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May 1966

Westinghouse Astronuclear Laboratory

EXPERIMENTAL INVESTIGATION OF INTERSTITIAL CORROSION

FOR AN ISOTHERMAL MODEL PHASE I
(Title Unclassified)

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May 1966

MASTER

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FOR AN ISOTHERMAL MODEL PHASE I
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Classification cancelled for change to

by authority of Doc

by H.J.C. TIC, date SEP 10 1973

by

R. J. Steffen
Fluid Flow Laboratory

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ABSTRACT

A test rig has been designed and fabricated to supply information on graphite corrosion in narrow slots. The test section is an axially split graphite cylinder containing a gap that is varied in thickness from 0.001 inches to 0.006 inches, the width of the slot is 1 inch, its length 2 inches. All the support hardware is fabricated of molybdenum to eliminate the generation of extraneous hydrocarbons which has been a serious problem in past designs⁽¹⁾.

The tests described cover gaps of 0.006, 0.004, 0.002 and 0.001 inches in thickness. The tests were conducted at 3500°R for 30 minutes with hydrogen flows of 0.0001 lb/sec. The inlet pressure levels were maintained at 200 psig.

Post-test examination showed corrosion for the full length of the slot, decreasing toward the exit of the slot. Measurements of the 0.006 inch gap showed that the gap opened up to 0.067 inches at the inlet and 0.011 inches at outlet. The weight loss was 2.363 gms.

Measurements of the 0.004 inch gap showed that the gap opened up to 0.041 inches at inlet and 0.0047 at the outlet. The weight loss was 0.966 gms. Alignment problems and high pressure drops obtained with the 0.002 and 0.001 inch fixtures made it impossible to match the test conditions under which the first two fixtures were tested. Photos and surface regression data are included for general information. The test series is designed to independently show the effects of the parameters controlling this reaction and to what degree each exercises its influence.

(1) Steffen, R., Test Series HHT-6, Preliminary Interelement Corrosion Study, WANL-TME-1138, 3-65, Confidential Restricted Data.

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A second series of tests were also initiated to demonstrate the effectiveness of various surface coatings as corrosion inhibitors. Two sets of flow slots were coated with NbC on one face and ZrC on the other face. Two additional flow slots were coated with NbC on one face, the other face was left unprotected. All these fixtures were tested at 3500°R for 30 minutes with hydrogen flows approaching 0.0001 lb/sec at 200 psig inlet pressure. Surface regression data, coating condition, and weight losses are presented for general information. The data does not lend itself to correlation with current theories due to the fact that the time at which coating breakdown occurred is not known. The results give an indication of coating effectiveness.

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INTRODUCTION

The corrosion tests reported in Reference (1) demonstrated the feasibility of a method of testing corrosion in thin slots, and pointed out the need for a way to stop contamination of the inlet hydrogen with hydrocarbons generated by corrosion of graphite hardware used to support the test specimen. This problem was solved by the use of molybdenum hardware to support the test specimen and a molybdenum can which separated the specimen and heater element atmospheres.

The test hardware performance was excellent and is capable of providing large quantities of basic corrosion data on a configuration that is easy to analyze and is not clouded by the complexities of large elaborate test rigs. Corrosion data for this program was obtained in slots of the following thickness, .001, .002, .004 and .006 inches. All flow paths are 1 inch in width and 2 inches long.

The first series of tests is being conducted to determine the effects of gap size on the corrosion rate. All other parameters including inlet pressure, material temperature, material, flow rate and inlet gas temperature were held constant. Material temperatures were limited to a value below 4000°R to insure longevity of the molybdenum components. Other test series will be run to determine the effect of each of the above variables. The second test series examined the effectiveness of ZrC and NbC as hydrogen protection coatings. The results of this series qualitatively indicate that ZrC is as effective as NbC if the coating is properly applied.

Data to date shows that the temperature gradient along the axis of the test fixture is approximately 25°, the exit end being the hotter. Material temperature levels from run to run can vary as much as 140° as a maximum but will be reduced as more skill is acquired in operation of the equipment.

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EXPERIMENTAL EQUIPMENT

The support equipment connected with this test which includes the furnace, loop and control system is covered in detail under the experimental equipment section in Reference (1). This section in this report will be devoted to a description of the molybdenum hardware and the graphite test section.

Figure 1 is an excerpt from Sheet 1 of Drawing No. NT701464 showing Item 151 which is an assembly of the test fixture. The rig is detailed on Drawing No. NT701486.

Figure 2 is a schematic of the molybdenum test fixture showing it disassembled and assembled. This figure describes each part, shows the location of thermocouples and the hydrogen flow path. The test specimen designated by Nos. 7 and 16 in Figure 2 is an HLM-85 graphite cylinder tapered on each end and split along its axis. The cylinder measures 2 inches in length and 1.344 inches in diameter. One-half of the flow gap thickness is surface ground in each portion of the cylinder so the flow gap of desired thickness and 1 inch in width is obtained when the cylinder is put back together. Two holes are bored in each end of the specimen. The two in the inlet end accommodate the alignment pins designated as Item 15 and the two in the exit end are for the inlet and outlet material temperature thermocouples. The inlet thermocouple being designated as Item 17 in Figure 2. The test specimen is inserted in the housing designated as Item 1 until it bottoms on the matching tapered surface which serves as a seal and also aids in holding the split cylinder together. The molybdenum plugs designated as Items 6 and 14 are the next item to be assembled. These items contain a tapered surface which mates with the taper cut on the inlet end of the specimen. This plug assembly also contains a flow gap identical to the one ground in the specimen and provides a well established flow regime prior to the beginning of the graphite

material. Alignment pins are pressed into holes in the molybdenum plugs, and can be considered an integral part of the plugs. These pins fit in the holes bored in the inlet face of the graphite specimen and are designed to allow pin movement perpendicular to the flow slot but do not allow the two assemblies to rotate relative to each other. Item 13 has an internal taper which fits to a taper on the plug assembly. This clamp forces the 2 halves of the plug assembly together which in turn clamps the inlet end of the test specimen. Item 12 is an externally threaded nut which threads into the housing and applies an axial force to the stack of components. This force tightens all tapers which solidly contain the test fixture, assures integrity of the flow slot and effects a seal on the tapered exit portion of the specimen.

Items 3 and 4 are then attached to the exit portion of the housing. Item 4 is a cap adapter which holds the assembly in the molybdenum outer can. Item 3 is a seal that seals between the cap and housing. The complete housing assembly is then inserted in the molybdenum outer can and threaded in until the tapered surface on the inside diameter of the can meets solidly with the tapered surface on the cap. These are the main sealing surfaces which seal hydrogen in the can. The next component to be added is the hydrogen delivery tube which consists of the plug described as Item 5 and a piece of 1/2-inch molybdenum tubing 24 inches long. The plug and tube are welded together and threaded into the inlet end of the molybdenum outer can. The seal here is again accomplished by the mating of two tapered surfaces. The complete assembly is then loaded in a special wrench and installed in the furnace graphite support barrel described as Item 18. Sealing the threads is accomplished by a taper on the threaded end of the molybdenum can and a taper above the threads in the graphite barrel. The heater element plus the inlet flange is lowered over the hydrogen delivery tube and can to complete

the assembly of the furnace inlet. The material and gas temperature thermocouples are installed through the exhaust cone of the furnace to complete the entire assembly.

Figures 3 through 9 show the test fixture in various stages of assembly.

The inlet material temperature is taken at a point 0.25 inches from the inlet face and at a distance of 0.080 inches from the original surface of the flow slot. The exit temperature is taken at a point 0.25 inches from the exit face and at a distance of 0.080 inches from the original surface of the flow slot. The thermocouples used are tungsten-tungsten 26% rhenium with molybdenum sheaths. The temperatures are continuously recorded on a multipoint millivolt recorder, the exit temperature is also monitored on a potentiometer to check the accuracy of the printout.

The exit gas temperature is measured at a point 0.69 inches up from the exit end of the cap. The probe is a shielded bead chromel-alumel thermocouple. This temperature is also continuously printed out on a multipoint recorder.

The heater element, Item 10 Figure 2, has been coated with NbC to reduce the amount of hot carbon in close proximity with the molybdenum can. The heater element chamber is kept pressurized with helium to prevent corrosion of the element thus insuring long life. The inlet pressure to the test fixture is measured by a static pressure probe located in the hydrogen inlet line. The exit pressure is measured by a static pressure probe in the exhaust plenum of the furnace. The grain direction of the graphite used in fabrication of the test specimens is always parallel to the axis of the specimen.

Prior to the build containing the flow slot the molybdenum fixture is assembled with a dummy test specimen containing no flow slot. The entire assembly

is then internally pressurized to a value of 100 psig with helium gas and all seals are checked for leaks with "Leak-Tek".

DEVELOPMENT AND OPERATION

Prior to installation the test specimen is sent to Quality Control to have the surface of the flow groove mapped. Groove depth measurements are taken at 1/4-inch intervals along the length of the slot. The result is 45 depth measurements describing each surface of the groove. Nine gap width measurements are taken at 1/4-inch intervals to describe each gap width.

The initial test series consisted of tests designed to study the effects of gap thickness on the observed corrosion. The gap widths were 0.001, 0.002, 0.004 and 0.006 inches. Each build was run at the following conditions.

Inlet Pressure	200 psig
Material Temperature	3500°R
Test Gas	Hydrogen
Flow Rate	0.0001 lb/sec
Time	30 min.

Prior to each test a data sheet shown in Figure 10 was filled out on each assembly. This data sheet contains the dimensions which accurately describe the surfaces of the channel walls. The measurements were taken with a dial indicator graduated in 0.0001 inches fitted with the medium ball probe. Before and after each measurement the level of the piece was checked by checking the zero on the mating surfaces located on each side of the flow groove. Groove width measurements were taken with an optical comparator if the sides of the gap could be easily seen. If not, a toolmakers microscope was used. Each instrument reads to 0.0001 inches. Figure 11 is a sketch showing where the dimensions were taken.

Figure 12 is a data sheet which contains the weights of the test specimen and component hardware. This sheet is filled out after the initial measurements are taken and before the post test measurements are taken. This procedure eliminates the possibility of further weight loss due to handling during the measuring operation. Small parts of the assembly, including the specimen, were weighed on a balance accurate to ± 0.0002 gm, and the large components were weighed on a balance accurate to ± 0.2 gms.

The test fixture is initially run cold with helium gas to check loop performance and specimen pressure differentials. The system is then switched to cold hydrogen to determine if the transfer from helium to hydrogen is smooth and there will be a minimum of flow adjustment when steady state is obtained. Specimen pressure differentials are also checked with cold hydrogen. When full hydrogen flow is developed the inlet and exit gas sample rates are adjusted so the drawing of gas samples has little or no effect on the overall stability of the system.

At the beginning of a hot test run the furnace and control loop are evacuated to 28 inches Hg vacuum three times. At the end of each evacuation the system is back-filled with helium. At the end of the last evacuation, the required flow rate of helium is established and the power is turned on. The power is increased until the required material temperatures are attained at which time a hot helium reading is taken, the inlet to the specimen is then switched to hydrogen gas. Time is not counted until the instruments indicate that hydrogen is flowing through the specimen. Due to the volume of the system and low flow rates this takes approximately 1.5 minutes. Time is then started and readings are taken every 5 minutes. Orifice data, water flow, test section ΔP , test time, spot material temperatures, delivery pressure and power readings are taken visually and recorded as read on the log sheet shown in Figure 13, gas samples are drawn

toward the end of the run. At the end of approximately 28.5 minutes of hot hydrogen operation the helium is switched on, after a 1.5-minute lag, another hot helium point is recorded and the power is gradually reduced to zero. The flow is left on until the thermocouples indicate that the test section is reading 200°F; at this point flow is shut off.

The low flow rates are measured by a Hastings mass flow meter calibrated to read in standard cc H₂/min. The flow is also monitored by a 0.046-inch diameter sharp edged orifice plate. The Hastings Flow Meter is considered more accurate at these low flows, so the flow indicated by this instrument was reported. When the fixture is removed from the furnace the weights of the components are taken in order of disassembly. The test specimen is then sent to the Photo Lab for coverage and then to Quality Control to have the surfaces mapped. The width measurements taken after test represent the actual corroded width rather than the machined width. In some cases the corroded width at the exit of the specimen is less than the machined width.

RESULTS

The first specimen run contained a 0.006 inch thick gap. When the test fixture was assembled, a molybdenum disulfide base compound called "Moly-coat" was used as a lubricant on all molybdenum-to-molybdenum threads and tapered surfaces. When the test fixture was disassembled it was found that the threads on the hydrogen delivery tube and the externally threaded nut were seized to the mating parts. All other threads came apart easily and still had traces of "Moly-coat" on them. When the specimen was exposed it was found that it had become wedged in the holder due to the close tolerances between the 2 diameters. The specimen and plug assembly were pressed out so the molybdenum plugs could be removed. Figure 14 is a

photo of what the inlet looked like after test. Figure 15 shows the exit end of the flow slot. During the 0.006-inch run, portions of the taper on the molybdenum plugs became fixed to the wall of the specimen holder; it was felt that the close tolerance between the plug and wall was responsible for this. As a result, material from the periphery of the cylinder was removed as it was pressed out of the specimen holder. Figures 16 and 17 show the specimen and where the material was removed. All the loose material was saved and its weight subtracted from the weight loss of the specimen.

To correct this condition, 0.004 inches was removed from the ID of the holder. The lubrication problem was solved by the use of "Neolube" on the threads that had seized. Figure 18 shows the faces of the 0.006-inch flow gap after test. Note that the sealing surfaces at the edge of the slot show no corrosion indicating that the seal is effective and the integrity of the flow slot is maintained during the test. Figure 17 shows the main sealing surface on the exit end of the specimen. The absence of corrosion on this surface indicates the seal was functioning throughout the test. Figure 19 is a sketch of the centerline profile of the flow slot. The figure also shows the average running conditions and weight loss for 30 minutes of operation.

The next specimen to be tested contained a 0.004-inch flow gap. Figure 20 shows the centerline profile of the flow slot and lists the average running conditions and weight loss for 27 minutes of operation. Figure 21 shows the inlet end and gap of the 0.004-inch specimen prior to test. Figure 22 shows the flow slot walls prior to test. Note the flaw lines in the material. These cracks are flaws probably caused by the extrusion process which formed the graphite log from which the specimens were cut. Figure 23 shows the inlet end and gap of the 0.004-

inch specimen after test. Note that the corrosion on the inlet face was sufficient to almost completely eradicate the markings visible in Figure 21. Corrosion is also evident on portions of the taper around the inlet end. This corrosion indicates that the molybdenum plugs were not mating properly with the face of the specimen. Figure 24 shows the exit end of the specimen. Here examination of the tapered surfaces on this end indicates the lack of corrosion demonstrating the effectiveness of the seal. Figure 25 is a photo of the surfaces of the flow groove. Note that the material flaws are not as evident as shown in Figure 22. Here again the sealing surfaces on the sides of the flow slot are free from corrosion. Also, the corrosion width is less than the machined width toward the exit of the fixture. Measurements show that this was due in part to a difference in gap width between the two sections and a possible machined misalignment of the 2 gaps when the two halves were put together. The difference in width alone is not sufficient to cover an area that wide. The horizontal lines visible on the seal surfaces are a grid pattern used to locate the measuring probe.

Figure 26 is a photo of the plug and graphite specimen assembly after test. No corrosion is found on the outer walls of the cylinder, however, a small amount is noticed where the molybdenum and graphite tapers meet. The clearance between the 2 components allowed this area to be flushed with hydrogen before it passed through the slot. Figures 27, 28, 29, 30 and 31 present reduced data plus pre and post test surface regression measurements. Pre test measurements using the method adopted as a standard were not taken on the 0.006-inch specimen. Tables 1, 2, 3, and 4 appendix B present test data including pre and post test weight loss measurements plus comments recorded during the actual run.

The corrosion results obtained with this test fixture were excellent. Figures 19 and 20 showing the centerline profile indicate surface regression as would normally be expected. The corrosion decreased with distance as the hydrocarbon concentration increased with distance. Analyzing the test fixture using theories developed to predict corrosion in reactor geometries show that the actual weight loss is high compared to the calculated weight loss. The calculated weight loss was approximately 1 gram lower than actual in both cases. Calculated profiles also reflected this difference in weight by showing surface regressions 10 to 15 mils less than the actual measurements at the inlet of the flow slot. Calculated profiles very closely approached the actual profiles for the last half of the test fixture. These slight variations from theory can be explained by consideration of C_2H_2 concentrations for the first 1/4 inch of the flow slot and extraneous corrosion taking place on the inlet surface of the test specimen. Both these factors tend to increase actual weight losses and create variations from the theoretical analysis.

Gas samples taken from the inlet line to the furnace during each test showed the gas to contain a hydrocarbon concentration of 1 ppm. The exhaust sample from the 0.004-inch flow slot test was analyzed by mass spectrography methods and found to contain percentages of hydrogen, helium, nitrogen, oxygen, argon and methane. Figure 32 shows the mole percent of each constituent. Such gas analyses are extremely difficult and require extensive varification before being useful.

Figure 33 is a plot of the differential pressure across the test piece versus run time, the curves appear reasonable by showing a decrease in ΔP with an increase in flow area as corrosion progresses.

Figure 34 is a composite curve for the 0.006-inch build showing the profile across the 1-inch gap at the inlet and every 1/4 inch to the exit. The first 1/4 inch in from the inlet seems to be fairly irregular. At 1/2 inch in a regular pattern is formed which takes permanent shape at the 3/4-inch depth. This permanent shape suggests that there is more corrosion at the 1/4-inch and 3/4-inch widths than at the center and edges. A possible explanation for this profile can be found in the isothermal pattern in the test section. The cylindrical test specimen is heated by a radiant heater which surrounds it. The lines of constant temperature take an oblong shape around the flow slot, the lines intersecting with this grid are similar to the lines of flux around a bar magnet. This condition shows that the center of the flow slot is the coolest portion of the fixture, the extremes being the hottest. This sort of situation would tend to produce more corrosion toward the edges of the gap which is indicated by the profile plot. It is also possible that the method of extraction from the test fixture contributed to this condition; reference to the beginning of the "Results" section will give the details of how and why the specimen froze in the holder. The first method tried was to force the specimen out with a plastic rod; when this proved unsuccessful, mallet blows were employed. The area of contact between the test specimen and the plastic rod was small, which concentrated the majority of the energy in the center of the specimen. It is possible that the energy delivered to the rod was sufficient to locally deform the material producing the ridge in the middle of the flow gap. The effect could not have been totally created by the method of extraction because deformations of this magnitude are more than sufficient to fracture the material and no fracture occurred. Another possible contribution could be that due to the close tolerances between the specimen and the

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holder in the first run, the differential expansion loaded the circumference of the cylinder and created the deflection along the middle of the gap. The corrosion at the inlet was severe enough to remove it, but along the length of the channel it remained.

Figure 35 is a composite curve for the 0.004-inch build showing the profile across the 1-inch gap. The irregular inlet edge noticed in the 0.006-inch test is present in this curve. The trend of the curves indicates that corrosion was greater on the opposite sides of each half of the specimen. This is indicated by the slope of the top and bottom curves. Notice that the consistent pattern present in the plot of the 0.006-inch data is not present in the 0.004-inch data. Seeing that both test specimens were tested under near identical conditions, it is reasonable to assume that the constant temperature pattern on the cylinder does not produce as large an effect as anticipated from the results of the 0.006-inch data. Evidence of this nature substantiates theories that close fits and method of extraction were responsible for the pattern.

The 0.004-inch data shows some irregularities but they tend to be in the opposite direction and less pronounced, also the consistency of the 0.006-inch data is not present.

Figure 36 is a composite curve showing the axial profile of the 0.006-inch test specimen. The curves describe the axial shape of the slot at 1/4-inch intervals across the face. This set of curves reflects the pattern shown in Figure 34 where the corrosion at the 1/4-inch and 3/4-inch stations is the severest. It is interesting to examine the shape of the inlet of the fixture, at the mid-point and the 3/4-inch plane. This condition could be caused by a combination of two factors. The first of which would be a slight misalignment between

the molybdenum plugs and the test section. The second of which would be flaws in the graphite material causing severe local corrosion, which would cause the measurements to reflect this type of profile.

Figure 37 is a composite curve showing the axial profile of the 0.004-inch slot at 1/4-inch intervals across the face. This set of curves shows the severest corrosion areas on the upper portion was at the far edge of the slot. The lower portion shows the heaviest corrosion to be taking place at the central and 3/4-inch station. It is interesting to note that across the entire width of the inlet the shape is consistent. No cross-over noticed in the 0.006-inch data is present. It is also evident from the curves that the far edge station showed no regression for the last half of the passage, Figure 25 shows this to be true. Here again the slight irregularities in the curves could be caused by misalignment of the molybdenum inlet plugs or variations in the density of the material. The variations caused in the 0.006-inch data that were not present in the 0.004-inch data seem to have been removed by the increase in clearance between the specimen and the holder.

In order to meet the flow rate requirement of this test series the 0.002-inch specimen had to be tested at an increased pressure due to choking when the fixture was brought to temperature. The adjustments in inlet pressure changed the flow rate during the run which produced transients, in parameters which were designed to be constants. The results are presented for general information and are not directly comparable to the larger gaps due to the different operating conditions. Figures 38, 39, 40 and 41 present reduced data, exhaust gas sample analysis, plus pre and post test surface regression measurements. Tables 5 and 6 appendix B present test data including pre and post test weight loss measurements plus comments recorded during the actual run.

Figure 42 is a photo of the inlet of the specimen after test. The photo shows that the heaviest corrosion has taken place on the right side of the slot.

Figure 43 shows the exit of the flow section. It can be seen that the irregular corrosion pattern extended for the entire length of the flow path. Notice here the clean appearance of the tapered seal surface.

Figure 44 shows the surfaces of the flow slot and the path the corrosion pattern takes, notice that a large amount of material was removed from the inlet face of the specimen confusing the weight loss data.

The irregular corrosion pattern was possibly caused by slight mis-matching of the 2 fixture components during the machining process. With a gap of 0.002 inches a slight mis-match would represent a fair percentage of the total gap width. If these discontinuities were matched side for side, during assembly of the fixture, they would cause a path of least resistance which would direct the flow of hydrogen gas causing the pattern shown in Figure 44.

The problems associated with the 0.002-inch fixture were present with the 0.001-inch fixture but were more severe. The test was discontinued after 13 minutes of run time after both high temperature thermocouples failed, the data is presented for general information. Figures 45, 46 and 47 present reduced data plus pre and post test surface regression measurements. Tables 7 and 8 appendix B present test data including pre and post weight loss measurements plus comments recorded during the actual run. Figure 48 shows the inlet face of the test specimen and the start of an irregular corrosion pattern. Figure 49 shows the faces of the flow slot and the extent to which the corrosion pattern had progressed at time of abort.

At this point in the program, emphasis was shifted to test specimens that had coatings on the faces of the flow slot. All these specimens had their external surfaces coated with NbC to eliminate the attack of the inlet face during the run. To reduce alignment and pressure drop problems to a minimum, the 0.006-inch flow slot was chosen to be a constant during this series.

Two sets of fixtures were coated with NbC on one side of the flow slot and the graphite on the other side was left unprotected. All specimens were made of Graphitite "G" to be consistent with the NRX-A core filler strip material. Two sets of fixtures were coated with NbC on one side of the flow slot and ZrC on the other. In all cases, the coating on the inlet face of the specimen extended to the edge of the flow slot. The ZrC coating was applied by a technique proposed to coat NRX-A core parts. The Zr powder was applied as a paint and the part was then rapidly heated to a temperature at which the Zr would flow and carbide with the graphite.

The first specimen to be tested in this series was a 0.006-inch flow slot with NbC and unprotected graphite designated as Ser. No. 5. Figure 50 shows the surfaces of the flow slot prior to test. The half on the left is uncoated, the half on the right being NbC coated. Note the dark area in the middle of the coated side. This is an area of thin coating. The 4 plugged holes on the sealing surfaces of coated piece were created by molybdenum pins that were inserted to hold graphite rails which elevated the slot so it could be coated and also protected the sealing surfaces from being covered. When the rails were removed, the molybdenum pins broke off and were left in the holes. A pass with a surface grinder removed any material which protruded from the hole. Figure 51 shows the coating on the outer surfaces of the test fixture. Figures 52, 53 and 54 present

reduced data plus pre and post test surface regression measurements. Tables 9 and 10 appendix B present test data including pre and post test weight loss measurements plus comments recorded during the actual run.

Figure 55 shows the surfaces of the flow gap after test. Note that the dark area in Figure 50 shows much clearer in this photo because any coating that was on the graphite has been removed. The inlet edge of the flow slot also shows coating damage. The non-coated section shows severe attack particularly in the first 1/4 inch of slot length. Reference to Figures 53 and 54 show how much surface regression took place. Data from this run will be difficult to analyze with theoretical methods because the time at which the coating broke through is not known. The coating on the outside of the specimen also shows attack as can be seen in Figure 55A indicating that the overall quality of the coating was not good. The parts were placed in the baffles of a coating furnace where the vapor flow over them was not evenly distributed.

The next two fixtures to be tested had coatings of NbC on one side and ZrC on the other side of the flow slot. These fixtures are designated Ser. No. 3 and 4.

Figure 56 shows the ZrC coated surfaces of fixtures 3 and 4. The appearance of the two coated parts are quite different even though the two parts were coated by the same process. The coating on piece Ser. No. 3 appears to be shiny, smooth and impervious. The coating on piece Ser. No. 4 appears to dull, rough and porous.

Ser. No. 3 specimen was run in helium for 30 minutes. Figure 57 shows the surfaces of the fixture before test. Table 11 appendix B is the log sheet showing test conditions and data. Figure 58 is a table showing the reduced data and the weight loss.

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Figure 59 shows the condition of the coated surfaces after the run.

Figure 60 is a close up of the inlet edges of the flow slot. The NbC coating shows less discoloration than the ZrC coating, microscopic examination of both inlet edges revealed small cracks and local areas of spalling. Color photos of these specimens are available upon request. This fixture was then tested at 3500°R in hydrogen for 30 minutes. Figures 61, 62 and 63 present reduced data plus pre and post test surface regression measurements. Tables 12 and 13 appendix B present test data including pre and post test weight loss measurements plus comments recorded during the actual run.

Figure 64 shows the surfaces of the flow slot after test. The NbC coating is totally intact except for some local removal at the inlet edge. The ZrC coating also appears totally intact except for removal along the inlet and outlet edge. The attack on the inlet edge of the ZrC coated specimen is quite severe as can be seen in Figure 65, also evident is a corrosion area in the last .75 inch of slot length on the ZrC piece where the coating meets the side of the flow groove. This area was not covered during the coating process as can be seen in Figure 57. Ser. No. 4 having the NbC-ZrC coating combination was next to be tested. This specimen was run at 3500°R in hydrogen for 30 minutes. No helium run was performed as was on Ser. No. 3. Figure 66 shows the coated surfaces of the flow groove prior to test. Cross hatch pattern clearly visible on the NbC coating is the reference used while the measurement data is being taken. Figures 67, 68 and 69 present reduced data plus pre and post test surface regression measurements. Tables 14 and 15 appendix B present test data including pre and post test weight loss measurements plus comments recorded during the actual run. Table 14 appendix B gives an account of the abort which occurred at 12 minutes

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and 34 seconds into the test. The abort was caused by a pressure surge which caused the hydrogen delivery hose to come loose.

Figure 70 is a photo of the coated surfaces of the flow slot. The NbC coating is totally intact while no trace of the ZrC coating exists. The parabolic flow pattern on the outlet side of the NbC coated surface was created by the back flow of helium gas after the abort.

The odd shaped pattern on the inlet end of the NbC coated surface was caused by graphite dust which created an obstruction in the flow slot and prevented the helium gas from touching this surface.

Color photos of this fixture are available upon request.

The last test to be conducted in this series was on a specimen which had a NbC uncoated flow slot combination designated Ser. No. 6.

Figure 71 is a photo of the flow slot surfaces before test. The axial lines on the uncoated surface were caused by NbC picked up by the surface grinder wheel from the inlet and outlet edge of the flow groove. This condition was eliminated from the rest of the fixtures by reducing the depth of the cut taken.

The dark areas in the NbC coating located at edges of the flow slot at station .75 are areas of thin coating created by poor distribution of the coating vapor. Figures 72, 73 and 74 present reduced data plus pre and post surface regression measurements. Tables 16 and 17 appendix B present test data including pre and post test weight loss measurements plus comments recorded during the actual run. Figure 75 shows the surface of the flow slot after test. The NbC coating has been removed in the areas where it was thin and surface cracks are visible across the coating at this station. Corrosion on the unprotected surface was very heavy for the first 1/2 inch and then rapidly tapers off, however, the corrosion extends for the entire length of the flow slot.

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CONCLUSIONS AND RECOMMENDATIONS

A method of testing has been conceived and proven capable of providing reliable data on graphite hydrogen corrosion in narrow flow passages.

Data obtained from this program are an excellent check of the current analytical techniques used to predict corrosion in the NRX-A core designs.

The information obtained from the NbC-ZrC coated flow slots indicates that the coating is effective in inhibiting graphite hydrogen corrosion. The results imply that a problem exists in some phase of the coating technique as demonstrated by the different characteristics displayed by two test fixtures coated by the same method.

The entire series points out the need for a more effective coating on the outside of the test specimen. The coating should be done in a furnace designed to coat small objects rather than in the baffles of a furnace designed to coat fuel elements.

It is recommended that the following steps be taken to further improve the quality of the data obtained.

1. Relocate the position of the inlet gas thermocouple to give more realistic inlet gas temperature measurements.
2. It is recommended that further studies be carried out on 0.006-inch uncoated flow gaps to determine the effect of test parameters on observed hydrogen corrosion under closely controlled conditions in order to determine the coefficients in the corrosion rate equations.
3. Incorporate in the present test system an accurate method of continuously monitoring the exit gas for hydrocarbon content.

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4. Design and fabricate a furnace which will be capable of testing test specimens up to 12 inches in length, incorporating refinements gained by operation of the present facility.

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APPENDIX A

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Figure 1
 Test Specimen Assembly

① HOUSING	⑩ HEATER
② PIN	⑪ OUTER CAN
③ SEAL	⑫ NUT
④ CAP	⑬ CLAMP
⑤ PLUG	⑭ UPPER PLUG
⑥ LOWER PLUG	⑮ PIN
⑦ LOWER SEGMENT	⑯ UPPER SPECIMEN
⑧ INLET TUBE	⑰ THERMOCOUPLE
⑨ INSULATION	⑱ GRAPHITE SUPPORT BARREL

Figure 2
 Schematic View of Test Hardware

Figure 3
Exploded View of Test Hardware

Figure 4
Close Up of Components

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Figure 5
Assembled Hardware

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Figure 6
Molybdenum Hydrogen Delivery Tube

Figure 7
Exploded View of Test Specimen and Inlet Plugs

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Figure 8
Assembly of Specimen and Inlet Section

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Figure 9
Exit of Specimen Assembly

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Upper Half Depth Measurement

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30
31	32	33	34	35
36	37	38	39	40
41	42	43	44	45

Lower Half Depth Measurement

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30
31	32	33	34	35
36	37	38	39	40
41	42	43	44	45

Upper Half
Width Measurement

1 -
2 -
3 -
4 -
5 -
6 -
7 -
8 -
9 -

Lower Half
Width Measurement

1 -
2 -
3 -
4 -
5 -
6 -
7 -
8 -
9 -

Figure 10
Surface Measurement Data Sheet

Figure 11
 Measurements Taken on the HHT-6.2 Corrosion Test Piece

UPPER HALF OF GRAPHITE TEST FIXTURE

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK
	AFTER TEST									BEFORE DIM CHECK

REMARKS

LOWER HALF OF GRAPHITE TEST FIXTURE

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK
	AFTER TEST									BEFORE DIM CHECK

REMARKS

REMARKS

FLUID FLOW LAB
 DATA SHEET
 HHTG INTERSTITIAL CORROSION
 TEST BUILD NO. _____

TEST RECORD BOOK NO. _____ RUN NO. _____ SHEET _____ OF _____
 TIME OF DAY _____ DATE _____
 ENGINEER _____ OPERATOR _____
 BAR PRESSURE _____ @ _____ °F TEST GAS _____
 SUPPLY PRESSURE BEFORE _____ PSI SUPPLY PRESSURE AFTER _____ PSI
 SUPPLY TEMP BEFORE _____ °F SUPPLY TEMP AFTER _____ °F
 VACUUM PRIOR TO TESTING _____ INHG
 VACUUM AFTER TESTING _____ INHG

CONFIGURATION _____ ASSEMBLY NO. _____
 DIMENSION A _____ INCHES TYPICAL
 ORIFICE SIZE _____
 ORIFICE OI _____ INCHES

DRAWN BY: J.R. KUZMA
 ENGINEER: BOB STEFFEN
 D. SPEC. 751523AG

WEIGHT OF GRAPHITE
 HEATER ELEMENT

WEIGHT
BEFORE TEST
AFTER TEST

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FLUID FLOW LAB

LOG SHEET

HHTG INTERSTITIAL CORROSION

TEST BUILD No. _____

TEST RECORD BOOK NO. _____ RUN NO. _____ SHEET _____ OF _____

TEST RECORD BOOK NO. _____ RUN NO. _____ SHEET _____ OF _____
TIME OF DAY _____ DATE _____

ENGINEER _____ OPERATOR _____

ENGINEER _____ OPERATOR _____
BAR PRESSURE ____ @ ____ °F TEST GAS _____

SUPPLY PRESSURE BEFORE ____ PSI SUPPLY PRESSURE AFTER ____ PSI

SUPPLY PRESSURE BEFORE _____ PSI SUPPLY PRESSURE AFTER _____ PSI
SUPPLY TEMP BEFORE _____ °F SUPPLY TEMP AFTER _____ °F

SUPPLY TEMP BEFORE _____ °F SUPPLY TEMP AFTER _____ °F
VACUUM PRIOR TO TESTING _____ INHG

VACUUM PRIOR TO TESTING _____ INHG
VACUUM AFTER TESTING _____ INHG

CONFIGURATION ASSEMBLY NO.

DIMENSION A _____ INCHES TYPICAL _____

ORIFICE SIZE

ORIFICE OF _____ INCHES

DRAWN BY J. R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

Figure 13
Log Sheet

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Figure 14
0.006 inch Specimen After Test

Figure 15
0.006 inch Specimen Exit After Test

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Figure 16
0.006 inch Specimen Inlet After Test

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Figure 17
0.006 inch Specimen After Test

Figure 18
Face of 0.006-inch Flow Slot After Test

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INTERSTITIAL CORROSION TESTS .006-INCH ORIGINAL GAP THICKNESS
SURFACE REGRESSION AFTER 30 MIN. RUN AT 3521°R INLET AND 3539°R EXIT
INLET PRESSURE = 208 PSIG
FLOW RATE = .0000926 LB/SEC HYDROGEN
GAP LENGTH = 2-INCHES
GAP WIDTH = 1-INCH
WEIGHT LOSS = 2.363 GMS

Figure 19
Test Conditions for 0.006-inch Flow Gap Fixture
2.5 Times Normal Size

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INTERSTITIAL CORROSION TEST .004-INCH ORIGINAL GAP THICKNESS
SURFACE REGRESSION AFTER 27 MIN. RUN AT 3443°R INLET AND 3485°R EXIT
INLET PRESSURE = 222 PSIG
FLOW RATE = .0000973 LB/SEC HYDROGEN
GAP LENGTH = 2-INCHES
GAP WIDTH = 1-INCH
WEIGHT LOSS = 1.966 GMS.

Figure 20
Test Conditions for 0.004-inch Flow Gap Fixture
2.5 Times Normal Size

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Figure 21
Inlet Face of 0.004-inch Flow Slot Specimen Before Test

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Figure 22
Walls of 0.004 inch-Flow Slot Prior to Test

Figure 23
Inlet of 0.004-inch Flow Gap After Test

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Figure 24
Exit of 0.004-inch Flow Slot After Test

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Figure 25
Surfaces of 0.004-inch Flow Slot After Test

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Figure 26
0.004-inch Specimen After Test with Plugs in Place

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar = 29.34 in. Hg @ 75°F 0.006-inch HLM-85 Uncoated Gap

Point Number	Time Min	Rig ΔP psid	Gas Inlet Temp. °R	Gas Exit Temp. °R	Mtl. Inlet Temp. °R	Mtl. Exit Temp. °R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	0	5.01	548.1	1964	3544	3560	.0000926	210
2	4	3.6	548.1	2000	3520	3540		212
3	8	3.65	548	1930	3516	3538		210
4	12	2.65	548.5	1971	3513	3534		208
5	16	2.42	549	1985	3513	3540		206
6	20	2.2	549	1992	3520	3534		208
7	24	2.1	549	2060	3508	3527		208
8	28	2.05	549	2060	3534	3544		208

Initial Gap 0.006 inch
 Gap increase at inlet 0.0418 inch
 Gap increase at outlet 0.0043 inch
 Total weight loss 2.363 gms

Figure 27
 Reduced Data Tabulation for an 0.006-inch HLM-85 Uncoated Gap

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar = 29.52 in. Hg @ 74°F 0.004-inch HLM-85 Uncoated Gap

Point Number	Time Min	Rig ΔP psid	Gas Inlet Temp. °R	Gas Exit Temp. °R	Mtl. Inlet Temp. °R	Mtl. Exit Temp. °R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	4	19.6	548	1860	3405	3470	.0000973	232
2	8	11.9	548	1838	3405	3476		223
3	12	8.6	548.3	1892	3443	3492		220
4	16	6.3	548.3	1960	3467	3503		219
5	20	4.9	548.7	1900	3464	3491		219
6	24	3.7	548.8	2095	3474	3485		221
Samples Taken	27							

Initial Gap 0.004 inch
Total Weight Loss 1.966 gms

Figure 28

Reduced Data Tabulation for an 0.004-inch HLM-85 Uncoated Gap

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Upper Half Depth Measurement

1 .039	2 .037	3 .032	4 .025	5 .018
6 .015	7 .017	8 .030	9 .024	10 .023
11 .012	12 .021	13 .026	14 .022	15 .013
16 .007	17 .018	18 .018	19 .020	20 .006
21 .009	22 .013	23 .015	24 .018	25 .006
26 .007	27 .014	28 .012	29 .013	30 .006
31 .005	32 .012	33 .009	34 .013	35 .005
36 .004	37 .010	38 .006	39 .008	40 .004
41 .004	42 .009	43 .005	44 .007	45 .005

Lower Half Depth Measurement

1 .043	2 .035	3 .035	4 .030	5 .032
6 .020	7 .025	8 .031	9 .020	10 .018
11 .020	12 .023	13 .023	14 .021	15 .005
16 .010	17 .020	18 .016	19 .017	20 .005
21 .005	22 .017	23 .012	24 .016	25 .005
26 .005	27 .015	28 .012	29 .016	30 .004
31 .005	32 .012	33 .008	34 .013	35 .003
36 .007	37 .010	38 .006	39 .011	40 .004
41 .011	42 .009	43 .006	44 .009	45 .0035

Upper Half
 Width Measurement

1 -	1.04
2 -	1.00
3 -	1.00
4 -	1.00
5 -	.960
6 -	.960
7 -	.960
8 -	.940
9 -	.940

Lower Half
 Width Measurement

1 -	1.06
2 -	1.04
3 -	1.05
4 -	1.00
5 -	1.00
6 -	.980
7 -	.960
8 -	.960
9 -	.900

Figure 29
 Measurements Taken On 0.006" Fixture - After Test

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0017	2 .0017	3 .0017	4 .0017	5 .0017	1 .0015	2 .0015	3 .0016	4 .0016	5 .0016
6 .0019	7 .0019	8 .0019	9 .0019	10 .0019	6 .0016	7 .0016	8 .0016	9 .0016	10 .0016
11 .0019	12 .0019	13 .0019	14 .0019	15 .0019	11 .0016	12 .0016	13 .0017	14 .0017	15 .0017
16 .0019	17 .0019	18 .0019	19 .0019	20 .0018	16 .0016	17 .0016	18 .0016	19 .0016	20 .0016
21 .0018	22 .0018	23 .0018	24 .0018	25 .0018	21 .0015	22 .0015	23 .0016	24 .0016	25 .0017
26 .0018	27 .0018	28 .0018	29 .0018	30 .0018	26 .0016	27 .0016	28 .0016	29 .0016	30 .0017
31 .0018	32 .0018	33 .0018	34 .0018	35 .0018	31 .0016	32 .0016	33 .0016	34 .0016	35 .0016
36 .0019	37 .0019	38 .0019	39 .0018	40 .0018	36 .0016	37 .0016	38 .0016	39 .0017	40 .0017
41 .0018	42 .0018	43 .0018	44 .0018	45 .0018	41 .0015	42 .0015	43 .0015	44 .0016	45 .0016
<u>Upper Half Width Measurement</u>					<u>Lower Half Width Measurement</u>				
1 -	1.036				1 -	.999			
2 -	1.036				2 -	1.000			
3 -	1.036				3 -	1.000			
4 -	1.036				4 -	1.000			
5 -	1.036				5 -	1.000			
6 -	1.036				6 -	1.000			
7 -	1.036				7 -	1.000			
8 -	1.036				8 -	1.000			
9 -	1.036				9 -	1.000			

Figure 30
Measurements Taken On 0.004" Gap Fixture - Before Test

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Lower Half Depth Measurement

1 .015	2 .018	3 .022	4 .017	5 .019
6 .010	7 .012	8 .012	9 .009	10 .006
11 .009	12 .0095	13 .0095	14 .008	15 .005
16 .009	17 .0095	18 .0095	19 .007	20 .003
21 .0085	22 .0085	23 .008	24 .006	25 .002
26 .009	27 .009	28 .007	29 .005	30 .002
31 .005	32 .005	33 .006	34 .0035	35 .002
36 .004	37 .003	38 .004	39 .003	40 .002
41 .0035	42 .003	43 .003	44 .002	45 .002

Upper Half Depth Measurement

1 .015	2 .013	3 .019	4 .017	5 .015
6 .0055	7 .008	8 .009	9 .012	10 .013
11 .0032	12 .0064	13 .008	14 .0085	15 .011
16 .003	17 .005	18 .007	19 .007	20 .010
21 .0022	22 .0035	23 .006	24 .006	25 .0075
26 .0025	27 .0035	28 .004	29 .005	30 .007
31 .002	32 .0027	33 .004	34 .004	35 .006
36 .002	37 .004	38 .003	39 .003	40 .007
41 .0018	42 .002	43 .0017	44 .003	45 .0035

Lower Half
Width Measurement

1 - 1.043
2 - 1.036
3 - 1.006
4 - 1.000
5 - 1.000
6 - 1.000
7 - 1.000
8 - 1.000
9 - 1.000

Upper Half
Width Measurement

1 - 1.045
2 - 1.042
3 - 1.037
4 - 1.035
5 - 1.035
6 - 1.034
7 - 1.034
8 - 1.034
9 - 1.035

Figure 31
 Measurements Taken On 0.004" Gap Fixture - After Test

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<u>Constituent</u>	<u>Mole %</u>
Hydrogen	19.68
Helium	79.58
Methane	.09
Nitrogen	.51
Oxygen	.13
Argon	.01

Figure 32

Analysis of Exit Gas Sample Taken During Test of 0.004 inch Flow Gap

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RIC SID - ΔP ΔG IR

Figure 33

ΔP Across HHT-6 Test Fixture vs Time

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Measurements Taken At Inlet, Outlet
 And Every 1/4 Inch Of Length

Figure 34
 Profile Across 0.006-inch Test Fixture After Test

Measurements Taken At Inlet, Outlet
 And Every 1/4 Inch Of Length

Figure 35
 Profile Across 0.004-inch Test Fixture After Test

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Figure 36
Axial Profile of 0.006-inch Flow Section After Test

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Figure 37
Axial Profile of 0.004-inch Flow Section After Test

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar = 28.41 in. Hg @ 88°F 0.002-inch HLM-85 Uncoated Gap

Point Number	Time Min	Rig ΔP psid	Gas Inlet Temp. °R	Gas Exit Temp. °R	Mtl. Inlet Temp. °R	Mtl. Exit Temp. °R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	0	110	554	1196	3430	3534	.0000926	293
2	5	99	554	1189	3377	3505		258
3	11	58	552	1226	3490	3585		230
4	16	30.5	552	1188	3473	3528		226
5	20	22	551	1173	3508	3513		240
6	25	10.3	551	1184	3537	3515		237
7	28.5	5.8	551	1197	3562	3516		244

Samples
 Taken 29

Helium
 Gas to
 Rig 30

Initial Gap 0.002 inch
 Total weight Loss 2.5099 gms

Figure 38
 Reduced Data Tabulation for an 0.002-inch HLM-85 Uncoated Gap

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Analysis of Exit Gas Sample Taken During Test of 0.002" Flow Gap

<u>Constituent</u>	<u>Mole %</u>
Hydrogen	48.51
Helium	50.74
Methane	.14
Nitrogen	.49
Oxygen	.11
Argon	.01

Figure 39

Analysis of Exit Gas Sample Taken During Test of 0.002-inch Flow Gap

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .001	2 .001	3 .001	4 .001	5 .001	1 .0008	2 .0008	3 .0008	4 .0008	5 .0008
6 .001	7 .001	8 .001	9 .001	10 .001	6 .0008	7 .0008	8 .0008	9 .0008	10 .0008
11 .001	12 .001	13 .001	14 .001	15 .001	11 .0009	12 .0009	13 .0009	14 .0009	15 .0009
16 .0011	17 .0011	18 .0011	19 .0011	20 .0011	16 .0009	17 .0009	18 .0009	19 .0009	20 .0009
21 .0011	22 .0011	23 .0011	24 .0011	25 .0011	21 .0009	22 .0009	23 .0009	24 .0009	25 .0009
26 .0011	27 .0011	28 .0011	29 .0011	30 .0011	26 .0009	27 .0009	28 .0009	29 .0009	30 .0009
31 .0011	32 .0011	33 .0011	34 .0011	35 .0011	31 .0009	32 .0009	33 .0009	34 .0009	35 .0009
36 .0011	37 .0011	38 .0011	39 .0011	40 .0011	36 .0009	37 .0009	38 .0009	39 .0009	40 .0009
41 .0011	42 .0011	43 .0011	44 .0011	45 .0011	41 .0009	42 .0009	43 .0009	44 .0009	45 .0009

Upper Half
Width Measurement

1 - .995
2 - .995
3 - .995
4 - .995
5 - .995
6 - .995
7 - .995
8 - .995
9 - .995

Lower Half
Width Measurement

1 - 1.018
2 - 1.018
3 - 1.018
4 - 1.018
5 - 1.018
6 - 1.018
7 - 1.018
8 - 1.018
9 - 1.018

Figure 40
Measurements Taken On 0.002" Gap Fixture - Before Test

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1	2	3	4	5	1	2	3	4	5
.0073	.0179	.0174	.0297	.0331	.0214	.0206	.0149	.0232	.0149
6	7	8	9	10	6	7	8	9	10
.0056	.0133	.0135	.0327	.0235	.0235	.0210	.0113	.0115	.0009
11	12	13	14	15	11	12	13	14	15
.0015	.0050	.0086	.0258	.0187	.0059	.0164	.0071	.0075	.0011
16	17	18	19	20	16	17	18	19	20
.0013	.0069	.0035	.0064	.0018	.0059	.0198	.0046	.0036	.0047
21	22	23	24	25	21	22	23	24	25
.0055	.0042	.0037	.0183	.0012	.0010	.0152	.0029	.0043	.0057
26	27	28	29	30	26	27	28	29	30
.0013	.0021	.0015	.0065	.0018	.0010	.0087	.0016	.0022	.0010
31	32	33	34	35	31	32	33	34	35
.0013	.0016	.0012	.0042	.0012	.0009	.0048	.0013	.0015	.0022
36	37	38	39	40	36	37	38	39	40
.0011	.0011	.0025	.0022	.0011	.0008	.0161	.0008	.0009	.0011
41	42	43	44	45	41	42	43	44	45
.0010	.0010	.0010	.0014	.0011	.0006	.0009	.0007	.0006	.0005

Upper Half
Width Measurement

1 -	1.075
2 -	.994
3 -	.994
4 -	.995
5 -	.995
6 -	.996
7 -	.996
8 -	.996
9 -	.995

Lower Half
Width Measurement

1 -	1.030
2 -	1.025
3 -	1.015
4 -	1.015
5 -	1.016
6 -	1.016
7 -	1.015
8 -	1.016
9 -	1.015

Figure 41
 Measurements Taken On 0.002" Gap Fixture - After Test

Figure 42
0.002-inch Gap Fixture After Test

Figure 43
Exit of 0.002-inch Flow Slot After Test

Figure 44
Surfaces of 0.002-inch Flow Slot After Test

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar = 29.61 in. Hg @ 72°F 0.001-inch HLM-85 Uncoated Gap

Point Number	Time Min	Rig ΔP psid	Av. Gas Inlet Temp. °R	Av. Gas Exit Temp. °R	Av. Mtl. Inlet Temp. °R	Av. Mtl. Exit Temp. °R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	0	98	541	1260	3592	3525	.0000274	224
2	5	100						222
3	10	101						223
4	13	--						--

Initial gap 0.001 inch
Total weight loss .733 gms

Figure 45

Reduced Data Tabulation for an 0.00-inch HLM-85 Uncoated Gap

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0005	2 .0005	3 .0005	4 .0005	5 .0005	1 .0005	2 .0005	3 .0005	4 .0004	5 .0004
6 .0005	7 .0005	8 .0005	9 .0005	10 .0005	6 .0005	7 .0005	8 .0005	9 .0004	10 .0005
11 .0005	12 .0005	13 .0005	14 .0005	15 .0005	11 .0005	12 .0005	13 .0005	14 .0005	15 .0004
16 .0005	17 .0005	18 .0005	19 .0005	20 .0005	16 .0005	17 .0005	18 .0005	19 .0005	20 .0005
21 .0005	22 .0005	23 .0005	24 .0005	25 .0005	21 .0005	22 .0005	23 .0005	24 .0005	25 .0005
26 .0005	27 .0005	28 .0005	29 .0005	30 .0005	26 .0005	27 .0005	28 .0005	29 .0005	30 .0005
31 .0005	32 .0005	33 .0005	34 .0005	35 .0005	31 .0005	32 .0005	33 .0005	34 .0005	35 .0005
36 .0005	37 .0005	38 .0005	39 .0005	40 .0005	36 .0005	37 .0005	38 .0005	39 .0005	40 .0005
41 .0005	42 .0005	43 .0005	44 .0005	45 .0005	41 .0005	42 .0005	43 .0005	44 .0005	45 .0005

Upper Half
 Width Measurement

1 - 1.009
 2 - 1.009
 3 - 1.009
 4 - 1.009
 5 - 1.010
 6 - 1.009
 7 - 1.010
 8 - 1.009
 9 - 1.005

Lower Half
 Width Measurement

1 - 1.016
 2 - 1.015
 3 - 1.014
 4 - 1.015
 5 - 1.014
 6 - 1.014
 7 - 1.014
 8 - 1.014
 9 - 1.014

Figure 46
 Measurements Taken On 0.001" Gap Fixture - Before Test

<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0010	2 .0014	3 .0015	4 .0060	5 .0068	1 .0031	2 .0026	3 .0015	4 .0006	5 .0004
6 .0004	7 .0004	8 .0003	9 .0003	10 .0003	6 .0007	7 .0010	8 .0004	9 .0004	10 .0004
11 .0004	12 .0005	13 .0005	14 .0005	15 .0005	11 .0007	12 .0009	13 .0006	14 .0006	15 .0004
16 .0005	17 .0005	18 .0004	19 .0004	20 .0004	16 .0006	17 .0008	18 .0007	19 .0006	20 .0005
21 .0004	22 .0004	23 .0004	24 .0003	25 .0003	21 .0006	22 .0005	23 .0004	24 .0004	25 .0004
26 .0004	27 .0003	28 .0019	29 .0003	30 .0003	26 .0004	27 .0004	28 .0004	29 .0004	30 .0004
31 .0003	32 .0003	33 .0004	34 .0003	35 .0003	31 .0008	32 .0006	33 .0005	34 .0004	35 .0003
36 .0004	37 .0003	38 .0003	39 .0003	40 .0003	36 .0003	37 .0003	38 .0003	39 .0003	40 .0003
41 .0004	42 .0004	43 .0003	44 .0003	45 .0003	41 .0003	42 .0003	43 .0003	44 .0003	45 .0003

Upper Half
 Width Measurement

1 - 1.016
 2 - 1.010
 3 - 1.009
 4 - 1.009
 5 - 1.009
 6 - 1.009
 7 - 1.009
 8 - 1.010
 9 - 1.010

Lower Half
 Depth Measurement

1 - 1.023
 2 - 1.019
 3 - 1.019
 4 - 1.018
 5 - 1.018
 6 - 1.018
 7 - 1.019
 8 - 1.017
 9 - 1.016

Figure 47
 Measurements Taken On 0.001" Gap Fixture - After Test

Figure 48
Inlet of .001" Slot After Test

Figure 49
Faces of .001" Flow Slot After Test

Figure 50
Surfaces of .006" Flow Slot With NbC
Coating on One Side Serial No. 5

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Figure 51
Coating on Outer Test Specimen Surfaces

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar - 29.58 in. Hg @ 75°F 0.006-inch NbC-Graphitite "G" Gap Serial No. 5

Point Number	Time Min	Rig ΔP psid	Gas Inlet Temp. °R	Gas Exit Temp. °R	Mtl. Inlet Temp. °R	Mtl. Exit Temp. °R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	0	5.8	520	2112	3557	3485	.0000832	208
2	5	3.8	520	2195	3533	3478		210
3	10	3.4	520	2195	3562	3503		210
4	15	3.0	520	2145	3566	3520		210
5	20	2.5	520	1980	3555	3517		210
6	25	2.0	520	2150	3517	3485		210
7	28.75	1.95	520	2045	3513	3478		210

Samples
Taken 29
He On 30
He to
fixture 31.25

Initial Gap 0.006 inch
Total weight loss 1.594 gms

Figure 52

Reduced Data Tabulation for an 0.006-inch NbC-Graphitite "G" Gap Ser. No. 5

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0024	2 .0025	3 .0025	4 .0024	5 .0024	1 .0028	2 .0029	3 .0030	4 .0030	5 .0029
6 .0024	7 .0025	8 .0025	9 .0025	10 .0024	6 .0030	7 .0032	8 .0033	9 .0033	10 .0033
11 .0025	12 .0026	13 .0026	14 .0026	15 .0025	11 .0035	12 .0037	13 .0037	14 .0037	15 .0037
16 .0026	17 .0026	18 .0026	19 .0026	20 .0026	16 .0037	17 .0038	18 .0038	19 .0038	20 .0037
21 .0026	22 .0026	23 .0026	24 .0026	25 .0027	21 .0036	22 .0037	23 .0037	24 .0037	25 .0038
26 .0026	27 .0026	28 .0026	29 .0026	30 .0027	26 .0037	27 .0038	28 .0038	29 .0037	30 .0037
31 .0027	32 .0026	33 .0025	34 .0025	35 .0026	31 .0035	32 .0036	33 .0037	34 .0035	35 .0036
36 .0025	37 .0024	38 .0024	39 .0024	40 .0024	36 .0034	37 .0034	38 .0034	39 .0033	40 .0032
41 .0023	42 .0023	43 .0023	44 .0023	45 .0023	41 .0030	42 .0030	43 .0032	44 .0032	45 .0031

Upper Half
Width Measurement

1 - 1.019
2 - 1.020
3 - 1.0195
4 - 1.020
5 - 1.019
6 - 1.019
7 - 1.019
8 - 1.020
9 - 1.019

Lower Half
Width Measurement

1 - 1.000
2 - 1.000
3 - 1.0004
4 - 1.001
5 - 1.001
6 - 1.0015
7 - 1.001
8 - 1.000
9 - 1.0005

Figure 53
 Measurements Taken On 0.006" Gap Fixture - Before Test
 NbC-Graphitite "G" - Serial No.5

<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0371	2 .0408	3 .0368	4 .0353	5 .0425	1 .022	2 .028	3 .034	4 .0305	5 .032
6 .0249	7 .0270	8 .0275	9 .0275	10 .0270	6 .0036	7 .0035	8 .0035	9 .0035	10 .0040
11 .0086	12 .0201	13 .0207	14 .0217	15 .0203	11 .0149	12 .0037	13 .0037	14 .0038	15 .0042
16 .0106	17 .0188	18 .0161	19 .0183	20 .0158	16 .0216	17 .0188	18 .0048	19 .0043	20 .0148
21 .0146	22 .0132	23 .0123	24 .0116	25 .0167	21 .0189	22 .0157	23 .0140	24 .0165	25 .0180
26 .0132	27 .0095	28 .0094	29 .0108	30 .0119	26 .0120	27 .0130	28 .0112	29 .0107	30 .0165
31 .0104	32 .0074	33 .0064	34 .0096	35 .0092	31 .0129	32 .0046	33 .0038	34 .0038	35 .0069
36 .0075	37 .0078	38 .0061	39 .0093	40 .0101	36 .0039	37 .0037	38 .0036	39 .0035	40 .0035
41 .0059	42 .0062	43 .0030	44 .0057	45 .0064	41 .0035	42 .0034	43 .0033	44 .0033	45 .0032

Upper Half
Width Measurement

1 -	1.031
2 -	1.025
3 -	1.027
4 -	1.033
5 -	1.027
6 -	1.019
7 -	1.020
8 -	1.021
9 -	1.020

Lower Half
Width Measurement

1 -	1.032
2 -	1.027
3 -	1.023
4 -	1.016
5 -	1.014
6 -	1.017
7 -	1.013
8 -	1.010
9 -	.9995

Figure 54
 Measurements Taken On 0.006" Gap Fixture - After Test
 NbC-Graphitite "G" - Serial No.5

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Figure 55
Flow Surfaces of NbC Graphitite "G"
Flow Slot Ser. No. 5 After Test

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Figure 55A
Outer Surfaces of .006" NbC Graphitite "G"
Specimen Ser. No. 5 After Test

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Figure 56
ZrC Coated Flow Slot Surfaces
Prior to Test

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Figure 57
Specimen No. 3 ZrC vs NbC .006"
Flow Slot Before Test

Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar - 29.56 in. Hg @ 71°F 0.0006-inch NbC-ZrC Gap Serial No. 3

Point Number	Time Min	Rig ΔP psid	Gas Inlet Temp. °R	Gas Exit Temp. °R	Mtl. Inlet Temp. °R	Mtl. Exit Temp. °R	Av. Flow lb/sec H _e	Inlet Pressure psig
1	0	11.5	415	1860	3553	3523	.000053	214
2	5	12.4	415	1855	3562	3523		214
3	10	10.4	415	1835	3565	3522		214
4	15	12.7	415	1860	3562	3522		214
5	20	12.5	415	1850	3553	3507		214
6	25	12.8	415	1850	3553	3507		214
7	30	11.5	4.5	1838	3556	3507		214

Initial Gap 0.006 inch
Total weight loss 0.008 gms

NbC 0.002 gms
ZrC 0.006 gms

Figure 58
Reduced Data Tabulation for an 0.0006-inch NbC-ZrC Gap Ser. No. 3

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Figure 59
Surfaces of .006 ZrC-NbC Flow Slot
Ser. #3 After 30 Min. Run in Helium

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Figure 60
Inlet Edge of .005" NbC-ZrC Flow
Slot No. 3 After Helium Run

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar - 29.56 in. Hg @ 74°F 0.006-inch NbC-ZrC Gap Serial No. 3

Point Number	Time Min	Rig ΔP psid	Av. Gas Inlet Temp. °R	Av. Gas Exit Temp. °R	Av. Mtl. Inlet Temp. °R	Av. Mtl. Exit Temp. °R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	0	10.0	520	1615	3512	3522	.0000824	212
2	5	3.7						210
3	10	2.33						210
4	15	2.0						210
5	20	1.9						210
6	25	1.65						210
7	28.5	1.8						210

Samples
 Taken 28.75
 He On 29
 He to
 fixture 30

Initial gap 0.006 inch
 Total weight loss 0.813 gms

NbC 0.272 gms
 ZrC .541 gms

Figure 61

Reduced Data Tabulation for an 0.006-inch NbC-ZrC Gap Ser. No. 3

<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1	2	3	4	5	1	2	3	4	5
.0021	.0022	.0025	.0025	.0025	.0014	.0018	.0015	.0015	.0018
6	7	8	9	10	6	7	8	9	10
.0022	.0023	.0024	.0024	.0024	.0022	.0024	.0023	.0022	.0021
11	12	13	14	15	11	12	13	14	15
.0022	.0023	.0024	.0024	.0024	.0023	.0025	.0024	.0024	.0022
16	17	18	19	20	16	17	18	19	20
.0024	.0024	.0026	.0026	.0026	.0023	.0025	.0025	.0025	.0024
21	22	23	24	25	21	22	23	24	25
.0029	.0029	.0020	.0028	.0028	.0025	.0025	.0025	.0024	.0025
26	27	28	29	30	26	27	28	29	30
.0028	.0028	.0028	.0027	.0024	.0025	.0025	.0024	.0024	.0020
31	32	33	34	35	31	32	33	34	35
.0028	.0027	.0027	.0026	.0024	.0023	.0025	.0025	.0022	.0016
36	37	38	39	40	36	37	38	39	40
.0025	.0025	.0025	.0023	.0020	.0025	.0026	.0024	.0024	.0020
41	42	43	44	45	41	42	43	44	45
.0022	.0023	.0023	.0021	.0018	.0016	.0014	.0014	.0013	.0014

Upper Half
 Width Measurement

1 - .995
 2 - .997
 3 - .997
 4 - .997
 5 - .997
 6 - .998
 7 - .997
 8 - .995
 9 - .996

Lower Half
 Width Measurement

1 - 1.011
 2 - 1.018
 3 - 1.020
 4 - 1.026
 5 - 1.019
 6 - 1.025
 7 - 1.021
 8 - 1.018
 9 - 1.013

Figure 62
 Measurements Taken On 0.006" Gap Fixture - Before Test
 NbC - ZrC Serial No.3

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Upper Half Depth Measurement

1 .0025	2 .0027	3 .0029	4 .0028	5 .0026
6 .0028	7 .0029	8 .0030	9 .0030	10 .0029
11 .0030	12 .0031	13 .0032	14 .0032	15 .0030
16 .0031	17 .0032	18 .0032	19 .0032	20 .0031
21 .0030	22 .0031	23 .0032	24 .0032	25 .0031
26 .0029	27 .0029	28 .0030	29 .0030	30 .0029
31 .0027	32 .0027	33 .0027	34 .0028	35 .0027
36 .0023	37 .0023	38 .0023	39 .0023	40 .0023
41 .0018	42 .0018	43 .0019	44 .0019	45 .0018

Lower Half Depth Measurement

1 .0020	2 .0034	3 .0024	4 .0044	5 .0032
6 .0023	7 .0023	8 .0022	9 .0022	10 .0021
11 .0023	12 .0023	13 .0022	14 .0022	15 .0022
16 .0024	17 .0024	18 .0023	19 .0023	20 .0022
21 .0024	22 .0024	23 .0023	24 .0022	25 .0020
26 .0023	27 .0023	28 .0023	29 .0023	30 .0020
31 .0023	32 .0023	33 .0022	34 .0022	35 .0018
36 .0021	37 .0022	38 .0020	39 .0020	40 .0018
41 .0016	42 .0018	43 .0017	44 .0017	45 .0043

Upper Half
Width Measurement

1 -	.9910
2 -	.9881
3 -	.9902
4 -	.9909
5 -	.9946
6 -	.9948
7 -	.9977
8 -	.9925
9 -	.9892

Lower Half
Width Measurement

1 -	Corroded Full Width
2 -	1.0370
3 -	1.0531
4 -	1.0439
5 -	1.0420
6 -	1.0362
7 -	1.0384
8 -	1.0418
9 -	1.0302

Figure 63
Measurements Taken On 0.006" Gap Fixture - After Test
NbC - ZrC Serial No.3

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Figure 64
Surfaces of .006" NbC - ZrC Flow
Slot After H₂ Test

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Figure 65
Inlet Faces of .006" NbC-ZrC
Flow Slot After Hydrogen Test

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Figure 66
Surfaces of the .006" NbC-ZrC Flow
Slot Ser. # 4 Before Test

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar - 29.32 in. Hg @ 74°F 0.006-inch NbC-ZrC Gap Serial No. 4

Point Number	Time Min	Rig ΔP psid	Gas Inlet Temp. °R	Gas Exit Temp. °R	Av. Mtl. Inlet Temp. °R	Av. Mtl. Exit Temp. °R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	0	5.0	514.8	1825	3412	3512	.0000793	208
2	5	9.3	519.0	2000				208

Aborted 12 min. 34 sec

Initial Gap 0.006 inch
Total weight loss 0.846 gms

NbC 0.101 gms
ZrC 0.745 gms

Figure 67

Reduced Data Tuabulation for an 0.006-inch NbC-ZrC Gap Ser. No. 4

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0028	2 .0027	3 .0028	4 .027	5 .0027	1 .0017	2 .0017	3 .0020	4 .0021	5 .0021
6 .0014	7 .0015	8 .0016	9 .0018	10 .0019	6 .0019	7 .0022	8 .0022	9 .0022	10 .0022
11 .0018	12 .0019	13 .0021	14 .0020	15 .0022	11 .0022	12 .0024	13 .0024	14 .0025	15 .0026
16 .0018	17 .0020	18 .0021	19 .0020	20 .0019	16 .0021	17 .0023	18 .0025	19 .0027	20 .0027
21 .0015	22 .0020	23 .0020	24 .0021	25 .0019	21 .0027	22 .0024	23 .0024	24 .0025	25 .0025
26 .0019	27 .0021	28 .0020	29 .0020	30 .0020	26 .0021	27 .0022	28 .0023	29 .0024	30 .0024
31 .0019	32 .0021	33 .0021	34 .0021	35 .0019	31 .0023	32 .0024	33 .0025	34 .0027	35 .0026
36 .0019	37 .0020	38 .0020	39 .0019	40 .0017	36 .0025	37 .0025	38 .0026	39 .0026	40 .0026
41 .0018	42 .0013	43 .0013	44 .0015	45 .0015	41 .0017	42 .0013	43 .0013	44 .0015	45 .0015

Upper Half
Width Measurement

1 - 1.014
 2 - 1.012
 3 - 1.0115
 4 - 1.016
 5 - 1.014
 6 - 1.014
 7 - 1.014
 8 - 1.025
 9 - 1.028

Lower Half
Width Measurement

1 - .994
 2 - 1.003
 3 - 1.004
 4 - 1.0035
 5 - 1.003
 6 - 1.003
 7 - 1.003
 8 - 1.003
 9 - 1.001

Figure 68
 Measurements Taken On 0.006" Gap Fixture - Before Test
 NbC - ZrC Serial No.4

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1	2	3	4	5	1	2	3	4	5
.0071	.0070	.0085	.0082	.0075	.0016	.0021	.0021	.0024	.0024
6	7	8	9	10	6	7	8	9	10
.0074	.0061	.0060	.0083	.0059	.0021	.0023	.0025	.0026	.0027
11	12	13	14	15	11	12	13	14	15
.0076	.0068	.0075	.0077	.0069	.0023	.0025	.0027	.0028	.0029
16	17	18	19	20	16	17	18	19	20
.0069	.0077	.0062	.0075	.0066	.0024	.0026	.0028	.0029	.0030
21	22	23	24	25	21	22	23	24	25
.0069	.0078	.0075	.0082	.0070	.0024	.0026	.0028	.0029	.0030
26	27	28	29	30	26	27	28	29	30
.0069	.0063	.0068	.0070	.0058	.0024	.0026	.0027	.0028	.0028
31	32	33	34	35	31	32	33	34	35
.0060	.0058	.0058	.0066	.0035	.0022	.0024	.0026	.0027	.0027
36	37	38	39	40	36	37	38	39	40
.0047	.0066	.0058	.0051	.0034	.0021	.0022	.0024	.0025	.0025
41	42	43	44	45	41	42	43	44	45
.0042	.0057	.0056	.0046	.0051	.0018	.0021	.0023	.0024	.0023

Upper Half Width Measurement

- 1 - Corroded Full Width
- 2 - 1.0272
- 3 - 1.0340
- 4 - 1.0335
- 5 - 1.0297
- 6 - 1.0287
- 7 - 1.0309
- 8 - 1.0302
- 9 - Corroded Full Width

Lower Half Width Measurement

- 1 - .9936
- 2 - .9939
- 3 - .9949
- 4 - .9951
- 5 - .9939
- 6 - .9931
- 7 - .9941
- 8 - .9931
- 9 - .9938

Figure 69
Measurements Taken On 0.006" Gap Fixture - After Test
NbC - ZrC Serial No.4

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Figure 70
Surfaces of .006" NbC-ZrC Flow Slot
Ser. # 4 After Test

Figure 71
Surfaces of .006" NbC - Graphitite "G"
Flow Slot Ser. #6 Prior to Test

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Reduced Data Tabulation For HHT-6.2 Corrosion Tests

P Bar = 29.40 in. Hg @ 74°F 0.006-inch NbC-Graphitite "G" Gap Serial No. 6

Point Number	Time Min	Rig ΔP psid	Av. Gas Inlet Temp.°R	Av. Gas Exit Temp.°R	Av. Mtl. Inlet Temp.°R	Av. Mtl. Exit Temp.°R	Av. Flow lb/sec H ₂	Inlet Pressure psig
1	0	12.0	520.4	2048	3516	3509	.0000654	106
2	5	10.3						106
3	10	9.5						105
4	15	8.0						106
5	20	6.8						106
6	25	5.6						106
7	28	4.9						106

Samples
 Taken 29
 He To
 fixture 30

Initial Gap 0.006 inch
 Total weight loss 1.095 gms

NbC 0.164 gms
 "G" 0.931 gms

Figure 72

Reduced Data Tabulation for an 0.006-inch NbC-Graphitite "G" Gap Ser. No. 6

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<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0032	2 .0035	3 .0035	4 .0035	5 .0033	1 .0026	2 .0030	3 .0028	4 .0025	5 .0027
6 .0036	7 .0037	8 .0037	9 .0036	10 .0036	6 .0028	7 .0029	8 .0029	9 .0029	10 .0028
11 .0038	12 .0039	13 .0039	14 .0038	15 .0037	11 .0027	12 .0030	13 .0029	14 .0032	15 .0028
16 .0039	17 .0039	18 .0039	19 .0039	20 .0039	16 .0028	17 .0029	18 .0029	19 .0029	20 .0027
21 .0038	22 .0039	23 .0039	24 .0039	25 .0039	21 .0028	22 .0030	23 .0029	24 .0029	25 .0027
26 .0037	27 .0037	28 .0038	29 .0037	30 .0038	26 .0029	27 .0030	28 .0029	29 .0029	30 .0027
31 .0036	32 .0036	33 .0034	34 .0037	35 .0037	31 .0029	32 .0030	33 .0031	34 .0030	35 .0029
36 .0035	37 .0035	38 .0035	39 .0036	40 .0036	36 .0029	37 .0031	38 .0032	39 .0030	40 .0029
41 .0034	42 .0033	43 .0035	44 .0035	45 .0035	41 .0032	42 .0033	43 .0033	44 .0032	45 .0029

Upper Half
Width Measurement

1 - 1.0255
2 - 1.0225
3 - 1.0238
4 - 1.0215
5 - 1.0214
6 - 1.0208
7 - 1.0212
8 - 1.0216
9 - 0.0200

Lower Half
Width Measurement

1 - 1.0189
2 - 1.0188
3 - 1.0192
4 - 1.0186
5 - 1.0188
6 - 1.0186
7 - 1.0189
8 - 1.0183
9 - 1.0191

Figure 73
Measurements Taken On 0.006" Gap Fixture - Before Test
NbC-Graphitite "G" - Serial No.6

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Astronuclear
Laboratory

WANI-TME-1430

<u>Upper Half Depth Measurement</u>					<u>Lower Half Depth Measurement</u>				
1 .0031	2 .0033	3 .0071	4 .0033	5 .0033	1 .0346	2 .0285	3 .0311	4 .0298	5 .0286
6 .0059	7 .0042	8 .0040	9 .0039	10 .0039	6 .0162	7 .0220	8 .0246	9 .0202	10 .0162
11 .0080	12 .0074	13 .0049	14 .0080	15 .0052	11 .0086	12 .0108	13 .0102	14 .0105	15 .0060
16 .0090	17 .0071	18 .0041	19 .0080	20 .0087	16 .0065	17 .0103	18 .0088	19 .0100	20 .0068
21 .0036	22 .0036	23 .0037	24 .0039	25 .0051	21 .0085	22 .0103	23 .0085	24 .0098	25 .0053
26 .0039	27 .0038	28 .0039	29 .0039	30 .0039	26 .0073	27 .0097	28 .0088	29 .0080	30 .0044
31 .0039	32 .0038	33 .0037	34 .0036	35 .0039	31 .0048	32 .0086	33 .0086	34 .0075	35 .0039
36 .0035	37 .0035	38 .0034	39 .0034	40 .0035	36 .0030	37 .0077	38 .0075	39 .0066	40 .0031
41 .0030	42 .0030	43 .0030	44 .0031	45 .0031	41 .0032	42 .0065	43 .0064	44 .0049	45 .0026

Upper Half
Width Measurement

1 - 1.027
2 - 1.022
3 - 1.022
4 - 1.029
5 - 1.037
6 - 1.020
7 - 1.019
8 - 1.020
9 - 1.017

Lower Half
Width Measurement

1 - 1.022
2 - 1.029
3 - 1.025
4 - 1.026
5 - 1.020
6 - 1.025
7 - 1.020
8 - 1.018
9 - 1.007

Figure 74
Measurements Taken On 0.006" Gap Fixture - After Test
NbC-Graphitite "G" - Serial No.6

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

Figure 75
Surfaces of .006" NbC Graphitite "G"
Flow Slot No. 6 After Test

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

**Astronuclear
Laboratory**
WANL-THE-1430

APPENDIX B

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

POINT	TIME	AET*	P O1 PSIG	ΔP O1 IN H ₂ O	H ₂ O FLOW GPM	ΔP 1-2 PSID	P 1 PSIG	P 2 PSIG	T MT1 MV	T MT2 MV	P IR PSIG	P OR PSIG	POWER INPUT		HASTINGS FLOW METER 500 CM ³ /HR	REMARKS
													VOLTS	AMPS		
	12:28		210	4.0	2.5	0.5	210				2260	345			14500	COLD HELIUM
	13:05		214	3.9	2.5	9.05	214		29.01	2250	350	29	980	14500		1240 POWER ON HOT HE THIS READING 13:07 SWITCH TO H ₂
1	13:10	0	210	4.8	3.65	5.01	210		28.76	28.77	1214	365	29	980	28750	
2	13:14	4	212	4.5	2.6	3.6	212		28.48	28.65	1210	365	29	980	27750	
3	13:18	8	210	4.5	2.95	3.65	210		28.44	28.62	1210	365	29	975	28,000	
4	13:22	12	209	4.8	2.5	2.65	208		28.42	28.58	1210	365	29	980	28,000	
5	13:26	16	206	4.9	2.65	2.42	206		28.42	28.58	1210	365	29	975	28,000	
6	13:30	20	208	4.8	2.7	2.2	208		28.48	28.54	1210	365	29	975	28,000	
7	13:34	24	208	4.8	2.65	2.1	208		28.35	28.41	1210	365	29	980	28,000	INCREASE 10 AMPS
8	13:38	28	208	4.8	2.65	2.05	208		28.64	28.69	1210	365	29.5	990	28,000	INDICATION OF LEAK IN SYSTEM SAMPLE TAKEN / Leak in He System
	13:39	29														SWITCH TO HE
	13:40	30														START TEMP. DECREASE
9	13:43		200	4.5	2.65	3.0	200		20.00	2250	350	23.0	330	15,300		WARM HE READING
	13:46															CONTINUE TEMP. DECREASE
	13:56		196	4.8	2.65	.4	196		.46	2250	350	0	0	15,200		POWER OFF COLD HE

* ACCUMULATED ELAPSED TIME IN MINUTES

FLUID FLOW LAB
LOG SHEET
HHTG INTERSTITIAL CORROSION

TEST BUILD NO. 1

TEST RECORD BOOK NO. _____ RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1300 hrs DATE 4 Aug 65
ENGINEER R.J. Steffen OPERATOR Foltis, Norm
BAR PRESSURE 29.340 75 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1200 PSI SUPPLY PRESSURE AFTER 1400 PSI
SUPPLY TEMP BEFORE 22 °F SUPPLY TEMP AFTER 21 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A.006 INCHES TYPICAL 213-217

ORIFICE SIZE
ORIFICE 01.046 INCHES

DRAWN BY J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

UPPER HALF OF GRAPHITE TEST FIXTURE

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H-J	WEIGHT
	PRIOR TO TEST	.6688	.6685	.6683	.668	.6679	.6680	.668	.668	34
	AFTER TEST	x	.6675	.6537	.6595	.6605	.6635	.665	.666	38.6949

REMARKS
USED FLAT HEAD MIC'S FOR DIMENSIONING

LOWER HALF OF GRAPHITE TEST FIXTURE

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H-J	WEIGHT
	PRIOR TO TEST	.6688	.6688	.6688	.6688	.6688	.6688	.6688	.6688	40.2208
	AFTER TEST	x	.668	.654	.6585	.663	.664	.666	.666	38.8869

REMARKS
USED FLAT HEAD MIC'S FOR DIMENSIONING.

WT OF ALUMINUM TRAY 1.3222 + RESIDUE 1.6719
WT OF RESIDUE FROM GRAPHITE TEST
PIECE AFTER TEST .3497

NOTE: POSSIBILITY OF SOME MOLY FRAGMENTS
MIXED IN WITH GRAPHITE

REMARKS

Total wt loss due to corrosion
2.3627 gms.

WEIGHT OF GRAPHITE
HEATER ELEMENT

WEIGHT	
BEFORE TEST	
AFTER TEST

FLUID FLOW LAB
DATA SHEET
HHTG INTERSTITIAL CORROSION
TEST BUILD NO. /

TEST RECORD BOOK NO. / RUN NO. / SHEET / OF /
TIME OF DAY 1300 hrs DATE 4 Aug 65
ENGINEER R.J. Steffen OPERATOR Sotter Horn
BAR PRESSURE 29.34 @ 75 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1200 PSI SUPPLY PRESSURE AFTER 1150 PSI
SUPPLY TEMP BEFORE 80 °F SUPPLY TEMP AFTER 81 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION ASSEMBLY NO
DIMENSION A .006 INCHES TYPICAL 213-217
ORIFICE SIZE
ORIFICE OF .046 INCHES

DRAWN BY: J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act, 1954

FLUID FLOW LAB

LOG SHEET

HHTG INTERSTITIAL CORROSION

TEST BUILD NO. 1

TEST RECORD BOOK NO _____ RUN NO 1 SHEET 1 OF 1
TIME OF DAY 1400 DATE 30 Aug 65
ENGINEER R.J. Steffen OPERATOR E. Soltis, E. Kennedy
BAR PRESSURE 29.52 @ 74 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1400 PSI SUPPLY PRESSURE AFTER 1000 PSI
SUPPLY TEMP BEFORE 74 °F SUPPLY TEMP AFTER 74 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A.004 INCHES TYPICAL 212-216

ORIFICE SIZE
ORIFICE 01.046 INCHES

DRAWN BY J.R.KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

[illegible]

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

UPPER HALF OF GRAPHITE TEST FIXTURE

DIM'S	REMARKS
DIM'S TAKEN WITH DEPTH MIC'S AT PTS. INDICATED	

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	J	WEIGHT
	PRIOR TO TEST	.0025	.002	.0015	.002	.002	.0025	.0025	.0025	.0025	AFTER DIM CHECK 39.8471
	AFTER TEST										BEFORE DIM CHECK 38.9225

LOWER HALF OF GRAPHITE TEST FIXTURE

DIM'S	REMARKS
DIM'S TAKEN WITH DEPTH MIC'S AT PTS. INDICATED	

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	J	WEIGHT
	PRIOR TO TEST	.002	.002	.002	.0025	.0025	.002	.0022	.0022	.002	AFTER DIM CHECK 39.9338
	AFTER TEST										BEFORE DIM CHECK 38.8926

		PRIOR TEST	AFTER TEST	
1	SMALL SEAL	22.0427	22.0469	+ .0042
2	LARGE CAP	411.78	411.81	+ .03
3	OUTER CAN	1107.7	1095.0	- 12.7
4	SPECIMEN HOLDER INNER CAN	865.0	865.2	+ .2
5	LARGE SEAL	42.6851	42.6947	+ .0004
6	SPECIMEN SUPPORTS	77.2216	77.2507	+ .0281
7	"	77.5753	77.6048	+ .0295
8	SMALL CAP	65.0387	65.0229	- .0108
TOTAL	1, 2, 3, 5, 6, 7, 8, 9, 10	1641.2	1639.4	- 1.8

WEIGHT OF GRAPHITE
HEATER ELEMENT

WEIGHT
BEFORE TEST
AFTER TEST

REMARKS

Westinghouse Astronuclear Laboratory
Pittsburgh, Pennsylvania

FLUID FLOW LAB
DATA SHEET
HHTG INTERSTITIAL CORROSION
TEST BUILD NO. 1

TEST RECORD BOOK NO. RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1400 DATE 30 Aug 65
ENGINEER R.J. Steffen OPERATOR Soltis, Kennedy
BAR PRESSURE 29.52 @ 74 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 400 PSI SUPPLY PRESSURE AFTER 1000 PSI
SUPPLY TEMP BEFORE 74 °F SUPPLY TEMP AFTER 74 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING INHG

CONFIGURATION ASSEMBLY NO
DIMENSION A 204 INCHES TYPICAL 212-216

ORIFICE SIZE
ORIFICE OI .046 INCHES

DRAWN BY: J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

POINT	TIME	AET*	P	ΔP	H ₂ O	ΔP	P ₁	P ₂	T ₁	T	P	P	POWER		Hastings Flow Meter Std cc/min H ₂	REMARKS
			O1 PSIG	O1 IN H ₂ O	FLOW GPM	I-2 PSID	I PSIG	I PSIG	MT1 MV	MT2 MV	IR PSIG	OR PSIG	VOLTS	AMPS		
#1	1346		210	2.3		12.1					990	350			14,200	COLD HELIUM
	1350															COLD H ₂ - 1 MIN FOR H ₂ TO
	1359		208	4.8		11.6					990	350			28,100	REACH TEST PIECE
	1400															1.5 FOR HELIUM TO REACH
	1408		210	3.2		14.1					980	350				TEST PIECE
	1408		210	3.2		14.1					980	350			12,800	COLD READING ON HELIUM
	1415															POWER ON
	1437		299	1.0	2.6	1.14				2864	930	350	32.0	1060	8,800	HOT HELIUM
#1	1400	0	293	2.0	2.5	110.0				2840	1280	350	32.0	1060	23,500	HYDROGEN IN
#2	1405	5	258	4.0	3.2	99.0				2831	1280	350	32.0	1060	28,500	
#3	1411	11	230	4.3	3.2	58.0				2928	1280	350	32.3	1055	29,000	
#4	1416	16	226	4.8	3.0	30.5				2841	1280	350	30.8	1010	30,500	
#5	1420	20	240	4.0	3.2	22.0				2830	1280	350	31.0	1020	28,000	
#6	1425	25	237	4.1	3.0	10.3				2834	1280	350	31.5	1030	28,000	
#7	1428.5	28.5	244	3.5	3.1	5.8				2836	1280	350	31.5	1030	27,250	
	1429	29														SAMPLE CHANGE TO HELIUM
	1430	30														HELIUM REACHED TEST PIECE

* ACCUMULATED ELAPSED TIME IN MINUTES

* ACCUMULATED ELAPSED TIME IN MINUTES

Westinghouse Astronuclear Laboratory
Pittsburgh, Pennsylvania

FLUID FLOW LAB
LOG SHEET
HHTG INTERSTITIAL CORROSION
TEST BUILD

TEST RECORD BOOK NO _____ RUN NO 1 SHEET 1 OF 1
TIME OF DAY 1400 DATE 22 Sept 65
ENGINEER R.J. Steffen OPERATOR E. Solis, E. Kennedy
BAR PRESSURE 28.4 @ 88 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 280 PSI SUPPLY PRESSURE AFTER 270 PSI
SUPPLY TEMP BEFORE 88 °F SUPPLY TEMP AFTER 88 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A .002 INCHES TYPICAL _____

ORIFICE SIZE
ORIFICE 01.046 INCHES

DRAWN BY J.R.KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

UPPER HALF OF GRAPHITE TEST FIXTURE

REMARKS
ROUGH SEALING SEALING SURFACE ON GRAPHITE ON RIGHT SIDE AT CONTACT POINT BETWEEN GRAPHITE SPECIMEN AND GUIDE

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 39.9230
	AFTER TEST									BEFORE DIM CHECK 38.8716

- 1.0514

LOWER HALF OF GRAPHITE TEST FIXTURE

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 40.6454
	AFTER TEST									BEFORE DIM CHECK 39.1869
1	OUTER CAN	1095.0								
2	INNER CAN	865.5		865.9						+ .4
3	LARGE CAP	411.7		411.72						+ .02
4	SMALL CAP	65.0244		65.0203						- .0041
5	LARGE SEAL	42.6950		42.6937						- .0013
6	SMALL SEAL	22.0419		22.0418						- .0001
7	SPECIMEN UPPER GUIDE	77.7977		77.8372						+ .0395
8	SPECIMEN LOWER GUIDE	77.5452		77.6256						+ .0804
9	TOTALS - 2, 3, 4	1642.8		1640.9						- 1.9
9	5, 6, 7, 8 ASSEMBLED									

- 1.4585
- 1.0514
- 2.5099 TOTAL WT LOSS OF GRAPHITE SPECIMENS

REMARKS
ALL PIECES CLEANED WITH ACETONE PRIOR WEIGHTS AND HANDLED WITH GLOVES

WEIGHT OF GRAPHITE HEATER ELEMENT

WEIGHT
BEFORE TEST
AFTER TEST

FLUID FLOW LAB
DATA SHEET
HHTG INTERSTITIAL CORROSION TEST BUILD NO. 1

TEST RECORD BOOK NO. RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1400 DATE 22 Sept 65
ENGINEER RJ Steffen OPERATOR E. Soltes, E. van der
BAR PRESSURE 2041 @ 88 °F OF TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1250 PSI SUPPLY PRESSURE AFTER 1270 PSI
SUPPLY TEMP BEFORE 88 °F SUPPLY TEMP AFTER 125 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING INHG

CONFIGURATION ASSEMBLY NO
DIMENSION A-202 INCHES TYPICAL

ORIFICE SIZE
ORIFICE 01 .046 INCHES

DRAWN BY: J.R KUZMA
ENGINEER BOB STEFFEN
D. SPEC. 751523AG

POINT	TIME	AET*	P O1	^{ORIFICE} ΔP O1	H ₂ O FLOW	ΔP 1-2	P 1	P 2	T MT1	T MT2	P 1R	P OR	POWER INPUT		Hasting Flow meter Std cu/m H ₂	REMARKS
			PSIG ORIFICE	IN H ₂ O	GPM	PSID	PSIG	PSIG	MV	MV	PSIG	PSIG	VOLTS	AMPS		
1	1330		221	.3	2.9	6.5					1080	330	—	—	4100	COLD HE
	1334															POWER ON
2.	1352		226	.3	2.9	102			28.5	28.51	1070	330	32.6	1070	3900	HOT HE
1	1400		224	.3	3.0	98				28.5	2120	310	32.8	1070	6900	HOT H ₂
2	1405		222	.3	3.1	100					2120	310	33	1070	9000	Thermocouples going bad.
3	1410		223	.3	3.0	101					2120	310	32.5	1060	9100	
4	1413															SHUT DOWN POWER OFF SWITCH TO HE
																Both High temperature Thermocouples went out Test aborted.

* ACCUMULATED ELAPSED TIME IN MINUTES

* ACCUMULATED ELAPSED TIME IN MINUTES

Westinghouse Astronuclear Laboratory
Pittsburgh, Pennsylvania

FLUID FLOW LAB

LOG SHEET

HHTG INTERSTITIAL CORROSION

TEST

BUILD NO 1

TEST RECORD BOOK NO _____ RUN NO 1 SHEET 1 OF 1

TIME OF DAY 1400 hrs DATE 5 October 65

ENGINEER R.J. Steffen OPERATOR Soltis Lesley

BAR PRESSURE 29.61 @ 72 °F TEST GAS Hydrogen

SUPPLY PRESSURE BEFORE 2080 PSI SUPPLY PRESSURE AFTER 2025 PSI

SUPPLY TEMP BEFORE 60 °F SUPPLY TEMP AFTER 60 °F

VACUUM PRIOR TO TESTING 28 INHG

VACUUM AFTER TESTING IN HG

CONFIGURATION ASSEMBLY NO.
DIMENSION A-001 INCHES TYPICAL _____

ORIFICE SIZE
ORIFICE 01.046 INCHES

DRAWN BY J. R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

UPPER HALF OF GRAPHITE TEST FIXTURE

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 40.3875
	AFTER TEST									BEFORE DIM CHECK 40.045

LOWER HALF OF GRAPHITE TEST FIXTURE

REMARKS
PIT LOCATED ALONG ONE SEALING EDGE OF SPECIMEN APPROX 3/4 OF THE WAY FROM INLET

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 40.0711
	AFTER TEST									BEFORE DIM CHECK 39.686

		PRIOR TEST	AFTER TEST
1	OUTER CAN	NO WTS TAKEN	
2	INNER CAN	865.6	
3	LARGE CAP	411.72	
4	SMALL CAP	65.0207	65.019
5	LARGE SEAL	42.6942	42.695
6	SMALL SEAL	22.0424	
7	LARGE SPECIMEN	78.3771	78.411
8	LOWER GUIDE	78.2039	78.226
9	TOTAL 2,3,4,5		

WEIGHT OF GRAPHITE
HEATER ELEMENT

WEIGHT
BEFORE TEST
AFTER TEST

REMARKS

FLUID FLOW LAB
DATA SHEET
HHTG INTERSTITIAL CORROSION
TEST BUILD NO. /

TEST RECORD BOOK NO. / RUN NO. / SHEET / OF /
TIME OF DAY 1400 hrs DATE 5 October 65
ENGINEER R.J. Steffen OPERATOR Soltis, Wesley
BAR PRESSURE 29.61 @ 72 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 200 PSI SUPPLY PRESSURE AFTER 200 PSI
SUPPLY TEMP BEFORE 60 °F SUPPLY TEMP AFTER 60 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION DIMENSION A .001 INCHES TYPICAL ASSEMBLY NO. /

ORIFICE SIZE
ORIFICE 01.046 INCHES

DRAWN BY: J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

Westinghouse Astronuclear Laboratory
Pittsburgh, Pennsylvania

FLUID FLOW LAB

LOG SHEET

HHTG INTERSTITIAL CORROSION

TEST BUILD NO. 1

TEST RECORD BOOK NO. _____ RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1000 DATE 11 Nov 65
ENGINEER R.I. Steffen OPERATOR Solis, Lashley
BAR PRESSURE 29.58 @ 75 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1500 PSI SUPPLY PRESSURE AFTER 1400 PSI
SUPPLY TEMP BEFORE 70 °F SUPPLY TEMP AFTER 70 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING _____ INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A.006 INCHES TYPICAL Nbc - Graphite #5

ORIFICE SIZE
ORIFICE OI.046 INCHES

DRAWN BY J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

POINT	TIME	AET*	P OI PSIG	ΔP OI IN H ₂ O	H ₂ O FLOW GPM	ΔP 1-2 PSID	P 1 PSIG	P 2 PSIG	T MT1 MV	T MT2 MV	P IR PSIG	P OR PSIG	POWER INPUT		Hastings Flowmeter std cu/min H ₂	REMARKS
			VOLTS	AMPS												
			210	1.8	0	.8					2100	275				cold He 10,100
	1413															cold H ₂ (introducing)
	1417 ²⁵	acc														cold H ₂ 19,000
	1421		210	2.0	0	.6					1600	280				cold H ₂ 24,500
	1423															cold He (switch to HE)
	1423 ⁵⁰	acc														Hastings decreasing
	1425 ¹⁰	acc														HE (shut down)
																ABOVE READING 3 11/12/65
11/11/65																
	0916		208	2.5	—	10				—	720	300	—	—	13,100	HE (COLD)
			208	2.0	2.8	8.4				28.95	680	300	29	980	11,300	HE (HOT)
#1	1000		208	2.5	2.8	5.8				28.93	1575	280	29	980	30,000	H ₂ (HOT)
#2	1005		210	2.0	2.8	3.8				28.82	1575	280	29	980	21,500	H ₂ (")
#3	1010		210	2.0	2.8	3.4				29.06	1575	280	29.5	980	22,000	H ₂ (")
#4	1015		210	2.1	2.8	3.0				29.20	1575	280	29.5	980	24,500	H ₂ (")
#5	1020		210	2.4	2.8	2.5				29.12	1575	280	29.5	980	27,000	H ₂ (")
#6	1025		210	2.0	2.8	2.0				28.94	1575	280	29.5	980	23,800	H ₂ (")
#7	1028 ³⁰		210	2.3	2.8	1.95				28.86	1575	280	29.5	980	28,000	H ₂ (")
	1029															
	1030															SWITCH TO HE
	1031 ¹⁵															HE TO FIXTURE
	1032															CUTTING POWER
	1034															POWER OFF
																INLET TRIM "N"
																OUTLET " " "
																ATMOS HE " " "
																CONTROL IN - 195
																" OUT - 250 to 260
																PROPORTIONAL-IN 100%
																" - OUT 100%
* ACCUMULATED ELAPSED TIME IN MINUTES																IN RESET-.03 OUT-.2

* ACCUMULATED ELAPSED TIME IN MINUTES

UPPER HALF OF GRAPHITE TEST FIXTURE

GRAPHITE
(NON COATED)

5

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 41.214
	AFTER TEST									BEFORE DIM CHECK 40.018

-1.196

LOWER HALF OF GRAPHITE TEST FIXTURE

NI OBIUM
COATED

5

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 41.255
	AFTER TEST									BEFORE DIM CHECK 40.857

- .398

Lower Slide - 77.093
Upper Slide - 77.462

REMARKS

WEIGHT OF GRAPHITE
HEATER ELEMENT

WEIGHT	
BEFORE TEST	
AFTER TEST

FLUID FLOW LAB
DATA SHEET
HHTG INTERSTITIAL CORROSION
TEST BUILD NO. 1

TEST RECORD BOOK NO. / RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1000 DATE 11 Nov 65
ENGINEER R.J. Steffen OPERATOR Galtis, Lashley
BAR PRESSURE 29.52 @ 75 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 500 PSI SUPPLY PRESSURE AFTER 400 PSI
SUPPLY TEMP BEFORE 70 °F SUPPLY TEMP AFTER 70 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A .006 INCHES TYPICAL N6c-Graphite #5

ORIFICE SIZE
ORIFICE OI .046 INCHES

DRAWN BY: J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

FLUID FLOW LAB

LOG SHEET

HHTG INTERSTITIAL CORROSION

TEST BUILD NO. 1

TEST RECORD BOOK NO. RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1400 DATE 1 Dec 65
ENGINEER R.T. Steffen OPERATOR Soltis Lashley
BAR PRESSURE 29.56 @ 71 °F TEST GAS Helium
SUPPLY PRESSURE BEFORE 1200 PSI SUPPLY PRESSURE AFTER 1100 PSI
SUPPLY TEMP BEFORE 58 °F SUPPLY TEMP AFTER 58 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A .006 INCHES TYPICAL 3 No. C-2rc

ORIFICE SIZE
ORIFICE OI .046 INCHES

DRAWN BY J. R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

POINT	TIME	AET*	P OI	ΔP OI	H2O FLOW	ΔP 1-2	P 1	P 2	T MT1	T MT2	P IR	P OR	POWER INPUT		HASTINGS FLOW METER STD CC/MIN H2	REMARKS
			PSIG	IN H2O	GPM	PSID	PSIG	PSIG	MV	MV	PSIG	PSIG	VOLTS	AMPS		
	1034		210	25	-	.7	-	-			290	1080			11,600	COLD HE
	1039															
	1333		214	30	-	.8					290	1080			14,300	COLD HE
	1335															POWER ON
# 1	1355		214	25	32	11.5			29.21 29.42		290	1080	296	980	8,500	HOT HE
# 2	1400		214	1.8	31	12.4			29.21 29.42		290	1080	29.5	980	10,700	HOT HE
# 3	1405		214	1.1	30	10.4			29.19		290	1080	29.4	980	8,400	HOT HE
# 4	1410		214	2.0	31	12.7			29.19		290	1080	29.5	980	10,200	HOT HE
# 5	1415		214	1.8	31	12.5			29.10		290	1075	29.2	970	10,100	HOT HE
# 6	1420		214	1.7	31	12.8			29.10		290	1075	29.4	975	10,400	HOT HE
# 7	1425		214	1.5	31	11.5			29.10		290	1075	29.2	970	8,900	HOT HE
	1426															POWER DECREASING
	1429															POWER OFF
	1431															Temp to 1500°F
	1434															Temp to 900°F
	1437															Temp to 400°F
	1445															Temp to 200°F

* ACCUMULATED ELAPSED TIME IN MINUTES

FLUID FLOW LAB

LOG SHEET

HHTG INTERSTITIAL CORROSION

TEST BUILD NO 2

TEST RECORD BOOK NO _____ RUN NO 2 SHEET 1 OF 1
TIME OF DAY 1400 DATE 10 Dec 65
ENGINEER RJ Steffen OPERATOR Soltis, Lashley
BAR PRESSURE 29.56 @ 74 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1500 PSI SUPPLY PRESSURE AFTER 1400 PSI
SUPPLY TEMP BEFORE 42 °F SUPPLY TEMP AFTER 42 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING _____ INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A .006 INCHES TYPICAL 3 NbC vs ZrC

ORIFICE SIZE
ORIFICE 01.046 INCHES

DRAWN BY J. R. KUZMA
ENGINEER- BOB STEFFEN
D. SPEC. 751523AG

Table 12

UPPER HALF OF GRAPHITE TEST FIXTURE

#3

NbC

REMARKS

* wt. after 30 min. Run at Temp in Helium.

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 41.405
	AFTER TEST									BEFORE DIM CHECK 41.403

GUIDE PRIOR He 79.111
79.110 Hz
AFTER He 79.111 *
79.124 Hz

LOWER HALF OF GRAPHITE TEST FIXTURE

#3

ZrC

REMARKS

* wt. after 30 min. Run at Temp in Helium.

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 41.235
	AFTER TEST									BEFORE DIM CHECK 41.229

GUIDE PRIOR He 78.591
78.590 Hz
AFTER He 78.591 *
78.624 Hz

REMARKS

SPECIMEN DEBR - 7.029
T.C. FRAGMENTS & DEBR - 7.145
OVERALL LOSS - 7.174

WEIGHT OF GRAPHITE
HEATER ELEMENT

WEIGHT
BEFORE TEST
AFTER TEST

Westinghouse Astronuclear Laboratory

Pittsburgh, Pennsylvania

FLUID FLOW LAB

DATA SHEET

HHTG INTERSTITIAL CORROSION
TEST

BUILD NO. 2

TEST RECORD BOOK NO. RUN NO. 2 SHEET 1 OF 1
TIME OF DAY 1400 DATE 10 Dec 65
ENGINEER R.J. Steffen OPERATOR Soltis, Lashley
BAR PRESSURE 29.55 @ 74 OF TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 500 PSI SUPPLY PRESSURE AFTER 1400 PSI
SUPPLY TEMP BEFORE 42 OF SUPPLY TEMP AFTER 42 OF
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION ASSEMBLY NO
DIMENSION A .006 INCHES TYPICAL 3 NbC vs ZrC

ORIFICE SIZE
ORIFICE OF .046 INCHES

DRAWN BY: J.R. KUZMA
ENGINEER BOB STEFFEN
D. SPEC. 751523AG

Westinghouse Astronuclear Laboratory
Pittsburgh, Pennsylvania

FLUID FLOW LAB
LOG SHEET
HHTG INTERSTITIAL CORROSION
TEST BUILD NO. 2

TEST RECORD BOOK NO. _____ RUN NO. 2 SHEET 1 OF 1
TIME OF DAY 1300 DATE 17 Jan 66
ENGINEER R.J. Steffen OPERATOR Seltis-Lashley
BAR PRESSURE 29.32 @ 74 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1500 PSI SUPPLY PRESSURE AFTER 40 PSI
SUPPLY TEMP BEFORE 30 °F SUPPLY TEMP AFTER 30 °F
VACUUM PRIOR TO TESTING 28" INHG
VACUUM AFTER TESTING _____ INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A .005 INCHES TYPICAL 4 N6C-Z1C

ORIFICE SIZE
ORIFICE OI .046 INCHES

DRAWN BY J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

POINT	TIME	AET*	P OI	ΔP OI	H2O FLOW	ΔP I-2	P I	P 2	T MT1	T MT2	P IR	P OR	POWER INPUT		HASTINGS "A"	REMARKS	HASTINGS "B"
			PSIG INLET	IN H2O	GPM	PSID	PSIG	PSIG	MV	MV	PSIG	PSIG	VOLTS	AMPS			
			210	10.5													
	1/13/66		210	6.0		165	—	—			1400	290	—	—	15,000	COLD HE	15,250
			210	10.5		1.4	—	—			1300	290	—	—	26,500	" H ₂	—
			210	6.0		1.6	—	—			1400	290	—	—	16,000	" HE	15,250
	1/14/66		208	6.8		1.8	—	—			1120	290	—	—	15,500	COLD HE	15,900
	1315															POWER ON	
	1338		208	6.0	3	17.3	—	—		2948	1280	290	23.4	790	14,750	HOT HE	15,000
#1	1345		208	5.0	3	7.2	—	—		28.25	1280	290	23.6	790	22,000		23,200
#2	1350		202	9.3	3	7.5	—	—		28.38	1280	290	24.0	800	26,100		—
#3	1355						—	—								BLEW LINE OFF	
*2	1357															12 min 34 sec	

Prior to the Third reading, the flow rate appeared to be very erratic. Attempts to regulate the flow rate resulted in fluctuations in inlet pressure. Adjustments of pop hand and reset time on the controller gave only temporary relief of the condition. Fluctuations in inlet pressure continued with increased severity. The decision was made to run the inlet valve on manual control to eliminate these fluctuations. When the change over from automatic to manual was made the valve was being closed to reduce the pressure surge when the change ~~over~~ was made. When the valve was put on manual control a pressure surge resulted which blew the Hydrogen inlet line off the Hydrogen delivery tube. The Test was immediately aborted by shutting off the power and Hydrogen. Helium was delivered to the vessel through the Helium atmosphere system. Initial inspection of the furnace showed the bellows which seals between the H₂ Delivery tube and the atmosphere to be stretched. This indicates that the Hydrogen delivery tube has failed as the cone gland slipped over the tube. The furnace will be opened and inspected.

* ACCUMULATED ELAPSED TIME IN MINUTES

UPPER HALF OF GRAPHITE TEST FIXTURE

4
ZrC

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 41.173
	AFTER TEST									BEFORE DIM CHECK 40.428

GUIDE - 78.744 - PRIOR TEST
78.757 AFTER "

LOWER HALF OF GRAPHITE TEST FIXTURE

4
NbC

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 41.592
	AFTER TEST									BEFORE DIM CHECK 41.491

GUIDE - 78.921 PRIOR TEST
78.927 AFTER "

TRAY + RESIDUE = 1.439
WT. OF TRAY = 1.380
RESIDUE .059

REMARKS

WEIGHT OF GRAPHITE
HEATER ELEMENT

WEIGHT
BEFORE TEST
AFTER TEST

FLUID FLOW LAB
DATA SHEET
HHTG INTERSTITIAL CORROSION
TEST BUILD NO. 2

TEST RECORD BOOK NO. _____ RUN NO. 2 SHEET 1 OF 1
TIME OF DAY 1300 DATE 17 Jan 65
ENGINEER R.J. Steffen OPERATOR Saltis-Kashley
BAR PRESSURE 29.32 @ 74 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1500 PSI SUPPLY PRESSURE AFTER 400 PSI
SUPPLY TEMP BEFORE 30 °F SUPPLY TEMP AFTER 30 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION ASSEMBLY NO
DIMENSION A .026 INCHES TYPICAL 4 N6C-R1C
ORIFICE SIZE
ORIFICE DI .046 INCHES

DRAWN BY: J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

FLUID FLOW LAB
LOG SHEET
HHTG INTERSTITIAL CORROSION

TEST BUILD NO. 1
TEST RECORD BOOK NO. RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1500 DATE 2 Feb 56
ENGINEER R J Steffen OPERATOR LeRoy Gorden
BAR PRESSURE 27.40 @ 74 °F TEST GAS Helium
SUPPLY PRESSURE BEFORE 140 PSI SUPPLY PRESSURE AFTER 140 PSI
SUPPLY TEMP BEFORE 25 °F SUPPLY TEMP AFTER 34 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING INHG

CONFIGURATION ASSEMBLY NO.
DIMENSION A .006 INCHES TYPICAL #5 W.C. Spec. 'G'

ORIFICE SIZE
ORIFICE OI .046 INCHES

DRAWN BY J. R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

HAND VALVE AP SET AT 5.0 2/3/66 JRS

POINT	TIME	AET*	P OI PSIG	ΔP OI IN H ₂ O	H ₂ O FLOW GPM	ΔP 1-2 PSID	P 1 PSIG	P 2 PSIG	T MT1 MV	T MT2 MV	P IR PSIG	P OR PSIG	POWER INPUT VOLTS AMPS	REMARKS HASTINGS A B
	1428		109	6.0	2.0	1.0	—	—	—		2060	285	—	11,900 11,250 COLD He
	1439	Power ON												
	1509		109	6.0	2.8	25.0	—	—	—	28.36	2000	285	24.7 760	11,400 11,300 HOT He
1.	0		110	8.0	2.6	12.0	—	—	—	28.67	1140	300	24.7 770	19,500 19,500 HOT He
2.	5		110	5.2	2.8	10.3	—	—	—	28.66	1140	300	25.0 764	18,600 19,600
3.	10		109	6.5	2.8	9.5	—	—	—	28.46	1140	300	24.5 760	19,250 20,750
4.	15		110	6.7	2.9	8.0	—	—	—	28.44	1140	300	24.5 800	19,300 21,000
5.	20		110	7.2	2.9	6.8	—	—	—	28.20	1140	300	24.0 800	20,600 21,800
6.	25		110	7.5	2.9	5.6	—	—	—	28.08	1140	300	24.0 800	20,900 21,900
7.	28		110	7.4	2.9	4.9	—	—	—	27.98	1140	300	24.2 800	20,750 21,750
	29	SAMPLE												
	30	SWITCHED TO He AND POWER DECREASE												

* ACCUMULATED ELAPSED TIME IN MINUTES

UPPER HALF OF GRAPHITE TEST FIXTURE

NiOBium
COATED

6

GUIDE WT

BEFORE TEST 79.243
AFTER TEST 79.255
F .012

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 41.260 41.225
	AFTER TEST									BEFORE DIM CHECK 41.061

LOSS - 00.164

LOWER HALF OF GRAPHITE TEST FIXTURE

GRAPHITE
(NON COATED)

6

GUIDE WT

BEFORE TEST 79.001
AFTER TEST 78.989
- .012

REMARKS

ITEM NO	CONFIGURATION	A	B	C	D	E	F	G	H	WEIGHT
	PRIOR TO TEST									AFTER DIM CHECK 40.868 40.836
	AFTER TEST									BEFORE DIM CHECK 39.905

LOSS - 00.931

REMARKS

WEIGHT OF GRAPHITE
HEATER ELEMENT

WEIGHT
BEFORE TEST
AFTER TEST

Westinghouse Astronuclear Laboratory

Pittsburgh, Pennsylvania

FLUID FLOW LAB

DATA SHEET

HHTG INTERSTITIAL CORROSION
TEST BUILD NO. 1

TEST RECORD BOOK NO. _____ RUN NO. 1 SHEET 1 OF 1
TIME OF DAY 1500 DATE 3 Feb 66
ENGINEER R.J. Steffen OPERATOR Lashley, Sorkis
BAR PRESSURE 29.40 @ 74 °F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1140 PSI SUPPLY PRESSURE AFTER 1140 PSI
SUPPLY TEMP BEFORE 28 °F SUPPLY TEMP AFTER 28 °F
VACUUM PRIOR TO TESTING 28 INHG
VACUUM AFTER TESTING - INHG

CONFIGURATION ASSEMBLY NO
DIMENSION A-.006 INCHES TYPICAL #6 NbC vs Graphite "G"

ORIFICE SIZE
ORIFICE 01.046 INCHES

DRAWN BY: J.R. KUZMA
ENGINEER: BOB STEFFEN
D. SPEC. 751523AG

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

APPENDIX C

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

Figure 1 shows the NbC coated heater element after test. The coating appears to be in excellent condition with no evidence of breakthrough or corrosion. The discoloration at the inlet and of the heater was caused by moisture in the helium atmosphere.

Figures 2 and 3 show the low power temperature distribution of the heater element, used during these tests. Axial stations were measured from the exit end of the heater, or the end that contains no terminals. The heater was heated in open air and its surface temperatures were recorded by an optical pyrometer. Low powers were used to prevent excessive oxidation of the heater. Two portions of the heater were checked at each power level. The areas are designated as terminal leg and hot leg. The terminal leg connects to the terminal of the heater element and has a steeper temperature gradient along it due to the extreme end effect. The hot leg is the leg next to the terminal leg, this leg has a flatter temperature gradient and appears to be the hotter of the two legs as higher input power levels are reached. Figure 3 can be extrapolated to obtain temperatures of the center plane of the heater. The central plane of the heater coincides with the central plane of the test specimen.

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RESTRICTED DATA
Atomic Energy Act - 1954

Astronuclear
Laboratory
WANI-TME-1430

Figure 1
NbC Coated Heater Element

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RESTRICTED DATA
Atomic Energy Act - 1954

Figure 2
 Temperature Distribution of an HHT-6
 Heater Element

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Atomic Energy Act - 1954

Astronuclear
Laboratory

WANL-TME-1430

Figure 3
Temperature Vs Watts For The Midpoint
(Station 4) of an HHT-6 Heater Element

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Atomic Energy Act - 1954