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SEP 29 1982

Mr. Paul S. Check, Director
CRBR Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Check:

TMBDB INSTRUMENTATION DEVELOPMENT

Reference: Letter HQ:S:82:028, J. R. Longenecker to P. S. Check, "Future Information for Review of CRBRP-3, Volume 2," dated May 14, 1982

In the above reference, a list of topics and reports to be submitted to the NRC in support of the CRBRP Thermal Margins Beyond the Design Base (TMBDB) was supplied. This letter transmits item 1 of the list in the above reference.

Sincerely,

John R. Longenecker

John R. Longenecker
Acting Director, Office of the
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LETTER REPORT

TMBDB INSTRUMENTATION DEVELOPMENT

SEPTEMBER 20, 1982

TMBDB INSTRUMENTATION DEVELOPMENT

I. INTRODUCTION

TMBDB instrumentation requirements for monitoring containment vessel shell temperature, containment atmosphere temperature, pressure, and hydrogen content are defined in CRBRP-3, Vol. 2. The purpose of this report is to describe the development tests for these instruments and to demonstrate that it is feasible to develop instrumentation that meets the requirements in CRBRP-3, Vol. 2.

II. SIGNAL CONDITIONING EQUIPMENT

All signal conditioning equipment is located in the Steam Generator Building. The Steam Generator Building is not subjected to the products of sodium combustion or to the extreme temperatures and pressures whichcharacterize the containment. The most severe TMBDB environmental concern in the Steam Generator Building arises from the radiation levels emanating from the containment. While these levels are not sufficient to affect the operation of equipment, they will limit operator access.* Unattended operation is a requirement and the systems have been designed for remote manual actuation from the Control Room.

III. HYDROGEN MONITORING INSTRUMENTATION

Two instruments are provided at different locations in the Steam Generator Building. The principal operating requirements of the Hydrogen Monitoring System under TMBDB conditions are listed in Table 1.The cabinets may be operated locally or remotely from the Control Room. Remote control features include actuation, calibration and filter blowback. The principal concern with this system is the containment sampling arrangement. To prevent plugging of the sampling tube, a filter assembly will be mounted at the entry end.

The development of the filtering system has been in three phases:

The first, or Scoping phase, completed in 1980, aimed at identifying basic problems of filtering sodium aerosols;

*At the Hydrogen Analyzer Sampling Station, the maximum whole body dose has been calculated to be ≈280 mrem assuming 2 minutes for ingress and egress with a 2 minute stay. These doses fall off rapidly following venting to 60 mrem for the same time interval at 50 hours.

The second, or Media Test phase, was to evaluate candidate filters under TMBDB environmental conditions;

The final phase, now in progress, is to test a prototype filter assembly in a simulated TMBDB scenario.

The three testing phases are summarized below.

Scoping Tests

Initial scoping tests were made in conjunction with tests of systems for air cleaning in the Containment Systems Test Facility (CSTF) at HEDL. The principal parameters for these tests were as follows:

TEST	Approx. Aerosol Conc. g/m^3	Average Temp. °C	Water Vapor %V	Aerosol Comp.	Filter Loading Ranges Observed in Testing g/m^2
AC1	6	≈ 100	1.2	70% Na_2O_2/30% NaOH	590 → 5600
AC2	20	≈ 75 (up to 160)	2.6	NaOH/0.7 H_2O	35 → 2000
AC3	6	≈ 90	3.1	Na_2CO_3	200 → 3000
AC4	10	≈ 110	2.3	NaOH/2 H_2O	150 → 3700
AC5	20	≈ 140	0.7	NaOH/0.2 H_2O	> 4500g
AC6	40	≈ 190	1.2	NaOH/1.0 H_2O	> 5000g

Each test lasted for about 50 hours and different filters were used. As the tests progressed, less effective filters were deleted and new types were tested, based on developing experience. When increases in pressure were observed, various blowback techniques were used to clean the filters.

The principal conclusions from the tests were:

- Aerosol composition is the dominating factor controlling filter loading.
- Na_2CO_3 and Na_2O_2 aerosols are filterable and filters loaded with these aerosols are readily blown back.
- Wet aerosols tend to plug filters and the plugged filters are difficult to blow back.
- The sample gas flowrate probably does not affect filter loading at velocities of 18 m/hr and below.
- The filter configuration and orientation are important only with respect to blowback and aerosol settling and plating.
- Use of settling chambers improves filtering efficiency.

From these conclusions, a further series of tests were planned based on the TMBDB limiting containment atmospheric conditions. The presence of sodium hydroxide in liquid state in these tests provided more severe plugging and corrosion problems than were experienced in the scoping tests.

MEDIA TESTS

To determine the performance of specific filter media under TMBDB conditions, seven tests, designated HFT3 and HFT9, were conducted at the Large Sodium Fire Facility (LSFF). The test method was to burn sodium vapors in a heated chamber, which held the test filters. Air flow through the chamber was controlled and steam and CO_2 were added to control test atmospheres and aerosol composition.

Tables 2 and 3 summarize the conditions of the HFT series of tests.

In a typical test, test conditions were first established. The test filter was blown back with nitrogen to clean the surface. Flow through the filter was started and the filter pressure drop monitored. When the pressure drop reached 100 in. H_2O, a brief blowback with nitrogen gas was used to clear the filters, then sample flow was resumed. The filters were considered to be plugged when the pressure drop could not be reduced below 100 in. H_2O by blowback. The duration of each test was approximately 10 hours. Total loading on each filter was calculated from the known filter flow and the measured aerosol concentration.

The results of the tests are summarized in Table 4. In this table, the filter loading is for the first blowback cycle only.

The following conclusions were reached:

- Filter loadings of 1200 g/m^2 can be expected for the worst case when moist NaOH aerosol filter deposits are heated to temperatures above the NaOH melting point.
- Filter loading for "dry" aerosols or sodium carbonate aerosols will be 2400 g/m^2 or greater.
- Filter efficiencies above 99% can be obtained.
- Fibrous types of filter media generally provide the highest loadings before plugging, followed by sintered powder media.
- Corrosion will occur for stainless steel media exposed to molten NaOH aerosols. Corrosion will be less for nickel powder media.
- Cleaning the filters by blowback generally will extend the filter life. Cleaning was most successful for fibrous media and for the dry type of aerosols.

- Several of the test filters ruptured on blowback due to the combined effects of temperature and corrosion. Filters should be designed for the application.

PROTOTYPE TEST

The capacity requirement of the filter system is based on the flow requirements of the hydrogen instrument, the length of time for which measurement is required, and the aerosol concentration. In the case of the CRBRP requirements listed in Table 1, the total aerosol capacity required by the sampling filter should be less than 1.4 kg.

Based on the filter media performance determined in the previous test phase, the prototype design will utilize nickel powder filters, and a settling chamber which significantly reduces the filter loading.

The prototype units will be tested under conditions of the TMBDB environment and the load and time exposure associated with TMBDB scenario. Present plans are for the prototype tests to start before the end of FY82 and full system tests to be completed in FY83.

With the availability of blowback and the capability of increasing sampling filter unit capacity and/or utilizing a backup filter, successful development of this component poses minimal risk.

IV. PRESSURE AND TEMPERATURE SENSOR PERFORMANCE

The successful performance of conventional thermocouples and pressure sensors over the extended test program period provides a basis for the survivability of equivalent containment instruments under TMBDB conditions, as discussed below.

Temperature Measurement

Temperature measurements in CSTF and LSFF are made using seamless stainless steel sheathed, M O insulated, Type K thermocouples, generally with ungrounded junctions. [9]Where possible, continuous lengths are used inside the test vessel.

In the CSTF, 1/16" OD thermocouples were used for 14 test runs. The temperature varied from 100 to 400°F in sodium oxide and hydroxide aerosols. The total exposure time was about 300 hours and the few failures observed have been from mechanically breaking the thermocouples while revising the test arrangements. The 1/16" OD stainless sheathed thermocouples were satisfactory for this service.

In the case of the LSFF tests, 1/8" OD thermocouples are being used. These thermocouples have now survived 100 hours of testing without failure in average temperatures between 800 and 900°F and with peaks of 1200°F.

The performance of the test atmosphere thermocouples provides assurance that the existing containment atmosphere and vessel shell temperature thermocouples will operate adequately.

Pressure Measurement

Pressure measurements within the various experimental vessels have used Bourdon gauges and diaphram gauges. These are connected to the vessel shell with 1/4 to 1/2" stainless steel tubing. Lengths vary from 10 to 50 feet. During hundreds of hours of testing with various aerosols, plugging of the sensor tube has not occurred probably due to the small pressure sensor system volume and the very small gas displacement required to reflect pressure changes.

The design and performance of these sensors again provides assurance that existing pressure measurement technology is adequate for TMBDB containment measurement.

TABLE 1

HYDROGEN SAMPLING SYSTEM REQUIREMENT

Sample System Delay Time[a]	10 minutes (max)
Sample Line Size[a]	61 m (200 ft) long 6.3 mm (0.25-in) ID
Filter Pressure Drop, Max[a]	34 kPa (5 psi)
Containment Temperature	16°C to 593°C (60°F to 1100°F)
Containment Atmosphere	0-10 v/o H_2O, 0-6 v/o CO_2
Operation Duration	500 hrs (with aerosol) 8000 hr total
Aerosol Concentration	46 g/m^3 (at CV conditions)
Aerosol Composition	Na_2O_2, NaOH, and Na_2CO_3
Aerosol Size	*AMMD = 5 μm, σ_g = 3.0
Required Instrument Flow[a]	150 cc/min (minimum) at 150°C (300°F)
Filter Efficiency[a]	Sufficient to protect system

(a) Adapted from CRBRP-3, Vol. 2

* Aerodynamic Mass Median Diameter

TABLE 2

HYDROGEN FILTER TEST CONDITIONS

		Peak Conditions		Condition when Filter Started		Aerosol Characteristics			
Test No.	Steam or CO_2 Addition	Aerosol g/m^3 (a) (STP)	Temp °C	Aerosol g/m^3 (STP)	Temp °C	AMMD(b) μm	σ_g	Major Chemical Form	Notes
HFT 3	S	107	200	44	100	2.9	2.3	$NaOH \cdot xH_2O$	Base case
HFT 4	S	175	250	63	75	2.2	2.0	$NaOH \cdot xH_2O$	Higher concentration
HFT 5	S	176	650	58	350	5.6	2.1	$NaOH_\ell$ (c)	Effect of molten NaOH
HFT 6	S	188	650	66	245	6.3	1.9	$NaOH_\ell$	Effect of molten NaOH
HFT 7	–	146	440	20	76	3.0	2.1	$Na_2O_2/NaOH_\ell$	Low temp start to molten NaOH
HFT 8	S, CO_2	166	660	48	388	5.1	2.1	$Na_2CO_3/NaOH_\ell$	CO_2 addition
HFT 9	S	166	620	154	330	4.8	2.1	$NaOH_\ell$	High concentration start

(a) STP; 0°C, 101 kPa
(b) Aerodynamic mass median diameter.
(c) $NaOH_\ell$ = Molten NaOH, MP - 318°C

TABLE 3

HFT AVERAGE ATMOSPHERE COMPOSITION

Test No.	Chamber Air Flow, m^3/min (STP)	Oxygen Vol %	Steam g/min	Steam Vol % H_2O	CO_2 g/min	CO_2 Vol %
HFT 3	1.0	19	85	11	0	0
HFT 4	0.6	17	85	18	0	0
HFT 5	0.7	17	85	15	0	0
HFT 6	1.0	17	85	11	0	0
HFT 7	0.6	17	0	1[(a)]	0	0
HFT 8	1.1	19	85	10	110	5
HFT 9	0.8	20	85	13	0	0

(a) Est. inlet air dew point of 10°C

TABLE 4

HFT RESULTS SUMMARIZED BY FILTER MEDIA

AVERAGE FILTER AEROSOL FIRST CYCLE LOADINGS, g/m^2

Media Type	HFT3	HFT4	HFT5	HFT6	HFT7	HFT8	HFT9
Powder	2590	3140	600	740	1110	1300	- -
Powder, Pleated	1600	1970	240	- -	- -	- -	- -
Screen	460	1740	2190	- -	1280	- -	7030
Fiber, Filterite	2610	3170	1280	9160	880	1090	- -
Fiber, HR	- -	- -	- -	1790	320	1020	- -
Nickel Powder	- -	- -	- -	450	- -	1400	9950
Nickel Screen	- -	- -	- -	- -	- -	- -	1810