1.5/0.5
C066501	9/2/94	1085	6	N/A
C067501	9/2/94	1085/685	6	1.5/0.5
C068503	9/6/94	1085	6	N/A
C069503	9/6/94	1085/685	6	1.5/0.5
C070505	9/7/94	1085	6	N/A
C071505	9/7/94	1085/685	6	1.5/0.5
C072509	9/14/94	1835	16	N/A
C073509	9/14/94	1835/685	16	1.5/0.5
C074508	9/15/94	1835	16	N/A
C075508	9/15/94	1835/685	16	1.5/0.5
C076507	9/16/94	1835	16	N/A
C077507	9/16/94	1835/685	16	1.5/0.5

The plots on pages 4-29 through 4-32 are not included in this nonproprietary document.

5.0 CONCLUSIONS

Based on the analysis of data obtained during the performance of the CMT tests, the following conclusions have been made concerning the measurement of water level in the CMT:

- For the heated RTD level instrument that was tested, a simple comparison of measured instantaneous ΔT against a fixed setpoint cannot be used to reliably detect the changing level within the CMT. An algorithm that will distinguish the uncovering of a level instrument sensor head is required for this instrument. An algorithm that is based on the change (past history) of the measured ΔT was developed and evaluated against data obtained by the level instrument used in the CMT test. This evaluation indicates reasonable responses can be obtained. The time delay associated with this type of algorithm and level instrument is on the order of less than two minutes. Application of such an algorithm for a specific AP600 instrument will need to be validated for the specific instrument and have to be shown to be valid for all necessary plant conditions.

- For the CMT tests, the active and reference RTD temperatures were individually measured and used as an input to a temperature difference calculation. The measurement resolution of the temperatures was 1°F, resulting in a 3°F to 4°F smear of the computed ΔT. The measurement resolution used in a plant application should be decreased to a value that is less than the measurement accuracy. Since current-generation distributed control equipment would be expected to have a measurement accuracy of 0.4 percent, the temperatures measured by the level instrument RTDs in the AP600 would be accurate to no better than 2°F or 3°F. Therefore, to minimize the smearing effect, a resolution less than 0.2°F should be carried through the temperature difference calculation.

- The rate of change of the water level in the CMT tests is consistent with the AP600 plant. Therefore, the level instrument in the test is subjected to prototypic level changes. Figures 3.5-23 and 3.5-50 of Reference 1 are plots of the CMT draindown during matrix tests C067501 (6 gpm) and C073509 (16 gpm). The CMT water level decreased at a rate of approximately 0.07 in. per second during the 6-gpm draindown and at a rate of approximately 0.22 in. per second during the 16-gpm draindown. These rates are consistent with rates that have been analyzed for the AP600 plant and documented in Reference 3. As illustrated in Figure 3.2-15 of Reference 3, a 1-in. cold leg break produces a CMT level decrease of between 0.06 and 0.11 in. per second. A double-ended pressure balance line break (Figure 3.2-7 of Reference 3) produces a CMT level decrease of 0.26 in. per second.

- The failure of the lowest level instrument sensor head has been determined to be the result of a failed heater circuit within the level probe. Such a failure, while only being a single data point, should be evaluated along with other reliability considerations when selecting and qualifying a specific instrument for use in the AP600 plant. If a similar type instrument is used, surveillance monitoring of the heater current can be used to detect this failure in the plant.

6.0 REFERENCES

1. Leonelli, K., *Core Makeup Tank Test Data Report,* WCAP-14217 (Proprietary), November 1994.

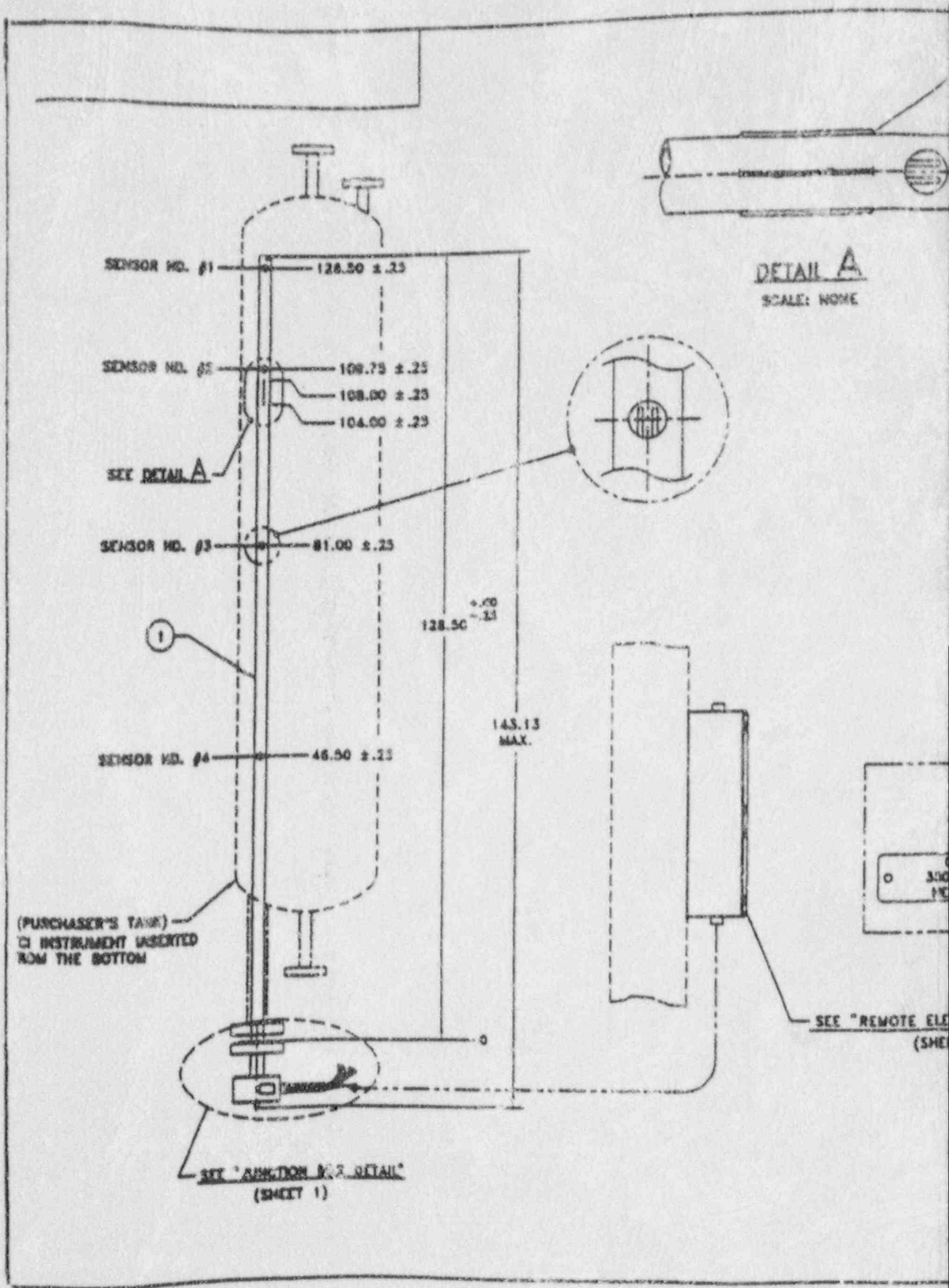
2. Haberstroh, R. C., J. P. Cunningham, L. E. Hochreiter, and R. F. Wright, *AP600 Core Makeup Tank Test Analysis,* WCAP-14215 (Proprietary), December 1994.

3. *AP600 Design Change Description Report*, June 30, 1994.

APPENDIX A

Drawing 93-388951

Multi-Point Level System
Model ML89HT



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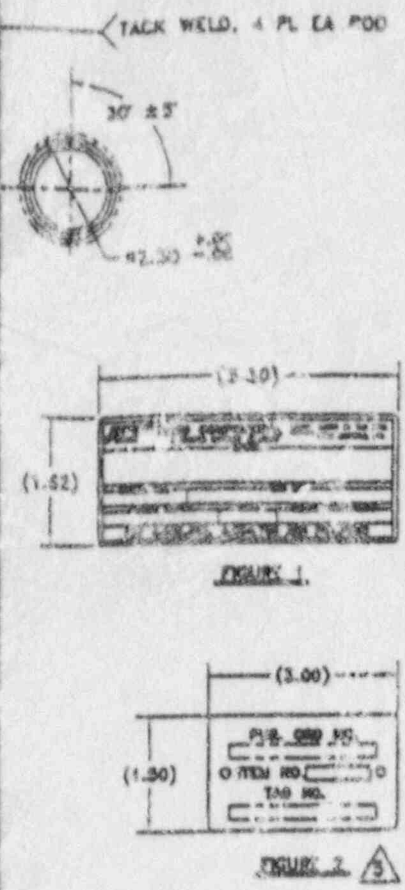


TAG NUMBERS				
CONF.	CIRCUIT BOARD		LEVEL ELEMENT	REMOTE ELECTRONICS
	HEAD NO.	FCI SERIAL NO.		
-01	1	3509-HA	PURCHASER TO ASSIGN	PURCHASER TO ASSIGN
	2	3509-HB		
	3	3509-HC		
	4	3509-HD		

CUSTOMER CONNECTIONS - INTERCONNECTING CABLE				
SENSOR HEAD NO. (REF.)	FROM LEVEL ELEMENT ENCLOSURE		TO REMOTE ELECTRONICS ENCLOSURE	
	SIGNAL DESCRIPTION	CONDUCTOR COLOR	TERMINAL NO.	TERMINAL BLOCK NO.
HEAD 1	GND	NATURAL/GREEN STRIPE	1	TB2
	GND SEN	NATURAL/YELLOW STRIPE	2	
	REF SEN	NATURAL/VIOLET STRIPE	3	
	ACT SEN	NATURAL/BLACK STRIPE	4	
	REF EXC	NATURAL/RED STRIPE	5	
	ACT EXC	NATURAL/ORANGE STRIPE	6	
	HTR +	NATURAL	7	
	HTR -	NATURAL/BLUE STRIPE	8	
HEAD 2	GND	NATURAL/GREEN STRIPE	9	
	GND SEN	NATURAL/YELLOW STRIPE	10	
	REF SEN	NATURAL/VIOLET STRIPE	11	
	ACT SEN	NATURAL/BLACK STRIPE	12	
	REF EXC	NATURAL/RED STRIPE	13	
	ACT EXC	NATURAL/ORANGE STRIPE	14	
	HTR +	NATURAL	15	
	HTR -	NATURAL/BLUE STRIPE	16	
HEAD 3	GND	NATURAL/GREEN STRIPE	1	TB3
	GND SEN	NATURAL/YELLOW STRIPE	2	
	REF SEN	NATURAL/VIOLET STRIPE	3	
	ACT SEN	NATURAL/BLACK STRIPE	4	
	REF EXC	NATURAL/RED STRIPE	5	
	ACT EXC	NATURAL/ORANGE STRIPE	6	
	HTR +	NATURAL	7	
	HTR -	NATURAL/BLUE STRIPE	8	
HEAD 4	GND	NATURAL/GREEN STRIPE	9	
	GND SEN	NATURAL/YELLOW STRIPE	10	
	REF SEN	NATURAL/VIOLET STRIPE	11	
	ACT SEN	NATURAL/BLACK STRIPE	12	
	REF EXC	NATURAL/RED STRIPE	13	
	ACT EXC	NATURAL/ORANGE STRIPE	14	
	HTR +	NATURAL	15	
	HTR -	NATURAL/BLUE STRIPE	16	
HEAD 1	SHIELD	BLACK	1	TB2
HEAD 2	SHIELD	BLACK	9	
HEAD 3	SHIELD	BLACK	1	TB3
HEAD 4	SHIELD	BLACK	9	

...ICAL TAG INFORMATION
(CIRCUIT BOARDS 1 THRU 4)

- CIRCUIT BOARD NO.
- FCI SERIAL NO. SEE "TAG NUMBERS" CHART
- SENSOR HEAD NO.

...ONICS ENCLOSURE"

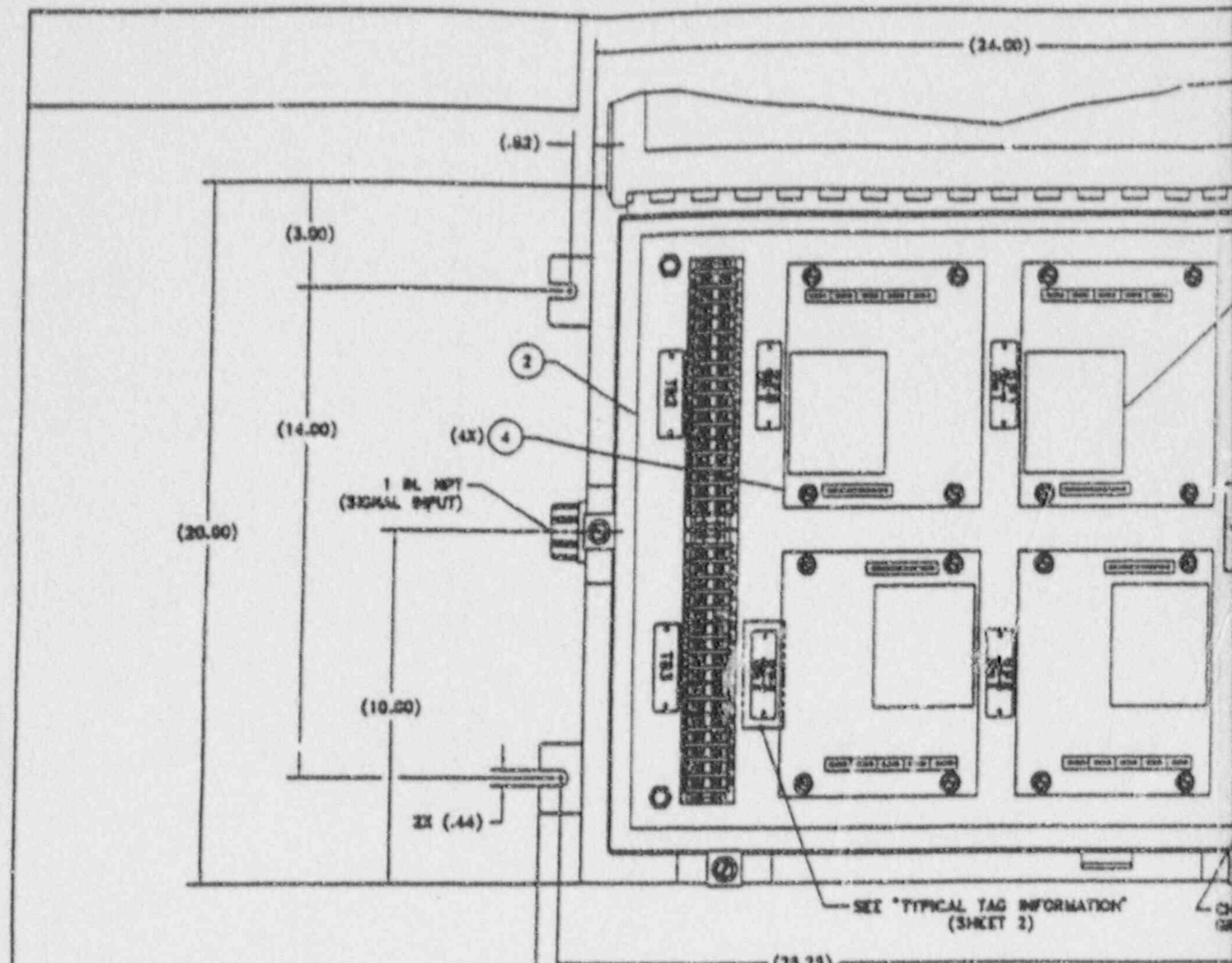
SEE SEPARATE PARTS LIST

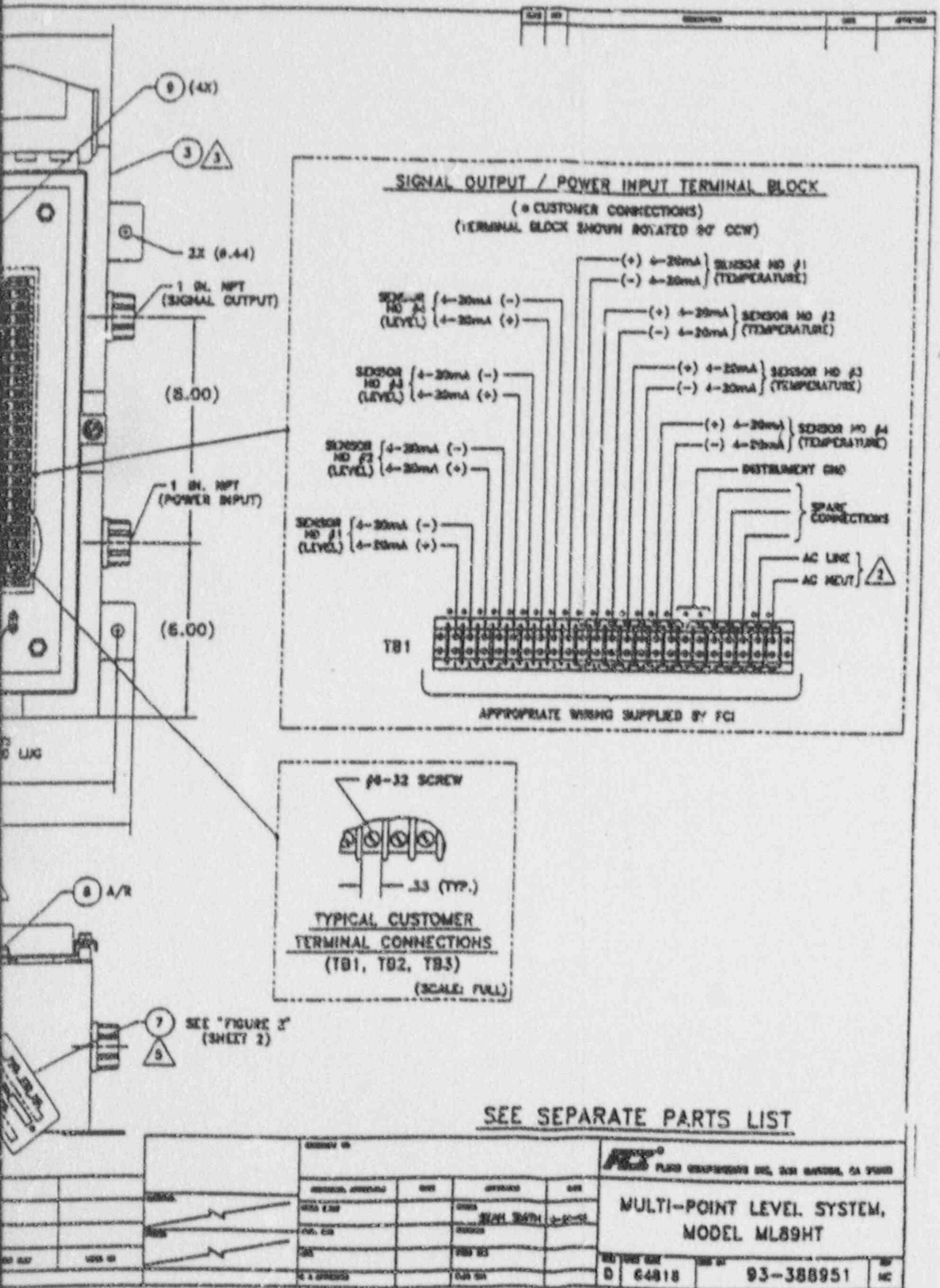
FCI FLUID COMPONENTS INC. SAN MARCOS, CA

MULTI-POINT LEVEL SYSTEM, MODEL ML89HT

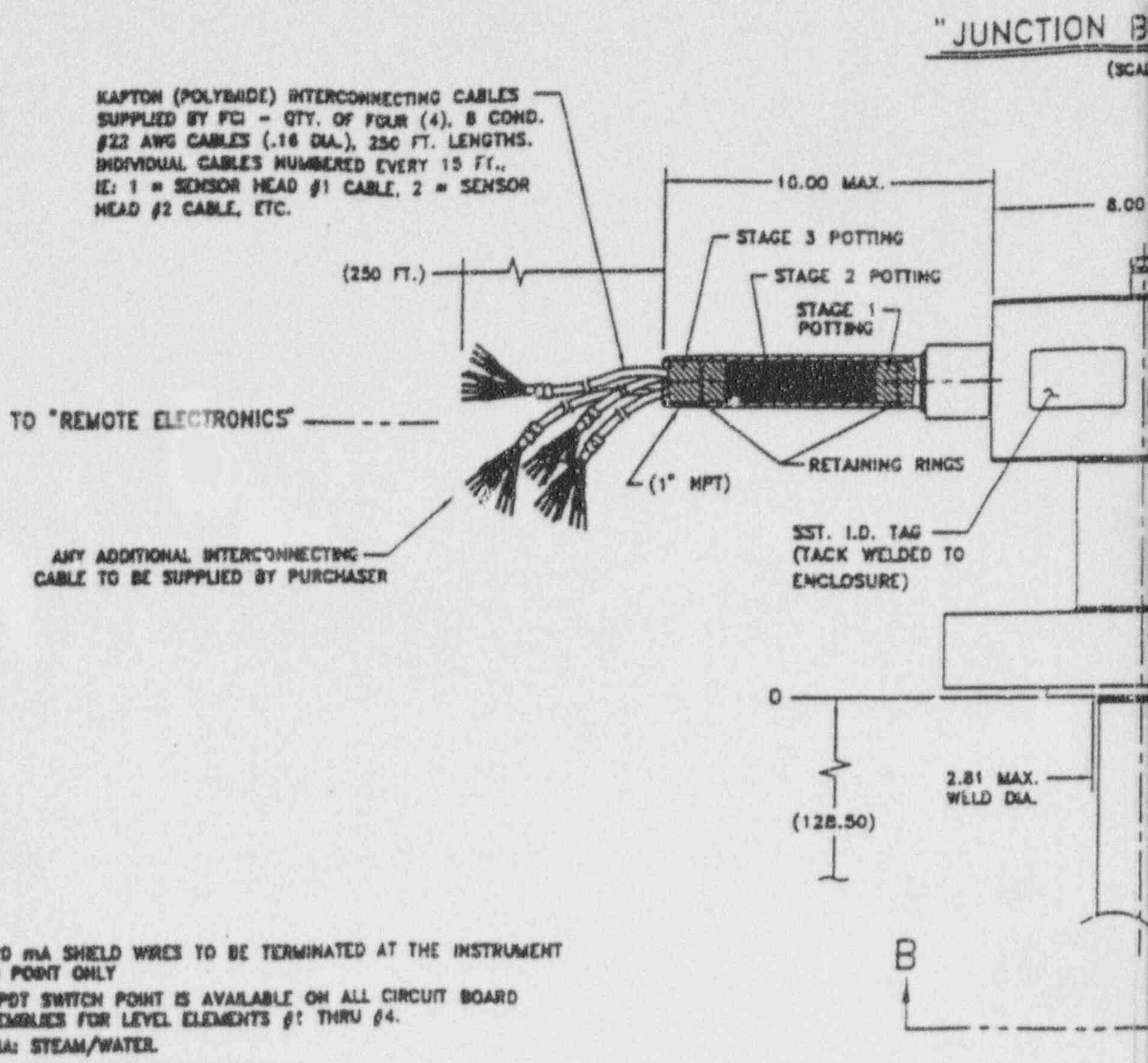
D 64818 93-388951 NC

9508310106-01

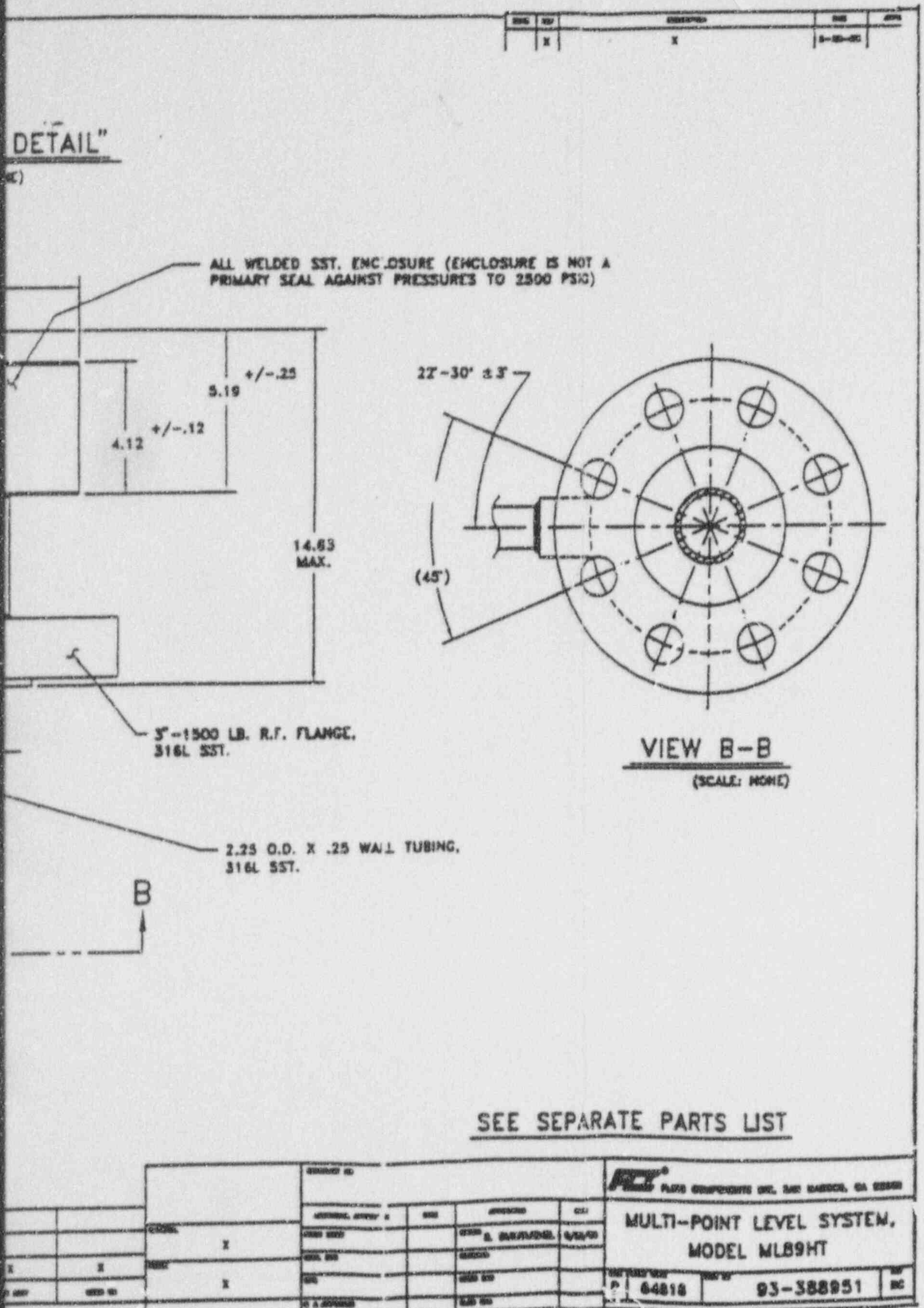

(24.00)
(.92)
(3.00)
(14.00)
(20.00)
(4X) 4
2
1 IN. NPT
(SIGNAL INPUT)
TB2
TB3
(10.00)
2X (.44)
SEE "TYPICAL TAG INFORMATION"
(SHEET 2)
(25.25)
(26.50)
REMOTE ELECTRONICS ENCLOSURE
APPROX WEIGHT: 60 LBS
SEE "FIGURE 1"
(SHEET 2)
(7.35)
(6.00)
(3.00)
(.19)



SIGNAL OUTPUT / POWER INPUT TERMINAL BLOCK
(TERMINAL BLOCK SHOWN ROTATED 90° CCW)
(+) 4-20mA
(-) 4-20mA
(TEMPERATURE)
(LEVEL)
INSTRUMENT GND
SPARE CONNECTIONS
AC LINE
AC NEUT
TB1
APPROPRIATE WIRING SUPPLIED BY FCI
(8.00)
(6.00)
1 IN. NPT (SIGNAL OUTPUT)
1 IN. NPT (POWER INPUT)
(4X)
A/R
SEE "FIGURE 2" (SHEET 2)
.33 (TYP.)
TYPICAL CUSTOMER TERMINAL CONNECTIONS
(TB1, TB2, TB3)
(SCALE: FULL)
SEE SEPARATE PARTS LIST
MULTI-POINT LEVEL SYSTEM, MODEL ML89HT
D
64818
93-388951



12. 4-20 mA SHIELD WIRES TO BE TERMINATED AT THE INSTRUMENT GND POINT ONLY
11. A DPDT SWITCH POINT IS AVAILABLE ON ALL CIRCUIT BOARD ASSEMBLIES FOR LEVEL ELEMENTS #1 THRU #4.
10. MEDIA: STEAM/WATER.
9. LEVEL ELEMENT OPERATING CONDITIONS:
   50°F TO 650°F
   2500 PSIG
8. ELECTRONICS OPERATING CONDITIONS:
   0°F TO 150°F
   0 TO 100% RELATIVE HUMIDITY
7. CENTER ITEMS 5 & 6 ON LID OF ENCLOSURE.
6. DRILL & PRIME AN .082 DIA HOLE APPROX WHERE SHOWN.
5. PERMANENTLY MARK INFORMATION ON TAGS WHERE INDICATED.
4. LEVEL ELEMENT ASSY HYDROSTATICALLY PRESSURE TESTED TO 3750 PSIG MIN FOR 10 MINUTES.
3. ELECTRONICS ENCLOSURE: NEMA 4, CONTINUOUS HINGE.
POWER INPUT: 120 VAC ±10%, 60Hz, 150 VA MAX LOAD.
MATERIAL: ALL WETTED SURFACES 316 SST WITH NICKEL BRAZE PER AMS 4777.



9508310106-03

PARTS LIST

PL-93

DRAWN SEAN SMITH MFG. SEE SHEET 1

CHECKED R. Dumouchel Q.A.

ENG.

ITEM NO.	QTY	PART NUMBER	PART NAME
1	1	015537-01	ELEMENT ASSY
2	1	015538-01	PANEL ASSY
3	1	015539-01	ENCLOSURE
4	REF	0017-A1C2A1A1	TRANSMITTER
5	1	015222-01	LABEL
6	1	015223-01	LAMINATE
7	1	705010-02	TAG
8	A/R	000038-01	LOCKWIRE
9	REF	010569-06	8 SEG. LINEARIZER
10			
11			
12			
13			
14			
15			
16			
17			
18			

388951-01	REV. NC	SHEET 4 OF 4

ITLE

MULTI-POINT LEVEL SYSTEM,
MODEL ML89HT

SCRIPTION	REF. DESIGNATOR
LTI-POINT LEVEL, ML89HT	
CHANNEL, 21" x 17"	
SY, 24" x 20" x 6"	
RCUIT BOARD MODULE	
TALIZED POLYESTER	
BEL	
T, IDENTIFICATION	
T	
AL RANGE SIGNAL OUTPUT	VARIATION #1403

9508310106-04