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AN OXYGEN-HYDROGEN METER ASSEMBLY FOR USE IN REMOTE SODIUM SAMPLING SYSTEMS

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ABSTRACT

An assembly of an electrolytic oxygen meter and a diffusion type hydrogen meter was designed to fit into the Multipurpose Sampler hardware already installed and operating on the four FFTF sodium systems. One of the key elements in this assembly is a ceramic-metal sealed oxygen sensor which allows use of a metal tube to extend the 51 cm (20 in.) between the sampler top and the flowing sodium region.

INTRODUCTION

The design of the Fast Flux Test Facility (FFTF) includes shielded space for oxygen-hydrogen meter modules which had been designed earlier.[1] This incorporated an oxygen meter using yttria doped thoria solid electrolyte tubes[2] and a hydrogen meter employing a nickel diffusion element[3] mounted in series in the sodium stream. Maintenance access was too limited with the original design to permit replacement of faulty sensors. Therefore, alternatives were considered and use of the Multipurpose Sample port for installation of oxygen and hydrogen sensors was investigated.

Because of the heavy reliance on the Multipurpose Sampler (MPS)[4] for monitoring sodium purity, the units were installed in duplicate in the hot cell where the primary sodium is sampled. Experience with the MPS indicated a high degree of reliability opening the prospects of a port becoming available for insertion of oxygen and hydrogen meter sensors into the sodium stream. The major stumbling block appeared to be the adaptation of the oxygen meter.

The oxygen meter used in the module described in Reference 1 used an electrolyte tube 16.5 cm long x 0.64 cm dia. (6.5 in. x 0.25 in.) of yttria doped thoria. The construction of the MPS is such that the length of the probe would have to be a minimum of 51 cm (20 in.). A monolithic ceramic tube of these dimensions would be fragile so composite metal ceramic structures were examined.[5] One was found to operate satisfactorily so it was incorporated in the design.

SYSTEM REQUIREMENTS

Geometry

The MPS closure is a Graylok hub of 2 inch pipe size and the distance from the hub face to the bottom of the sodium cup containing the sensors is 45.7 cm (18 in.). The sodium cup is 8.9 cm high x 4.1 cm dia. (3.5 in. x 1-5/8 in.). These are the crucial dimensions for designing an assembly.

For installation in the FFTF sampling cell, the overall length is restricted by the lift of the hoist. This dimension was not available when the unit was designed, but it turned out that the finished unit was the maximum length that could be handled. There is some leeway in the design of the hydrogen meter vacuum system so it could be readily modified to substantially shorten it.

System Integrity

Since the design was for use in the primary sodium of the FFTF, it would be in a radioactive system. This imposes more stringent requirements on the integrity of the closures and components. The thin nickel membrane of the hydrogen meter is designed with reinforcing ribs to provide support against collapse by system pressure which is normally in the 34.5-69 MPa range (5-10 psig). Corrosion of nickel is low at the operating temperature. So primary reliance for sodium containment is on the membrane. The supporting structure and the vacuum system provide a secondary boundary to the escape of sodium. Consideration is being given to adding a section of 3.18 mm (1/8 in.) tubing to act as a freeze vent.

The oxygen probe ceramic provides a less reliable barrier against sodium leakage. Therefore, the upper support structure and insulators are designed to provide thin annular paths that would serve as freeze vent seals to prevent sodium escaping from the probe envelope in the event of a ceramic failure.

The Graylok hub seal and the Marman Conoseals have proved quite reliable in various sodium systems applications including use on samplers. The operating mode of this design of insert puts more severe demands on them to maintain the argon cover gas pressure so the sodium level remains at the proper point to ensure circulation of sodium in the sample cup. Addition of a sodium level sensing device has been considered but not tested yet. If such a device was added, it could be connected to a control circuit to adjust the argon pressure as necessary to maintain the sodium level.

Technical Parameters

These are considered to be the sample flow rate, temperature control and signal processing.

Sample flow rate is controlled by balancing the pressure provided by an electromagnetic pump and the valve settings. It is normally in the range 0.39 to 1.15 l/min (0.1-0.3 gal/min). Heat is supplied by external furnaces with solid state power controllers. The measuring and controlling thermocouples are in a thermowell located in the sodium sample cup.

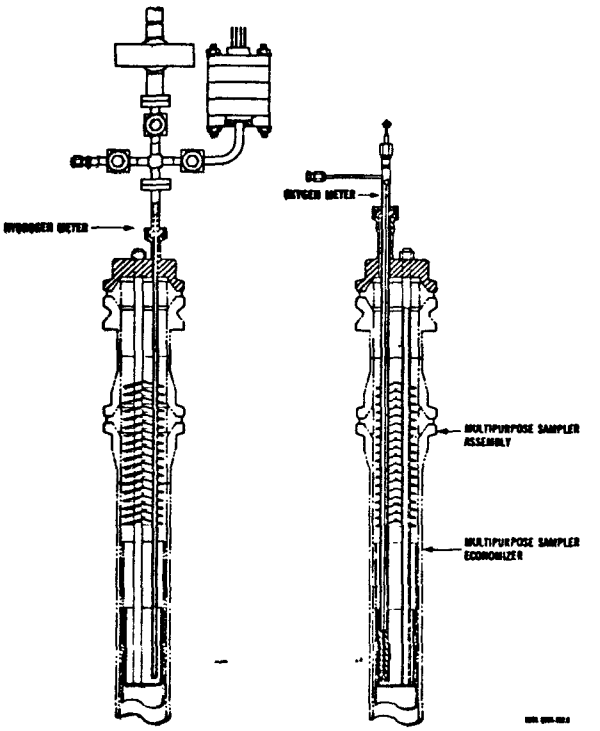
The signals are millivolt level. The oxygen meter is a high resistance cell of about 680 mv output so for accurate measurement, it must be measured by a high impedance voltmeter. The ion pump current and the ion gage output are converted by their respective controllers to 0-100 mv signals available for recording.

SYSTEM DESIGN

Probe Assembly

The overall probe assembly is shown schematically on Figure 1. The hydrogen membrane is attached to a 0.64 cm (1/4 in.) tube of 304 SS which is attached to a Conoseal flange. Above the flange, the vacuum system uses valves and fittings of 0.95 cm (3/8 in.) tube size. The vacuum pump is a Varian Vac ion pump of 2 l/sec pumping speed. The ion gage is a Varian Millitorr. Miniature vacuum flanges and Nupro bellows sealed valves are the remaining components of the vacuum system. The membrane is made from nickel tubing. Its initial wall thickness of 0.89 mm (0.035 in.) is reduced

Figure 1. OXYGEN-HYDROGEN METER INSERT FOR THE MULTIPURPOSE SAMPLER



to 0.30 mm (0.012 in.). Reinforcing ribs, of the original thickness, are spaced 2.54 cm (1 in.) apart. The total length is 7.6 cm (3 in.).

The oxygen probe uses a yttria doped thoria tube braze sealed into a tube of iron-nickel alloy. This probe is produced by the General Electric Co. It was attached to the Conoseal flange and 12 mm (1/2 in.) 304 SS support tube here at HEDL. The center electrical contact of molybdenum wire is insulated from the support tube by alumina insulators and a ceramic vacuum feed through. Probes tested to date have used indium-indium oxide as the reference electrode.

Signal Processing

The MPS installation at the FFTF is located in a shielded cell. The signal readout equipment is located in the operations area such that cable runs of approximately 30 m (100 ft) are required. Signal readout is through an Esterline Angus data logger. This unit is capable of taking the millivolt signals from the probes and calibration factors from the keyboard and printing out results in ppm of hydrogen and oxygen in the sodium.

The in-cell installation has not been completed so it has not been possible to determine whether or not an isolating amplifier is needed in the oxygen meter signal cable.

PERFORMANCE

Several candidate oxygen probes were tested in the assembly before the decision to use the General Electric one was made. The GE probe tested withstood five shutdown-restart cycles in three sodium loops without breakage. During the final test, some drifting occurred for about six weeks before the voltage stabilized. The data are shown on Figure 2. It is suspected the drifting results from interactions between the In-In_2O_3 reference material and the Mo electrical contact wire.

The hydrogen meter system gave problems with outgassing that required extended periods of pumping and bakeout before the system settled down to normal performance. During the last test, the ion pump current calibration factor had settled down to 0.06 ppm/μa.

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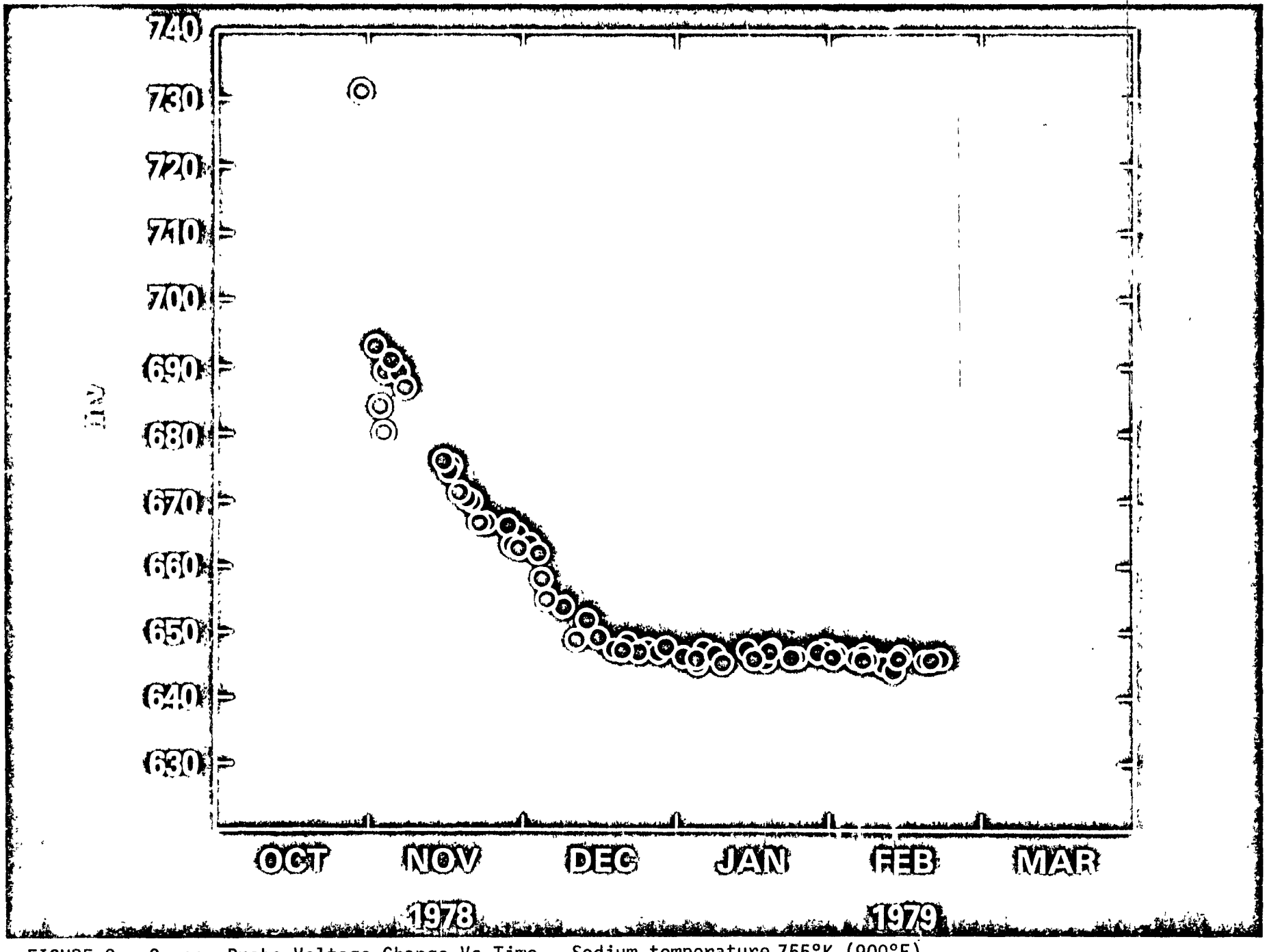

FIGURE 2. Oxygen Probe Voltage Change Vs Time. Sodium temperature 755°K (900°F). STCL Loop Cold Trap Temperature 405°K (270°F).

The data logger system has not been connected to the probe assembly. It has been tested for a short time on battery input and found to be stable.

CONCLUSIONS

The individual components of the described system have been tested and found to exhibit satisfactory performance.

Two areas of probe construction that need further examination are: a) reference electrode for the oxygen meter, and b) sodium level measurement and control.

Testing of the complete system including signal transmission through the shielding walls of a hot cell will be necessary to determine whether or not additional signal processing will be necessary.

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