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WANL-TME-1449

June, 1966

Westinghouse Astronuclear Laboratory

UPGRADING OF THE SINGLE ELEMENT

HYDROGEN CORROSION TEST

(Title Unclassified)

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HYDROGEN CORROSION TEST

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and Declassification~~

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ABSTRACT

A hardware development program was undertaken at WANL Fluid Flow Laboratory to upgrade furnace performance for the single element hydrogen corrosion test. Development of a spring loaded, segmented finger hot end chuck for testing of non standard geometry elements is described. Improvement in the direct gas inlet chuck for pinhole testing and long cold chucks to shape test temperature profiles are discussed. A nine view port furnace and 4 view port instrumentation ring were constructed to facilitate the collection of additional test temperature data for analytical purposes.

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INTRODUCTION

NERVA reference fuel undergoes a high temperature hydrogen corrosion test to evaluate the quality of the propellant flow channel coating under reactor operating conditions. This test is performed at WANL by centrally placing a single fuel element in a horizontal water cooled pressure vessel which is equipped to resistance heat the test sample with high direct current.

During typical test conditions, hydrogen enters the element at 670 psig and ambient temperature; flows at a rate of 500 scfm through the 19 coolant channels; exiting at 4460°R and 560 psig. An inert atmosphere of helium gas is maintained around the uncoated outer surfaces of the element to protect the graphite from hydrogen attack. Element surface temperatures which are measured with an optical pyrometer through pyrex view ports are used to determine applied power levels so as to approximate operating reactor temperature profiles.

During the 1966 contract year, research and development work to upgrade the corrosion furnace operation was undertaken by the Fluid Flow Laboratory. Initial improvements in hot and cold end element chucks* and radiation heat shielding are described in TME-1381 published in February of 1966. See supplement 2 of TME-744¹ for the thermal analysis concerning these initial improvements.

The present paper describes additional changes made in chucking and other furnace hardware to meet current testing problems and further upgrade the corrosion test.

* Chucks are graphite fixtures used to mechanically hold the test sample and maintain electrical contact with it.

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THE HOT END CHUCK

The hot end chuck used for hydrogen corrosion tests of NRX-A5 fuel elements consisted of a graphite cylinder centrally broached with a hexagonal hole to conform to the outer dimensions of the element with a tight sliding fit.² Three 1/4 inch graphite dowel pins extending through the walls of the chuck were held against alternate flats of the element with a graphite snap ring clasped around the O.D. in order to provide electrical continuity if the element should move. Good electrical contact was obtained when the hot element expanded into the slightly cooler hand fitted opening of the chuck and could be maintained even during graphitization shrinkage by the three pin arc suppressor.

During the preproduction testing of NRX-A6 fuel elements, it was determined that due to a new back coating process, the coating on the flats near the hot end of the element was built up as much as 2 thousandths of an inch. (See Figure 1). In order to fit chucks to these over size ends, the hexagonal opening had to be overbroached to clear the built up area with the result that a sloppy fit was obtained over the current carrying area from 50 to 51 inches(measured from the cold end). Loose fits in the primary contact area of the hot chuck caused most of the current to be routed through the 1/4 inch dowel pins with an ensuing increase in current density in this region. As a result, hot end arcing failure began to occur more frequently accompanied in most cases by holes bored in the element surface at pin locations.

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As Coated - One Step

Figure 1 Three Pin Hot Chuck

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To overcome this difficulty in maintaining electrical contact with elements with oversized hot ends, a different chucking arrangement had to be devised which would increase the current carrying area of the arc suppressors. Geometric limitations on pin size (they could not be made larger in diameter than the .435 inch flat width), suggested a new approach utilizing movable finger segments to provide low current density contact on the hot end.

Individual segments which were machined to fit the hot end contact area could be separated to slip over the enlarged tips without compromising the contiguity of chuck and element.

Two problems were encountered in designing a hot finger chuck. The first involved a method of holding the fingers against the element. Early designs used two sets of three tapered finger segments, which were forced into a conical cavity in the chuck body with a retaining nut. (See Figure 2). The fingers were thus pressed between the chuck and the element bringing the two bodies into intimate mechanical and electrical contact. Two difficulties however, became apparent with this approach. First the threaded retaining nut necessary to compress the fingers would often crack off due to thermal expansion of unevenly heated parts on the hot end. More important though, was the fact that the tapered finger chuck held the element fast at the hot end.

Figure 2 Experimental Hot End Chuck--Tapered Finger Type

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This positive hot end grip had a tendency to work against the cold chuck attachment (also of a tapered finger design) when the element experienced thermal expansion along its axis producing bowing or even breakage of the test sample.

To eliminate the possibility of any restriction of the elements axial movement during thermal expansion the tapered wedge design was given over for untapered finger segments which could be held in contact with the element by a positive spring pressure. A graphite snap ring spring which had been used with the three pin arc suppressors was adapted to circumscribe three finger segments which were broached with a .750 inch hexagonal hole (see Figure 3). When the fingers, encased by the snap ring, were forced over the .754 element, the spring circumference was expanded 12 mils applying a positive contact pressure of 1 pound to the element. Thus the element could slide through the fingers as much as necessary to allow for axial thermal expansion while enough force to sustain electrical continuity was maintained by the spring.

Two sets of these spring loaded fingers -- each $3/4$ inch long -- were packed inside a tubular chuck body in series. Each set of fingers had a current carrying area 4.6 times as great as that of the fuel element. In this way, if either set of fingers failed to maintain good contact with the element, the remaining set could carry the entire current without developing high enough densities to initiate arcing.

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Figure 3 Experimental Hot End Chuck--Spring Loaded Finger Type

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The second problem associated with the use of a segmented finger design on the hot end chuck was that of providing a gas tight seal of the spaces between the segments. This seal was necessary to prevent the helium furnace atmosphere which was maintained around the outer surfaces of the element at a pressure of 660 psi from leaking through the hot end chuck into the exit plenum of the furnace (which was kept at 560 psi). Such a leak, if permitted, would tend to inhibit corrosion of the element nozzle end -- prejudicing the results of the hydrogen corrosion test. An effective sealing mechanism for the spring finger chuck was provided by the use grafoil packing material. Two 5 mil thick foil washers punched with a .750 hex hole were inserted respectively in front of the first set of fingers and between sets of fingers to seal off gas flow between the finger segments. A 5 mil foil sleeve was also wrapped around the O.D. of the entire finger assembly to prevent gas leaking between the fingers and the chuck body. This seal arrangement demonstrated the ability under test to hold the 100 psi differential between atmosphere and exhaust without any signs of leakage.

The spring loaded finger chuck performed well on its check out run (Test No. 1821) providing both satisfactory electrical contact and gas seal properties. On Test No. 1814 it was used to produce a successful test of an element made of high expansion graphite. Experimental elements made of this type of material had a previous history of breakage under hot test due to the unusually high rate of thermal expansion. Two successful tests of A6 elements

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with enlarged hot ends were also conducted at the WANHES facility utilizing the spring finger design (tests 11459 & 11460). In general the spring loaded finger hot end chuck shows considerable promise for use in problem testing situations where maximum freedom of motion in combination with good gas seal properties prove desirable*.

COOL END CHUCK DEVELOPMENTS

Additional development work at the Fluid Flow Laboratory was devoted to improving cold chuck capabilities. The direct gas inlet cold chuck which was devised for pinhole corrosion testing was reworked to include a gas tight inlet plenum chamber. In order to produce the outward driving pressure difference between element channels and external surfaces which is associated with the production of pinholes, a means of sealing the hydrogen inlet line to the element cold end was developed which would allow independent control of the atmosphere pressure level external to the element (see discussion WANL-TME-1381 Pages 12 to 16). The inlet line seal consisted of alternate teflon and RTV rubber washers which were made to conform to the outside dimensions of the element and were forced against its external surfaces to prevent leakage along the flats. Boron nitrate holders for the washers were, in turn, sealed against the cold chuck plenum cavity walls with viton o-rings so as to prevent leakage along the chuck walls. Some evidence of a small amount hydrogen leakage into the element external atmosphere was nevertheless obtained under

* The spring loaded finger principle has recently been incorporated in a hot end chuck design which has proved similarly successful for cluster corrosion tests.

Figure 4 Aluminum Chuck Body and Seals

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test. The only remaining gas path available was through the pores in the graphite chuck body. It was therefore decided to rework the chuck body in metal to render the seal plenum chamber gas tight.

Aluminum was chosen for the chuck body material because of its lightness and low electrical resistance. The chuck would then neither become cumbersome nor begin heating due to the passage of current through its walls. A graphite thread in nose piece was incorporated in the chuck design to contain the cold end fingers in order that the aluminum chuck body would never experience the 2000°R temperatures found at the element "cold end". The aluminum chuck and labyrinth seal (developed previously) performed together satisfactorily on their first check out run (test 1821) with no sign of hydrogen leakage into the atmosphere. They have continued to be used to isolate the hydrogen inlet line on all subsequent single element tests.

The second group of cold end chuck experiments was conducted on extended length chucks to investigate corrosion test capabilities for shaping the element axial temperature profile. (See WANL-TME-744 Supplement 1³). In the Quality Control corrosion test there is a slight margin on conservatism in the simulation of reactor temperature profiles in the mid-band position; the slope of the axial profile being less than that in the reactor,

Figure 5 Long Cold Chucks

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a greater length of fuel element is exposed to mid-band corrosion in the electrical test. In order to correct this condition, it was recommended that the length of heated element might be shortened with the use of cold end chucks which would grip the element closer to the hot end than the standard 1.6 inch dimension.¹ This procedure would accomplish three things: First the length of heated element would be shortened accordingly causing the element temperature to rise from its 2000°R level at the cold end fingers to 4600°R set at the hot end within a reduced axial interval. Secondly, since the length of heated element was reduced there would be a corresponding reduction in exit gas temperature. Finally, because it turned out that approximately the same power was required to raise the hot end surface temperature to 4600°R for long and short chucks, the power density in the heated length of element was increased.

Cold chucks of six different lengths providing grips 4 inches, 6 inches, 8 inches, 10 inches, 12 inches, and 15 inches away from the inlet end of the element were made up and tested at the Fluid Flow Laboratory (see Figure 5).

Surface temperature profiles for three of these chucks are shown in comparison with the standard QC test profile in Figure 6. It is apparent from these data that the slope of the axial temperature profile can be easily manipulated with this technique if desired and the scope of corrosion tests capabilities correspondingly widened.

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Figure 6 Surface Temperature Profiles for Various Long Cold Chucks

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FACILITY UPGRADING

Several recent innovations in corrosion facility hardware have improved equipment durability and the quality of corrosion test information. A cold hydrogen bleed system was installed in the walls of the transition connector which channels exit gas from the furnace into the heat exchanger. This new flow system will allow a trickle of unheated hydrogen to enter the transition section, coating the wall with a film of cool gas which will insulate furnace parts from overheating during long term/high temperature runs.

A second modification of furnace equipment involved replacing the only remaining graphite heat shield (a 6 inch diameter 48 inch long tube which was being used as a retaining form for the three primary radiation heat shields described in TME-1381²) with a molybdenum tube rolled from 10 mil sheet. By eliminating this graphite shield, carbiding of the three primary molybdenum reflectors was reduced, prolonging the life of the furnace heat shields. Hydrogen could also be admitted to the furnace body atmosphere if desired, without fear of corroding unprotected graphite shields. This change in hardware configuration added flexibility to furnace mode of operation so as to include the capability to perform external corrosion experiments on NERVA fuel in addition to the bore corrosion tests conducted heretofore.

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In order to improve temperature profile information on the corrosion test a nine view port furnace was built and installed at the Fluid Flow laboratory high temperature test facility. This furnace was equipped so as to permit observation of fuel element surface temperatures with a pyro optical brightness pyrometer at 5.5 inch intervals along the entire length of the test sample. A periscope viewing system utilizing front surface mirrors was installed on each the furnace view ports and calibrated to determine intensity loss correction to observed surface temperatures. Observations made with the new view port/periscope system should provide much more complete temperature profile information than has been previously available for comparison of the corrosion test with reactor temperature conditions.

A new four view port instrumentation ring was designed and built for installation at the exit plenum of the furnace (see Figure 7). This addition to furnace instrumentation hardware will allow direct observation of the exit gas stream. Thermocouples or a newly designed gas enthalpy probe may now be inserted in the exhaust gas stream to measure element exit gas temperature. Observation of gas temperature probes inserted through one of the ring view ports may be made through any of the other ports with optical temperature instruments (i.e. pyrometers) to provide independent measurements of gas stream properties. In short use of the new exhaust plenum instrumentation ring will make it possible to monitor propellant properties

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at the fuel element outlet in a fashion consistent with the recommendations of WANL-TME-744³ so as to provide more complete information for analysis of the corrosion test.

SUMMARY

Recent improvements in high temperature furnace hardware have increased the capabilities of the corrosion facility for performing a variety of hydrogen corrosion tests. The spring loaded fingered hot chuck concept provides a method of testing fuel elements of non standard geometry. The aluminum direct gas inlet chuck by providing a positive seal of the hydrogen inlet line to the cold end of the element allows considerable flexibility in adjusting gas pressure levels to study corrosion effects at a variety of flow and pressure conditions. Some flexibility in shaping the corrosion test axial temperature profile is also provided with use of extended length cold chucks. High temperature/long duration tests can now be conducted with less risk of overtemperature damage to furnace hardware as a result of the recent practice of injecting cold hydrogen into the exhaust gas stream. Finally the replacement of the graphite radiation heat shield with one of molybdenum construction allows the possibility of running external corrosion experiments on NERVA fuel elements.

Likewise improvements in furnace instrumentation have provided more complete information on corrosion test parameters to aid in analysis of the electrical

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test. A nine view port furnace equipped with front surface mirror viewing system allows the observation of element surface temperatures at 5.5 inch intervals over its entire length. In addition a four view port hot end instrumentation ring will facilitate more complete measurement of exit gas properties than have been available heretofore. Thus the incorporation of various hardware innovations at the high temperature test facility has provided the capability to meet current testing problems at the Fluid Flow laboratory and upgraded the hydrogen corrosion test.

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