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FACIL:50-220 NINE MILE POINT #1, NIAGARA MOHAWK POWER CORP. 05000220
AUTH.NAME AUTHOR AFFILIATION
DISE,D.P. NIAGARA MOHAWK PWR
RECIP.NAME RECIPIENT AFFILIATION
IPPOLITO,T.A. ***OPERATING REACTORS BRANCH 3

SUBJECT: Responds to 780821 NRC ltr requesting addl info re spent fuel mod.Forwards "Boraflex 1 Suitability Rept." 556 RPT

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NIAGARA MOHAWK

Donald P. Dise
Vice President
Engineering

NIAGARA MOHAWK POWER CORPORATION/300 ERIE BOULEVARD WEST, SYRACUSE, N.Y. 13202/TELEPHONE (315) 474-1511

December 20, 1978

Division of Operating Reactors
Attention: Mr. Thomas A. Ippolito
Operating Reactors Branch #3
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: Nine Mile Point Unit #1
Docket No. 50-220
DPR-63

Dear Mr. Ippolito:

Your letter of August 21, 1978 requested additional information regarding the spent fuel pool modification for Nine Mile Point Unit 1. The attached information is in response to your request.

Very truly yours,

NIAGARA MOHAWK POWER CORPORATION

D. P. Dise
Vice President - Engineering

SWW/kmb
Attachment

A005
S 1/1

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P

Response to August 21, 1978

NUCLEAR REGULATORY COMMISSION QUESTIONS

Nine Mile Point Unit 1
Docket No. 50-220
DPR-63

1. Question

Provide the details of the uranium-235 loading and distribution in the fuel assembly which were used for the spent fuel pool criticality calculations.

Response

Figures 7 and 8 contained in the March 1978 submittal detail the fuel assembly model used in the criticality calculations. The fuel assembly is comprized of 64 0.64 inch by 0.64 inch cells containing homogenized fuel, water and cladding. The fuel assemblies are assumed to be unirradiated with an assembly average enrichment of 3.0 weight percent which is equivalent to a loading of 15.186 grams per axial centimeter of fuel assembly. A calculation, representing an explicit fuel pin distribution of selected U-235 enrichments typical of a 3.0 weight percent General Electric intra-assembly fuel pin arrangement is performed and included as a perturbation on the single average enrichment model results.

2. Question

Provide the areal density of boron-10 in the Boraflex plates which was used in the criticality calculations and provide the "quality assured" minimum value of this areal density (i.e., atoms of boron-10 per square centimeter of Boraflex plate).

Response

The boron-10 loading used for the criticality analysis was based on the minimum B_4C loading of 34.8 weight percent in the Boraflex and assuming 76 weight percent boron in the B_4C powder. This corresponds to a boron-10 loading in the minimum 0.10 inch thick Boraflex sheet of 0.0217 grams per square centimeter of cross section area (0.0217 gm B-10/cm^2-0.1 inch). This represents the minimum areal density required by specification to be incorporated into the as fabricated Boraflex plates. As a perturbation on the criticality calculation it was assumed that the boron content of the B_4C powder was 70 weight percent (0.0200 gm B^{10}/cm^2-0.1 inch), which represents an 8.5 percent reduction in boron-10 content of the Boraflex. Current production techniques indicate that the actual boron-10 loading in the Boraflex will be well above the 0.0217 gm B-10 value.

3. Question

Provide the calculated change in the storage lattice k_∞ with a small change in the boron-10 concentration in the Boraflex plates.

Reponse

The calculated change in the storage lattice k_∞ with a small change in boron-10 concentration in the Boraflex is shown in Figure 1.

4. Question

Will there be any place in the pool under any of the proposed changes where it will be possible to place a fuel assembly very close to the outside of a rack which is filled with fuel assemblies? Such a place might be the space between the outer periphery of the rack modules and the walls of the pool. What is the maximum neutron multiplication factor that can be obtained in this situation?

Response

Yes. However, the reactivity effect of a fresh fuel assembly located outside the fully loaded spent fuel storage rack has been evaluated for all postulated locations, including this area. The maximum perturbation associated with this event has been calculated to be $+0.018\Delta k$.

5. Question

Provide the nominal value of the k_∞ for the PDQ-7 cell model shown in Figure 7 of your submittal.

Response

The calculated k_∞ of the basic cell at 100 degree F is 0.8775.

6. Question

Provide the maximum value of the k_∞ that is obtained when the perturbations listed in Table 3 of your submittal are all assumed to be in the direction that gives an increased neutron multiplication factor.

Response

The maximum value of k_∞ for the spent fuel rack under worst mechanical and thermal conditions with calculational uncertainties is 0.8971.

7. Question

Provide the change in the multiplication factor when axial neutron leakage is assumed.

Response

The change in multiplication factor when axial leakage is assumed is $-0.0021\Delta k$.

8. Question

NRC procedures require that an on-site test be performed to verify within 95 percent confidence limits, that a sufficient number of neutron absorbing plates (i.e., poison plates) in the installed racks contain the required boron content to maintain the $k_{eff} \leq 0.95$. When the poison plates are made an integral part of the racks and the condition of the poison plates is continually monitored by surveillance tests, the NRC finds that a single, initial neutron attenuation test on the racks is sufficient. However, a single, initial neutron attenuation test will not be sufficient for the proposed racks with the removable poison inserts. Describe how you propose to periodically perform tests to verify, within 95 percent confidence limits, that there will always be a sufficient number of poison plates which contain the required boron content to maintain the $k_{eff} \leq 0.95$ in the proposed storage racks with the removable poison inserts.

Response

The rack design provides one semi-permanent poison assembly per fuel assembly. The poison inserts are not normally removeable and it is anticipated will not be removed from the fuel storage rack for the life of the rack, therefore we will satisfy NRC procedures. The poison assembly is locked in place by a lock bolt that cannot be removed without mechanically deforming the locking element. The lead-in funnel at the top of the fuel cell location is an integral part of the poison assembly and thus the presence of the neutron poison plates can be verified visually. The presence of the neutron poison plates will be verified visually prior to the installation of the storage racks in the pool.

Quality Assurance records, during manufacture, will confirm the installation of the Boraflex poison material into every poison assembly. A neutron attenuation test will be performed at the manufacturer's plant on 10 percent of the storage locations after the poison assemblies are installed and locked in the racks. A site verification neutron attenuation check will be performed on at least 5 storage locations in each rack module.

It should be noted that manufacturing process Quality Assurance procedures and controls provide assurance that the actual B_4C content of the Boraflex poison material is above minimum calculational levels established by Reactor Physics calculation models for each batch of B_4C and silicone material.

9. Question

Will any sources of neutrons other than spent fuel assemblies be stored in the spent fuel pool? If so, at what rate will they emit neutrons?

Response

Tabulated below are sources of neutrons other than spent fuel assemblies which may at times be stored in the spent fuel pool.

NEUTRON SOURCE	DESCRIPTION	NEUTRON RATE - n/sec
Start-up Sources	5 Sb-Be (γ-n) sources will be removed from the core during the next refueling outage, temporarily stored in the pool and eventually shipped off site (60 day half-life)	$\sim 4 \times 10^{7} - 3 \times 10^{9}$ (each source)
Am-Be Source	1 Am-Be (α-n) source; occasionally stored in the spent fuel pool	$\sim 12 \times 10^{6}$
Depleted LPRM's	Upon removal from the reactor during refuelings, LPRM's are stored in the spent fuel pool until disposed of	Minimum

10. Question

What will the maximum integrated neutron and gamma flux be in the Boraflex material over the lifetime of the racks? What spent fuel assembly power density and burn-up, and what rack life were assumed in calculating these maximum integrated fluxes? What is the assumed energy spectrum for the gamma flux?

Reponse

The maximum integrated neutron and gamma dose expected for the poison material will be 1.2×10^{11} Rads. The neutron dose is expected to be no more than 5×10^{8} Rads. For the gamma dose calculation, it is assumed that the poison is subjected to irradiation from the hottest spent fuel assembly (gamma dose design basis peaking factor of 1.25, burnup of 33,000 MWD/MT) from 10 days out of the reactor to 18 months when the next refueling occurs. It is assumed that the fuel assembly is then replaced by the hottest spent fuel assembly discharged at that time. There are 27 such cycles that correspond to a rack life of 40.5 years. Since over 70 percent of the gamma energy is in the 0 to 0.5 MEV group, 1 MEV gammas were assumed, making the resulting dose estimate conservatively high.

11. Question

What will the maximum temperature be in the center of the Boraflex material, assuming the highest neutron and gamma flux and the worst accident conditions?

Response

The maximum temperature in the center of the Boraflex material assuming worst accident conditions is 247 F.

12. Question

State the quantity and composition of the gas which will come out of the Boraflex material when it is being irradiated in the spent fuel pool.

Response

Currently a sample of Boraflex material is being exposed in the Phoenix Reactor at 2×10^8 R/hr (Gamma). The gas release from a 0.5 inch x 0.1 inch x 6 inch sample is 15 ml/hr. The composition of the gas being released has been measured as 10% O_2, 15% H_2, 45% N_2, 14% methane, and 3% ethane.

13. Question

On page 9 of your March 22, 1978 submittal, it is indicated that there is a poison slab which is sealed in a stainless steel casing. Is the Boraflex going to be sealed inside of a stainless steel casing?

Response

The Boraflex is canned in a stainless steel casing. The assembly is vented at the top and bottom to prevent gas build up in the casing.

14. Question

What will the chemical composition of the Boraflex be after receiving the design dose of irradiation?

Response

There will be little or no change in the chemical composition of the Boraflex after receiving the design dose of irradiation.

15. Question

What is the melting temperature of the Boraflex in the unirradiated condition?

Response

The Boraflex material does not melt below 1000 F. At 1300 F the Boraflex material begins to char.

16. Question

Is the Boraflex going to be bonded to stainless steel? If so, what will happen to this bond under the design dose of irradiation in conjunction with the design number of thermal cycles?

Response

The Boraflex is not bonded to the stainless steel casing.

17. Question

What will the physical properties such as the density, the modulus of rupture, and the compressive strength of the Boraflex be after it receives the design dose of irradiation in the spent fuel pool?

Response

Tests performed to date at greater than the design dose indicate that the only change in properties of the Boraflex after irradiation is an increase in stiffness of the material. This change does not consititute a problem with the material in regard to its function as a neutron absorber.

18. Question

Provide a detailed description of and the documented results of a prototypical experiment, which includes all significant aspects of the spent fuel pool situation and environment, that shows that these Boraflex plates will not become so brittle from irradiation in the spent fuel pool that they could be broken up by the insertion and removal of fuel assemblies or by a safe shutdown earthquake at some time in the design life of the spent fuel racks.

Response

A continuous program of irradiation of Boraflex is in progress at the Phoenix Reactor of the University of Michigan. Various tests on Boraflex to date, summarized in the attached "Boraflex 1 Suitability Report," No. 1047-1, have demonstrated that the material undergoes no significant physical or chemical change when exposed to 2×10^{19} rads gamma irradiation. Additional testing of the material is documented in the proprietary BISCO Procedure 748-10, "Irradiation Studies of Neutron Shielding Materials", a copy of which can be supplied on request.

The Boraflex material is fully supported in a double stainless steel can that is vented at the top and bottom to allow any gas generated to escape. The poison assembly is a complete unit that does not provide the bearing surface for the spent fuel. The rack structure provides this . Any distortion of the poison box assembly is contained in the slot within the rack that it occupies. A distortion will not affect the fuel cell.

All the structural analyses performed on the poison design racks assumed the poison material had zero strength and contributed nothing to the strength of the rack.

19. Question

If the Boraflex is to be exposed to the pool water, state the maximum percentage of boron oxide, B_2O_3, in the B_4C. Since B_2O_3 is soluble in water it will either be necessary to assume that this amount of boron is leached from the Boraflex plates or to experimentally show that this will not happen during the life of the racks.

Response

The B_2O_3 content in the B_4C is less than 0.75.

The Boraflex will be exposed to pool water, however, the silicone rubber matrix of the Boraflex essentially coats the B_4C and B_2O_3 particles to prevent the water from contacting it. A 4700 hour test at 240 F in Borated water has shown no leaching to occur. Even if leaching should occur, analysis shows this small decrease in Boron content would have little effect on the rack k_∞ (see figure 1).

20. Question

Describe the instrumentation and alarms on the spent fuel pool water level and temperature or reference the location in the FSAR where this description can be found.

Response

The level alarm system initiates when the water level in the spent fuel pool falls to elevation 338 feet 0 inches. The level alarm annunciator is located in the control room and on the spent fuel pool panel located on elevation 281 feet of the reactor building. The spent fuel pool filtration system has a low pump suction trip alarm and a low flow alarm, both of which would indicate low water level. The pump suction trip alarm and low flow alarm annunciate on the spent fuel pool panel at elevation 281 feet and the computer prints out an alarm in the control room. In addition, the computer prints out an alarm when the water level falls to elevation 338 feet 0 inches.

The temperature alarm system annunciator is located on the fuel pool panel on elevation 281 feet 0 inches, and a high fuel pool temperature alarm is printed on the computer. In addition, there is a fuel pool alarm in the control room which can be initiated by high temperature or anyone of several other parameters. When the fuel pool alarm is annunciated, it can be determined from the computer printout which of the parameters has caused the alarm, and action can be taken. The temperature alarm system is set to initiate at 113 F.

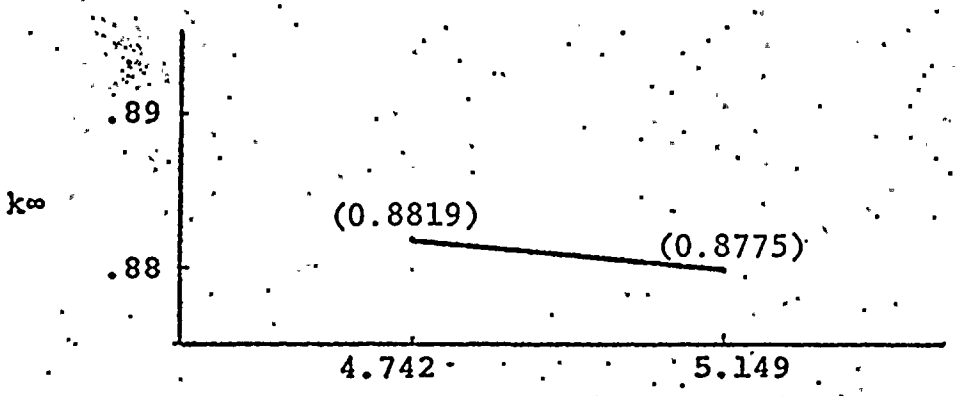
FIGURE 1

NINE MILE POINT NUCLEAR PLANT

SPENT FUEL STORAGE RACK k_∞

vs

BORON-10 LOADING IN BORAFLEX®



B^{10} Loading in Boraflex, Atoms B^{10} cm^{-3} x 10^{21}

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REPORT NO. 1047-1

BORATEX 1 STABILITY REPORT

February 24, 1978
Revised May 5, 1978
Revision 3

By

James Anderson
and
James Sharwood

ABSTRACT

BISCO's Boraflex 1 is a unique product containing boron carbide to absorb thermal neutrons yet the composite material is flexible and can be bent, shaped and bonded as required to fit unique shapes. The chemical composition of the matrix also includes certain elements that act to reflect and thermalize fast neutrons.

These materials have been subject to a series of long-term tests to verify the facts that they are stable, do not swell or crumble with exposure to high temperature or radiation, and will withstand a water soak condition typical of that found in a spent fuel pool.

The testing to date indicates that the material meets the stated requirements and exhibits minimal gas evolution during the various trials. It maintains its flexibility and mechanical shape and does not appear to swell or increase in dimensions.

Many of these tests are still in progress with final reports to be issued in the future. This report will be revised and updated as additional test data is documented.

1. THERMAL AGING OF THE BASE POLYMER

The polymer used in the Boraflex Type 1, is a highly stable silicone elastomer manufactured for BISCO by the Dow-Corning Corporation of Midland, Michigan.

Testing has been conducted using samples of material to

177° C in an oven condition with the Durometer, tensile strength, and elongation being measured at certain hourly intervals. Attachment 1 to this report contains the charts that illustrate performance of base polymer over a 5,880 hour test. Additional testing was conducted at 190° C for 5,160 hours with similar performance of the material.

A separate test of up to 5,840 hours was conducted to evaluate the carbon and hydrogen content and physical condition of the base polymer after heat aging at various temperatures, including 70° C, 150° C and 225° C.

Ten gram cubes of the base polymer were placed in aluminum weighing dishes in a forced air circulating oven pre-set at the stated data. At each listed time interval, a sample was withdrawn and examined for physical properties and the data recorded. The results of this test are reported in attachment 2. Additional tests of the samples are being conducted to determine the exact physical properties.

II. THE EFFECTS OF RADIATION ON MS-1 POLYMER AND BORAFLEX TYPE 1 MATERIALS

A series of radiation exposure tests have been conducted using various modes of irradiation to analyse the stability

of the material in a typical spent fuel rack application. The first test involved the long-term exposure of NS-1 polymer to gamma irradiation from a Cobalt 60 source. Table 3 illustrates the changes in tensile strength, elongation and elastic modulus versus radiation exposure up to 7.1×10^8 Rads gamma.

Samples of materials containing 2 per cent and 50 per cent boron carbide by weight were subjected to neutron and gamma irradiation in an especially fabricated test enclosure at the University of Michigan Ford Nuclear Reactor immediately adjacent to the reactor core. Two levels of testing 1×10^8 Rads gamma and 7.1×10^9 Rads gamma were conducted. The dimensions and the weight of the samples were monitored along with their hardness. Additionally, a study of gasses evolved from the test chamber was conducted. As noted in the test report, the sample with 2 per cent boron carbide exhibited no change in length during 1×10^8 Rads gamma exposure. The sample with 50 per cent boron carbide increased in length 0.001 inches, a change of .03 per cent.

The sample that was subjected to 7.1×10^9 Rads gamma decreased in length during the course of the test approximately 2.4 per cent.

During this test no attempt was made to thermally cool the samples while they were in the test chamber. It is estimated the samples saw a temperature in excess of 300° F in addition to the high gamma and neutron flux.

An analysis of the gasses given off from the sample is reported but the data is not complete in that no major controls were conducted in drying out the samples prior to their mixing for testing. Nor was any analysis made of the trace elements present in the boron carbide.

Additional exposure tests have been done at the spent fuel pool at Ames Laboratory to a total exposure of 1×10^8 Rads gamma. No conclusive mechanical dimensions were measured during this test - only whether or not the materials held together. Electron beam tests have been run on the materials, but are not being included in this report due to the uncertainty of this type of exposure and the high rate of thermal energy input into the samples. The basic results were that quarter inch thick samples were subject to 2×10^{11} Rads equivalent energy under an electron beam in a water bath with the only change of material being noted as that of a change of color and a stiffening of material.

III. EFFECTS OF HIGH TEMPERATURE BORATED WATER ON BISCO BORAFLEX 1 NEUTRON SHIELDING MATERIALS

Samples of Boraflex 1 were emersed in 3,000 PPM borated water for a period in excess of 4,700 hours. The water temperature was 240^0 F and the water had PH adjusted by the addition of sodium hydroxide to a range of 9.0 to 9.5.

Attachment 6 to this report details testing and illustrates the stability of the material. After 199 days of testing there was a slight decrease of 0.93 per cent on the 10-inch dimension of the sample. An average increase of the mass of the sample was .24 per cent postulated to be slight absorption of water on the surface of the materials. Gas evolution was noticed with a diminishing trend being detected. Some 36 per cent of the total gas was evolved during the first 25 per cent of the test period.

A similar test was conducted on BISCO polymer HS-2 which was developed for use as a neutron shield for the Arkansas Project. As reported by Wiley Laboratories in attachment 7 to this letter, materials were subject to 31 days of saturated soak at 240^0 F, the control sample, 8.59 pounds increased in weight 0.049 pounds. That equals .006 per cent which is attributed to the water absorption based on the total exposed

surface area of 252 square inches. This amounts to 2.38 x 10^{-5} pounds per square inch of exposed area. Other tests have shown that the magnitude of this value stabilizes after an initial exposure.

IV. NEUTRON AND GAMMA ATTENUATION TABLES FOR VARIOUS BORAFLEX COMPOUNDS

Samples of Boraflex 1 and Boraflex 2 were prepared with various weight per cent loadings of boron carbide to establish relative values of neutron attenuation versus boron carbide loading per unit thickness. The results are reported in attachment 8 to this report.

The tests have shown that as the boron carbide is reduced in mesh size the material becomes more efficient as a neutron shield.

A 60 mesh based Boraflex 1 will attenuate approximately 300 per cent more neutrons than a 20 mesh based Boraflex 1. Going further if the mesh size is reduced to 120 mesh it will attenuate approximately 10 to 20 per cent more neutrons than the 60 mesh mixture. Finally, a 300 mesh compound will attenuate approximately 10 per cent more neutrons than the 100 mesh compound.

Our current production size range is -100 mesh through approximately -400 mesh. The exact distribution varies somewhat based on total loading.

V. NOTATION ON STABILITY OF BORAFLEX COMPOUNDS

It is well known that silicone polymers will allow gasses to permeate through them, particularly those of a low molecular weight. As evidenced by our testing, as gasses are generated by the boron carbide and other elements present, they diffuse through the Boraflex sheet without causing any swelling or expansion of the material. In the event the boron carbide pellet fractures or expands, the flexible Boraflex polymer will allow this to a certain amount.

We have found that boron carbide by itself can contain certain elements that will produce gasses when exposed to a typical spent fuel pool water environment. We have placed stringent controls on our boron carbide suppliers and insist on special processing to remove these trace elements where possible.

The NS-1 polymer acts to provide a waterproof coating for the majority of the boron carbide in the matrix, thus reducing any chance of water contact.

The basic NS-I polymer includes carbon black and silica compounds which appear to have an effect in increasing the radiation resistance of the material. The addition of boron carbide acts to strengthen the matrix and stabilize it. This effect is reported in "Effects of Radiation on Materials and Components" by Kircher and Bowman.

Additionally, they report on gas generation by boron carbide and silicone elastomers.

The NS-I polymer exhibits very good short-term exposures to strong acidic and basic solutions and the unfilled polymer is extremely flame retardant with an ASTME 84 flame spread index less than 10. It is expected that when the polymer is filled with the boron carbide these values will be improved additionally.

The NS-I polymer contains chemically bound hydrogen, carbon, oxygen and silicone which will help to provide a moderating zone to improve neutron capture. As evidenced by the long-term radiation exposure tests, there are very few impurities present which thus allow the material to have a rapid cool-down after high radiation exposure.

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The following data is based on tests conducted by Dow Corning Company as part of a larger test program. The following includes thermal aging data in tables and plotted graphically, and vertical burn test data.

The data included in this report has been compiled at their Quality Control Lab in Midland, Michigan.

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2-15-78

QUALITY ASSURANCE PROGRAM

All lots of materials that made up the test samples were tested using the following ASTM methods for electrical, physical, and rheological properties.

Viscosity, HAF	ASTM-D-1084
Tack Free Time	MIL-S-7502
Non-Volatile Content, %	MIL-S-7502
Specific Gravity Solids	ASTM-D-792(A)
Durometer, Shore "A"	ASTM D-2240
Tensile, PST	ASTM D-412 Die C
Elongation, %	ASTM D-412 Die C
Tear Strength, lb/in.	ASTM D-624 Die B
Arc Resistance	ASTM D-495
Dielectric Constant	ASTM D-150
Dissipation Factor	ASTM D-150
Volume Resistivity	ASTM D-257
Surface Resistivity	ASTM D-257
Horizontal Burning	U.L. - 94

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ATTACHMENT 1A

THERMAL AGING

OF

BISCO NSI POLYMER AT 177°C

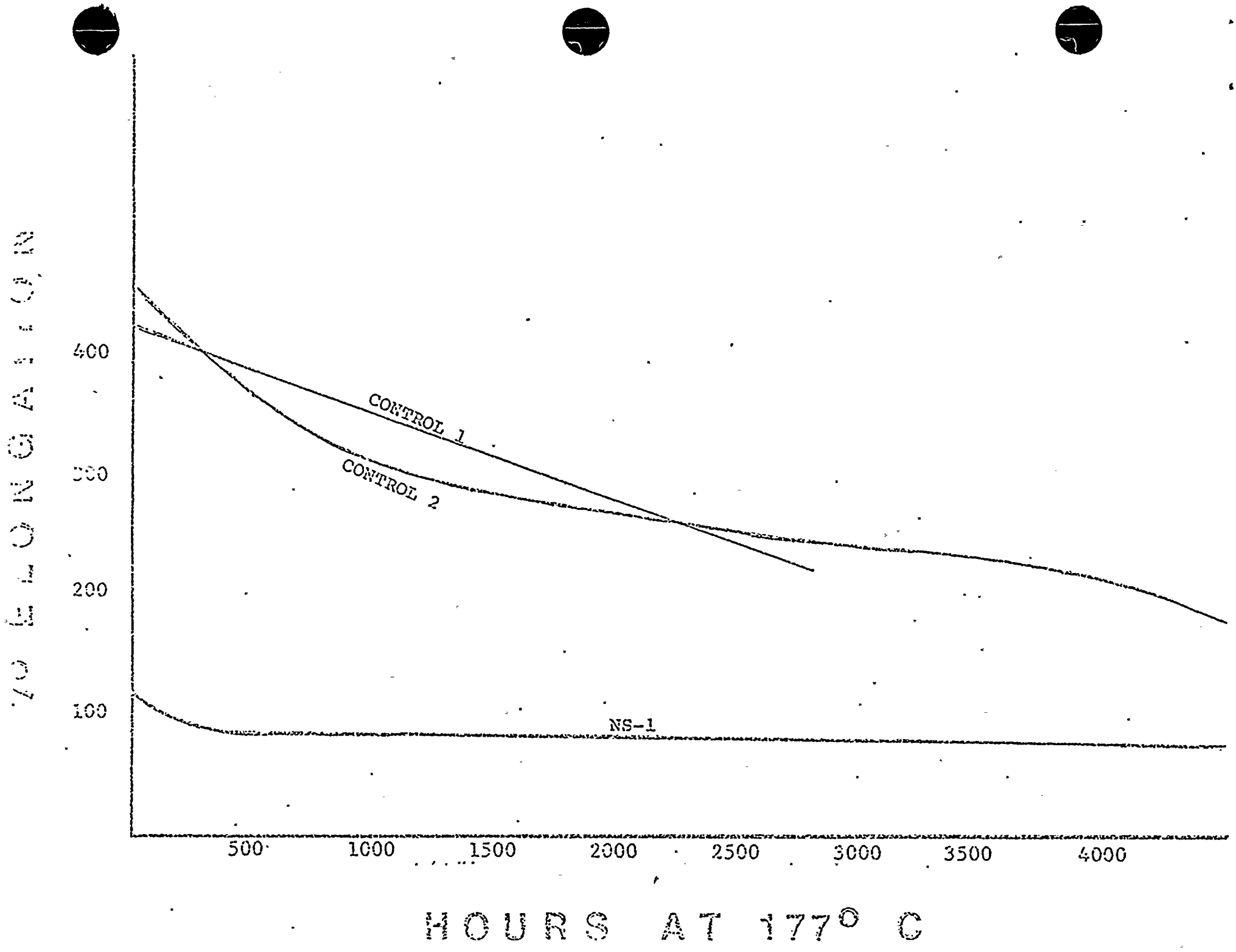
ATTACHMENT 1A

THERMAL AGING OF BISCO NSI POLYMER AT 177°C

Job 1047
2-15-78

Table IA

Hours	Durometer	Tensile	Elongation	Dielectric Strength
7 Days RT	53	460	116	540
120	62	464	70	
240	63	549	78	
360	62	505	82	
480	59	404	84	567
600	59	486	100	
720	63	522	88	
840	61	510	83	
960	64	490	78	560
1080	62	492	86	
1200	61	479	88	
1320	62	473	95	
1440	62	381	78	
1560	63	378	84	
1680	61	417	83	
1800	60	397	79	
1920	62	404	80	
2040	62	432	88	
2160	63	393	85	
2280	61	363	82	
2400	62	390	82	


% ELONGATION
400
300
200
100
CONTROL 1
CONTROL 2
NS-1
500
1000
1500
2000
2500
3000
3500
4000
HOURS AT 177° C

Job 1047
2-15-78

ATTACHMENT 1B

THERMAL AGING

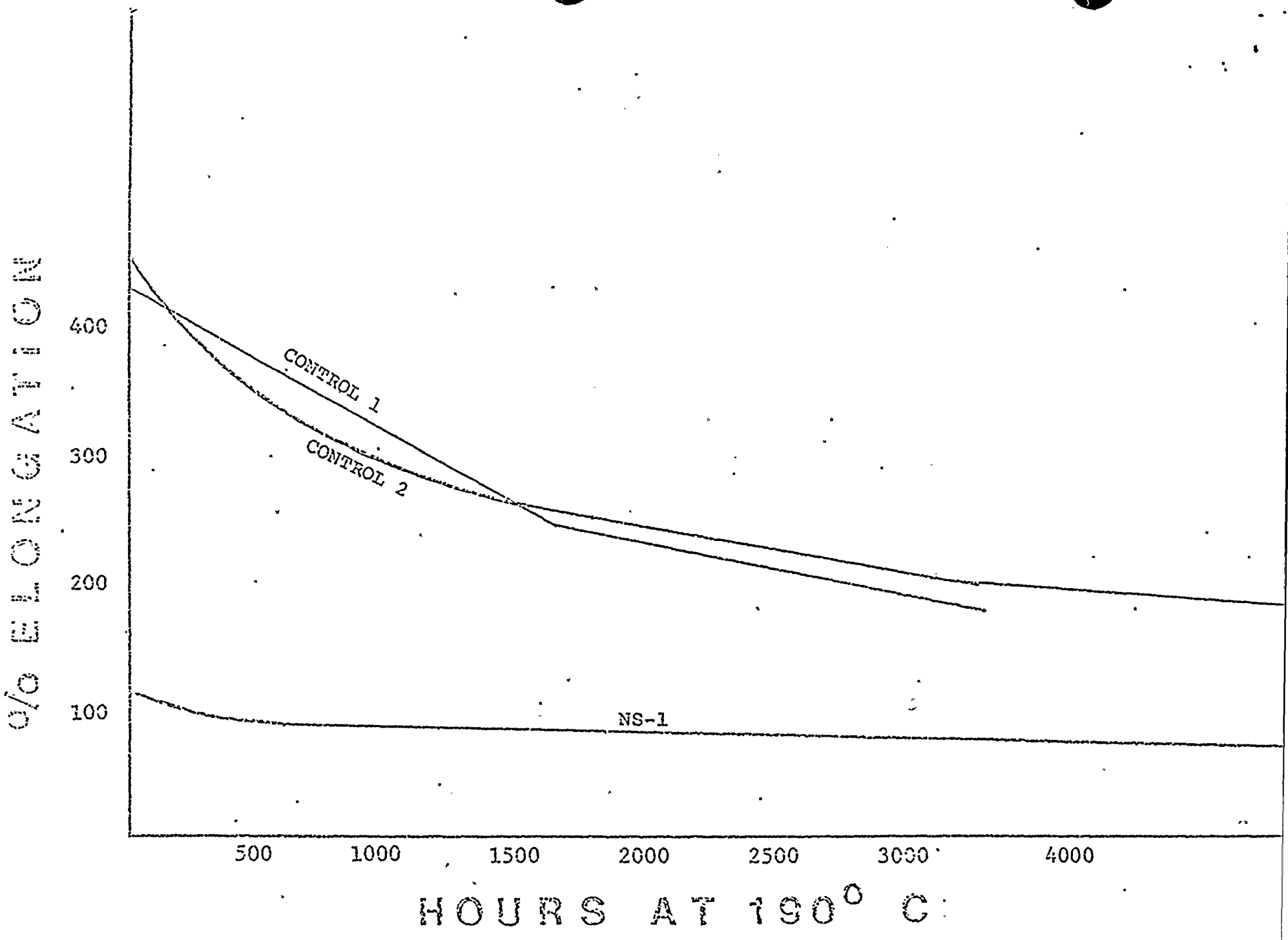
OF

BISCO NSI POLYMER AT 190°C

THERMAL AGING OF BISCO NSI POLYMER AT 190°C

Job 1047
2-15-78

Hours	Durometer	Tensile	Elongation	Dielectric Strength
3720	63	272	63	
4080	65	263	70	533
4560	67	310	55	
4800	63	261	50	
5040	64	258	73	560
5160	64	247	70	


% ELONGATION
400
300
200
100
CONTROL 1
CONTROL 2
NS-1
500
1000
1500
2000
2500
3000
4000
HOURS AT 190° C

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ATTACHMENT 2

BISCO NSI

C & H CONTENTS AND PHYSICAL CONDITION

AFTER HEAT AGING

ATTACHMENT 2

BISCO NST

C AND H CONTENTS AND PHYSICAL CONDITION

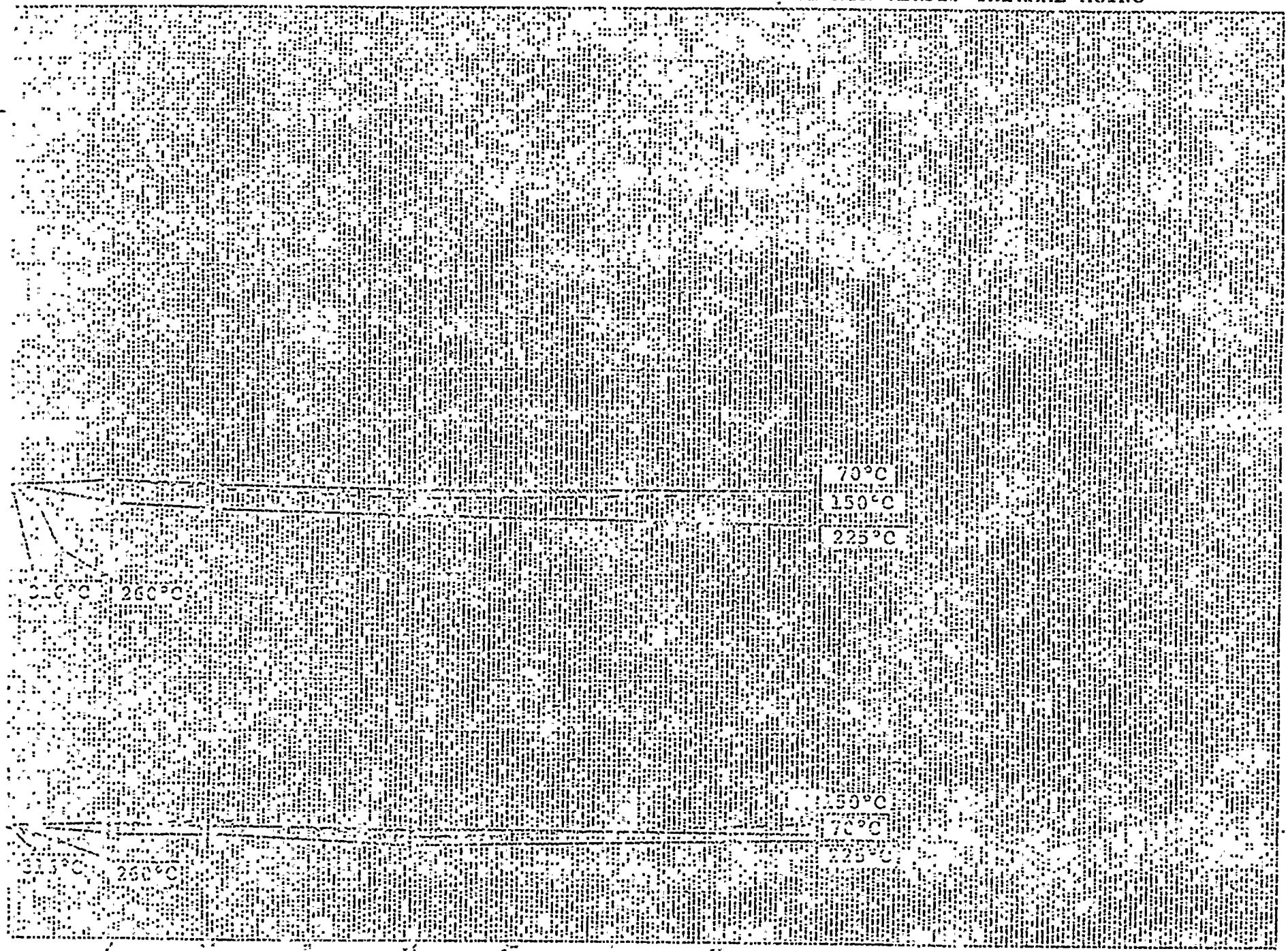
AFTER HEAT AGING

Time of Heat Aging	70°C	150°C	225°C	
Initial	4.3	4.3	4.3% H	%H
	17.4	17.4	17.4% C	
1 week	-	-	-	%H
2 weeks	-	-	-	
1 month	4.4	4.4	4.1	%H
	17.6	17.6	16.7	%C
	no change	no change	no change	condition
2 months	4.6	4.5	4.2	%H
	17.5	17.4	16.5	%C
	no change	no change	no change	condition
4 months	4.3	4.0	4.0	%H
	17.3	17.0	16.3	%C
	no change	no change	no change	condition
8 months	4.2	4.6	4.1	%H
	17.4	17.4	16.0	%C
	no change	no change	no change	condition

KEUFFEL & ESSER CO. 46 1513

FIGURE 1

CARBON AND HYDROGEN CONTENT OF DISCO NSHI POLYMER VERSES THERMAL AGING



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Job 1047
2-13-76

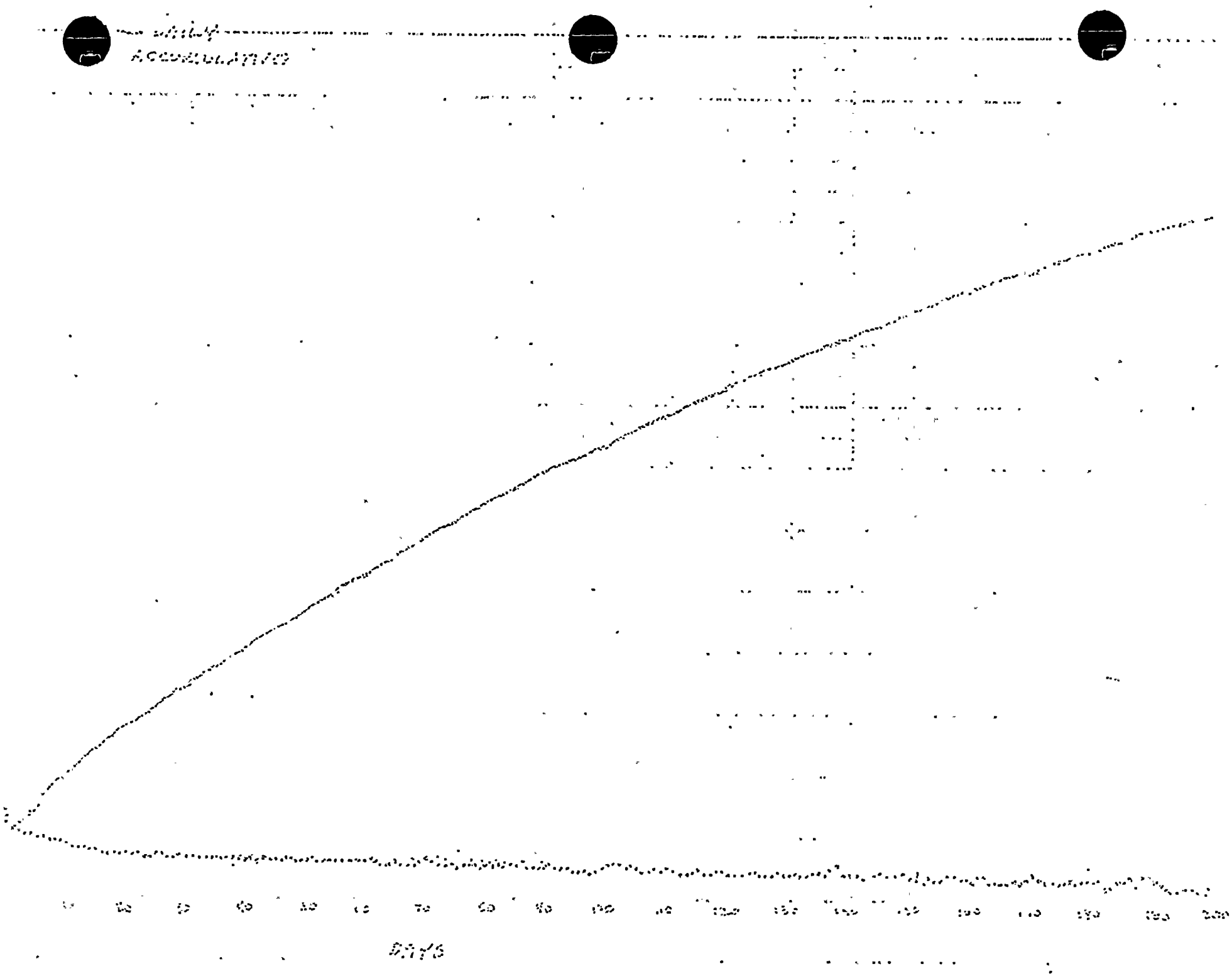
ATTACHMENT 3

EFFECT OF RADIATION

ON

BISCO NSI EXPOSED TO A

COBALT 60 SOURCE



ATTACHMENT 3

Job 1047
2-18-78

EFFECT OF RADIATION ON BISCO NSI

EXPOSED TO A COBALT 60 SOURCE

I. Dose Megarads	Tensile (PSI)	Elongation %	Elastic Modulus
0	510	68	750
16	516	55	938
60	550	40	1375
111	504	38	1326
164	553	23	2404
713	896	3.3	27,151

Sample: .1" x 1" Tensile Bar pulled @ 10 inches/minute

II. Dose Megarads	Stress for 20% Compression (PSI)	(%) Dynamic Comp. Set at 20% Comp.
0	19.	2.5%
14	206	0
68	396	0
119	652	0
486	2756 (shattered)	100

Sample: 1.125" Dia x 1" thick button compressed 20% @ 1 inch/min.

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Job 1047
2-18-78

ATTACHMENT 4

IRRADIATION TEST
OF
BISCO BORAFLEX TYPE I

2% AND 50% B & C

A. SHORT TERM EXPOSURE

3.5 hrs, 10^{16} N/cm^2, 1 X 10^8 Rads Gamma

B. LONG TERM EXPOSURE

237 hrs, 9 X 10^{17} N/cm^2, 7 X 10^9 Rads Gamma

THE UNIVERSITY OF MICHIGAN
PHOENIX MEMORIAL LABORATORY
FORD NUCLEAR REACTOR
ANN ARBOR, MICHIGAN 48105

December 2, 1976

Mr. James Sherwood
Brand Industrial Services, Inc.
630 Bonnie Lane
Elk Grove, Illinois

Dear Jim:

I have enclosed the silicon - 50% B_4C sample that we irradiated in March, 1976. As you may remember, the radioactivity content was too high to be sent earlier. The total radioactivity is about 1.85 microcuries of primarily Zn-65 which is exempt from control. The attached table lists the radioactivity content of the sample based upon our analysis. Also enclosed is a copy of the original test data to refresh your memory.

Very truly yours,

Reed R. Burn

Reed R. Burn
Reactor Manager

encl.
RRB:jab

BISCO Silicon – 50% B_4C Sample

RADIOISOTOPE CONTENT

Radioisotope	Half-Life	Microcuries	Microcuries/Gram
Eu 152	13 yr.	7.19×10^{-3}	1.09×10^{-3}
Lu 177m	161 d	4.59×10^{-5}	6.95×10^{-6}
Hf 181	42.4 d	4.97×10^{-2}	7.53×10^{-3}
Co 58	71.3 d	1.13×10^{-2}	1.71×10^{-3}
Mn 54	312.5 d	1.08×10^{-1}	1.64×10^{-2}
Sc 46	83.8 d	1.15×10^{-2}	1.74×10^{-3}
Fe 59	44.6 d	7.77×10^{-3}	1.18×10^{-3}
Zn 65	243.7 d	1.85	2.80×10^{-1}
Co 60	5.272 yr.	3.68×10^{-2}	5.58×10^{-3}
Ta 182	115 d	1.61×10^{-3}	2.44×10^{-4}
Na 22	2.601 yr.	3.00×10^{-4}	4.55×10^{-5}

Irradiation Date: March 31, 1976

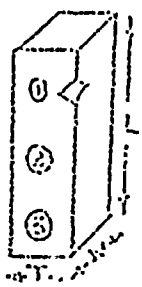
Radioactivity Measurement Date: November 24, 1976

Sample wt. 7.0 grams

Attest: Rod R. Brown Date: 12/2/76

BISCO Silicon – B_4C Samples

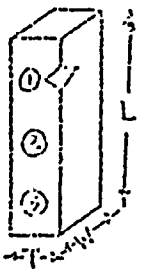
Short Term Irradiation

Test Sequence		2% B_4C Samples		50% B_4C Samples	
		Unirradiated (2 Notch)	Irradiated (1 Notch)	Unirradiated (2 Notch)	Irradiated (1 Notch)
Pre-irradiation weight (gm)		5.3	5.3	6.7	7.1
Pre-irradiation Dimensions (in)					
	T1	0.256	0.257	0.273	0.273
	T2	0.261	0.261	0.273	0.272
	T3	0.267	0.264	0.274	0.275
	W1	0.309	0.310	0.318	0.315
	W2	0.314	0.310	0.321	0.323
	W3	0.320	0.318	0.298	0.338
	L	3.016	3.011	3.022	3.026
2.5 Hour Irradiation					
Neutron Dose (N/cm^2)		----	1.26×10^{16}	-----	1.26×10^{16}
Gamma Dose (Rads)		----	1.05×10^{8}	-----	1.05×10^{8}
Gas Evolution Cylinder Pressure Buildup Rate (PSI/hr)		----	0.2	-----	0.2
Post Irradiation Weight (gm)		----	5.2	-----	7.0
Post Irradiation Dimensions (in)					
	T1	----	0.258	-----	0.270
	T2	----	0.261	-----	0.272
	T3	----	0.265	-----	0.275
	W1	----	0.313	-----	0.322
	W2	----	0.312	-----	0.330
	W3	----	0.318	-----	0.339
	L	----	3.011	-----	3.027
Hardness (Durometer Type A_2 Tester)		55	85	84	100

Attest: R W D R Burn Date: 4-2-76

BISCO Silicon – 50% B_4C Sample

Long Term Irradiation

Test Sequence		50% B_4C Sample
Pre-Irradiation Weight (gm)		7.0
Pre-Irradiation Dimensions (in)		
	T1	0.271
	T2	0.272
	T3	0.274
	W1	0.317
	W2	0.308
	W3	0.316
	L	3.020
237 Hour Irradiation		
Neutron Dose (N/cm^2)		8.53×10^{17}
Gamma Dose (Rads)		7.11×10^{9}
Gas Evolution		
Cylinder Pressure Buildup Rate (PSI/hr)		0.2
Hydrogen (%)		40.89
Oxygen (%)		5.93
Nitrogen (%)		33.72
Unknown (%)		19.50
Post Irradiation Weight (gm)		6.6
Post Irradiation Dimensions (in)		
	T1	0.262
	T2	0.262
	T3	0.264
	W1	0.311
	W2	0.301
	W3	0.309
	L	2.950

Attest: R. L. P. [illegible] Date: 1/2/74

G.C.# 18 V.S.# 18

ANALYSIS SHEET
Van Slyke Apparatus

Rad No. _____

Run No. 1 Vessel No. 2

Original Sample BISCO SILICON - 50% B_4C OFF GAS.

Sample, as measured _____

Radiation Source/Location _____ Date _____

Dose Rate _____ rads/hr

Irradiation Time _____ Total Dose _____ rads

Flow Rate 29.85 cc/min Col.#1 ____ cc/ ____ sec Col.#2 ____ cc/ ____ sec

Baragraph 30.36 Humid. 32 % Temp. 74°F

V.S. Temp. 23.7°C Vol. 0.823 cc

1ST SAMPLE AFTER 2 PURGES

	P_i	P_o
	620.7 mm	137.2 mm
	620.1 mm	137.4 mm
	619.8 mm	137.4 mm
3)	1860.6	3) 412
P_i ave	620.20 mm	P_o ave 137.33 mm
P_o ave	137.33 mm	
P_T	482.87 mm	

TF2 Closed 3:04 time

Loop Loaded _____ time

Run Start 3:05 time

Total Time 1 MIN.

Integrator Data

b 1 FILE 2
3235 ID

40	20	10	PK
30	30	30	SS
3	3	3	FP
5	5	5	AL
400	200	1	TI
		2	TA
		70	TS
3500 SECOND		100	MA
		50	PL
		50000	ML
			SF

TIME	AREA	
127 H_2	1431576	
249 O_2	20344	
579 N_2	95562	2
847 UNKNOWN	107106	3
	1654688	

TIME	CONC	
127	86.522	
249	1.229	
579	5.775	2
847	6.473	3
	99.999	

Sensitivity Factors Used — Summary Sheet

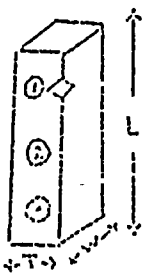
				Date	CALC PRESS.	% of MEAS.
1	H_2	1.377×10^{-4}	H_2/1-8	11-6-75	197.43	40.89
2	O_2	1.408×10^{-3}	O_2/1-2	9-8-75	28.64	5.93
3	N_2	1.704×10^{-3}	N_2/1-2	9-10-75	162.83	33.72
4					388.90 mm	80.54%
5	BALANCE UNKNOWN = 19.5% = 93.97 mm					
6						
7						

COMMENTS:

Attest: Paul R. Davis Date: 4/2/76

BISCO Silicon – 50% B_4C Sample

Long Term Irradiation

Test Sequence		50% B_4C Sample
Pre-Irradiation Weight (gm)		7.0
Pre-Irradiation Dimensions (in)		
	T1	0.271
	T2	0.272
	T3	0.274
	W1	0.317
	W2	0.308
	W3	0.316
	L	3.020
237 Hour Irradiation		
Neutron Dose (N/cm^2)		8.53×10^{17}
Gamma Dose (Rads)		7.11×10^{9}
Gas Evolution		
Cylinder Pressure Buildup Rate (PSI/hr)		0.2
Hydrogen (%)		40.89
Oxygen (%)		5.93
Nitrogen (%)		33.72
Methane (%)		19.50
Post Irradiation Weight (gm)		6.6
Post Irradiation Dimensions (in)		
	T1	0.262
	T2	0.262
	T3	0.264
	W1	0.311
	W2	0.301
	W3	0.309
	L	2.950

Attest: Rudd Brown Date: 12/2/76

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Job 1047
2-15-78

ATTACHMENT 5

GAMMA IRRADIATIONS

ATTACHMENT 5 Job 1047

2-24-78

Ames Laboratory ERDA

IOWA STATE UNIVERSITY
Ames, Iowa 50011

April 1, 1976 GAMMA IRRADIATIONS

Work Done for Grand Industrial Services, Inc.

Purpose: To determine effect of gamma irradiation on silicone rubber compounds

Irradiation Facility - Gamma irradiation facility, ALRR

Total Dose Desired:	Sample Nos.	Irradiation Period:
1.0×10^8 rads	5R1-12 thru 5R6-17	3-3-76 to 3-21-76

Sample Identification	Container	Irradiation Location	Total Dose Megarads
3 x 8" sheets (2)	1	R-1	107
Foam cube 3:1 ratio	2	R-2	105
Foam cube 1:1 ratio	2	R-2	105
Light grey slab	2	R-2	105
Pipe filled with 1:1 ratio mixture	3	R-3	105
Pipe filled with 3:1 ratio mixture	4	R-4	108
150 PCF block	5	R-5	105
250 PCF block	5	R-5	105
Refractory barrel	5	R-5	105
RFB 1600	5	R-5	105
CERA blanket	6	R-6	106
Black slab	6	R-6	106
Thermon T-63	6	R-6	106
New formulation 26#/ft^3	6	R-6	106

Gamma dose measurements were made using Fricke Ferrous Sulfate Dosimeters prior to initiating the irradiations and twice during the irradiation period. Using these measurements the irradiation times were adjusted so that the minimum exposure was 105 megarads. This allows for a 5% error in determining the dose received.

The changes in the physical characteristics of the samples can be observed. However, there is one characteristic that was noted, which was only apparent when the sample containers were opened at the end of the irradiation period. This change is the obvious generation of a gas during the irradiation. It was apparent in all the containers which held the silicon compounds. This may be the result of high energy gammas stripping the methane radical from the silicon.

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ATTACHMENT 6 ,Report 1047-1 JOB 1047
4-23-78 R-1

A Preliminary Report on the Effects of High Temperature Borated Water Exposure on BISCO Boraflex I Neutron Shielding Materials

Prepared by:
J. S. Anderson
Technical Director
Brand Industrial Services, Inc.
April 25, 1978

April 25, 1978

A PRELIMINARY REPORT ON THE EFFECTS OF HIGH TEMPERATURE BORATED WATER EXPOSURE ON BISCO BORAFLEX I NEUTRON SHIELDING MATERIALS

Abstract

Samples of BISCO Boraflex I were immersed in a borated water solution for a period in excess of 4,700 hours to allow examination of the effects of such immersion on the physical properties of the Boraflex.

The borated solution consisted of 3,000 parts per million boron in the form of boric acid, and was ph adjusted by the addition of sodium hydroxide to a range of 9.0 to 9.5. A constant temperature of 240°F was maintained in a pressure bomb type test vessel.

Measurement of the physical characteristics of the material after 199 days of test exposure indicates a dimensional decrease based on the measurement of the long side of the sample piece of 0.93% and an average increase of mass of the test samples of 0.24%.

The gas evolution of Boraflex I was measured under the test conditions with a total of 4.91 cubic inches of gas

at STP being generated per square inch of sample surface area over the entire test period. A diminishing gas evolution trend was detected, as evidenced by the fact that 36.3% to the total gas was evolved during the first quarter of the test period.

This report constitutes preliminary findings of a test still in progress. A final report will be issued with additional physical property measurements on completion of the test.

General

BISCO Boraflex I neutron shielding material was developed for application as a poison in high density spent fuel storage racks. The composition is based on the combination of a highly stable silicone elastomer, with a boron containing filler in the form of boron carbide. The boron concentration in Boraflex I can be varied over a broad range; however, the sample chosen for specific testing represents a boron carbide fill of 50% by weight.

The test conditions selected simulate those expected in a PWR spent fuel pool, under accident conditions that is, a borated water pool reaching a maximum temperature

of 240°F. The test length was originally set at 30 days; however, has been extended indefinitely to allow continuous long term monitor on the effects of that test environment on the physical characteristics of the material.

In addition to the physical characteristics, gas evolution of the Boraflex samples was monitored to determine what effects that gas evolution may have on design considerations of the storage rack.

All tests were performed at Terralab, Salt Lake City, Utah, a federally qualified laboratory, DPSA No. 18500.

Test Procedure

A high pressure test device was constructed, as shown in Figures 1 through 3, which contained the following functional divisions.

1. A temperature controlled pressurized sample enclosure which would maintain the test environment throughout the duration of the test period.

2. A water column separator system which would allow separation of evolved gases from the test chamber while maintaining the pressure and temperature requirements in the chamber.

3. An evolved gas collection area including a sample point to allow for periodic chemical analysis.

4. The necessary instrumentation to allow maintenance and measurement of the test environment.

The test equipment was constructed and maintained at the Terralab, Salt Lake City, Laboratory facility.

Six Boraflex I test samples were prepared, each sample being approximately 10.5" x 3.5" x 0.200" thick, and were manufactured according to BISCO standard manufacturing procedures for Boraflex I.

Prior to the initiation of the test, the following physical properties of each sample were measured and recorded.

1. Weight
2. Surface Area
3. Volume
4. Dimensions between reference points
5. Specific Gravity

The test environment consisted of a borated water containing 17,300 parts per million of boric acid (H_3BO_3), equivalent to 3,000 parts per million of boron in water. Sodium hydroxide (NaOh) was added in sufficient quantity to control a ph between the range of 9.0 and 9.5. The borated water was maintained at a constant 240°F and a minimum pressure of 10.2 PSIG.

The test samples were loaded into the pressure test chamber, in such a manner as to assure complete submersion of the samples at all times throughout the test. Pressure and temperature were monitored continuously to define any deviation from test conditions.

This test report covers the initial period of 0 to 199 days, equivalent to 4,776 hours. The test was continuous except for those instances where the samples were withdrawn for re-evaluation of physical parameters.

Test Results

Initial physical measurements of each of the six samples of Boraflex I was made prior to the initiation of the exposure tests and are listed in table I.

TABLE I

Initial Boraflex I Sample Physical Measurements

SAMPLE #	DIMINSIONS (inches)	MASS (grams)	DENSITY (lb/ft^3)
1	10.8 x 3.6 x 0.218	255.41	114.695
2	10.8 x 3.6 x 0.218	255.58	114.771
3	10.8 x 3.6 x 0.220	257.13	114.417
4	10.8 x 3.6 x 0.217	254.19	114.673
5	10.8 x 3.6 x 0.218	255.49	114.731
6	10.8 x 3.6 x 0.220	257.21	114.453
Average	10.8 x 3.6 x 0.219	255.84	114.623

The sample mass was 1535.04 trams (3.381bs.) and total sample surface area was 3254.33 CM^2 (504.5 in.^{2}).

Physical properties of the Boraflex samples were measured at intervals of 40, 80, 150 and 199 days. Those measurement intervals represent the only interruption of the continuous test exposure sequence. The following tables indicate the change of dimensional and weight characteristics of the Boraflex I test specimens at the measurement intervals. The dimensional stability shown in Table II is representative of the dimensional change in each plane however may be somewhat overstated due to the measurement accurancy limitations on length and width parameters. Thickness of the samples decreased over the 199 day test period from 0.000 inches to 0.002 inches. No indication of thickness increase was noted.

TABLE IV

Density Stability of Boraflex I (% Change from Original)

SAMPLE#	40 days	80 days	150 days	199 days
1	+0.82%	+1.60%	+1.87%	+5.27%
2	+0.42	+1.11	+1.88	+5.21
3	-0.10	+2.06	+1.93	+4.66
4	+1.44	+1.23	+1.06	+4.19
5	+1.21	+1.59	+1.42	+4.10
6	+0.32	-0.09	+1.07	+4.30
Average	+0.69%	+1.25%	+1.54%	+4.62%

Gas evolution of the Boraflex I samples was continuously monitored as described in the test procedures and reported in the following tables:

TABLE V

Accumulated gas volume evolved (Cubic inches per Sq. In. of sample area)

TIME (days)	TOTAL EVOLVED GAS (in^3/in^2)
40	1.48
50	1.78
80	2.61
100	3.09
150	4.15
199	4.90

TABLE VI

Boraflex I

Rate of gas evolution as a function of time

TIME (% of test period)	GAS EVOLUTION (% of total)	RATE FACTOR (% evolution/% time)
20%	30.2%	1.51
25	36.3	1.45
40	53.3	1.33
50	63.1	1.26
75	84.7	1.13
100%	100%	

The decreasing gas evoltuion rate trend is further quanified by the following summary:

Time under test	Evolution rate/day ($in.^3/in.^2$)
40 days	2.92×10^{-2}
80 days	2.65×10^{-2}
150 days	1.68×10^{-2}
199 days	1.20×10^{-2}

Complete compositional analysis of the evolved gases will not be completed until the termination of the test period. However, preliminary studies show those gases to be primarily Hydrogen, Methane, Ethane, and Carbon Dioxide. The ratio of those gases derived from the Boraflex I versus those derived from the borated water dissociation or recombination has not yet been determined.

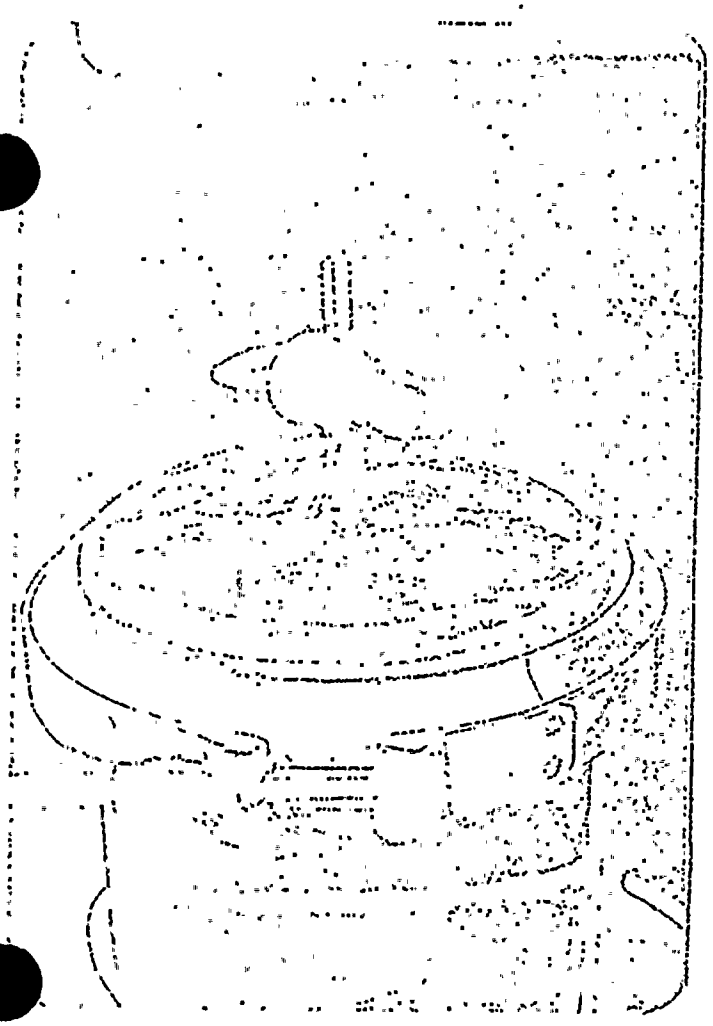


Figure 1
evolved gas collection area

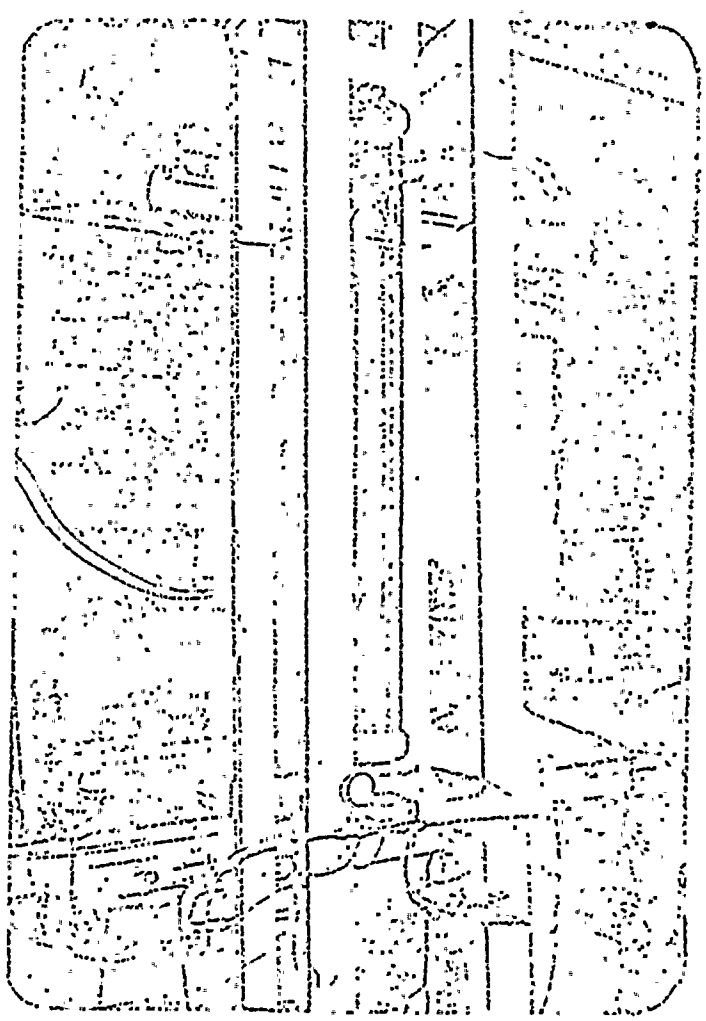


Figure 2
evoled gas separation column

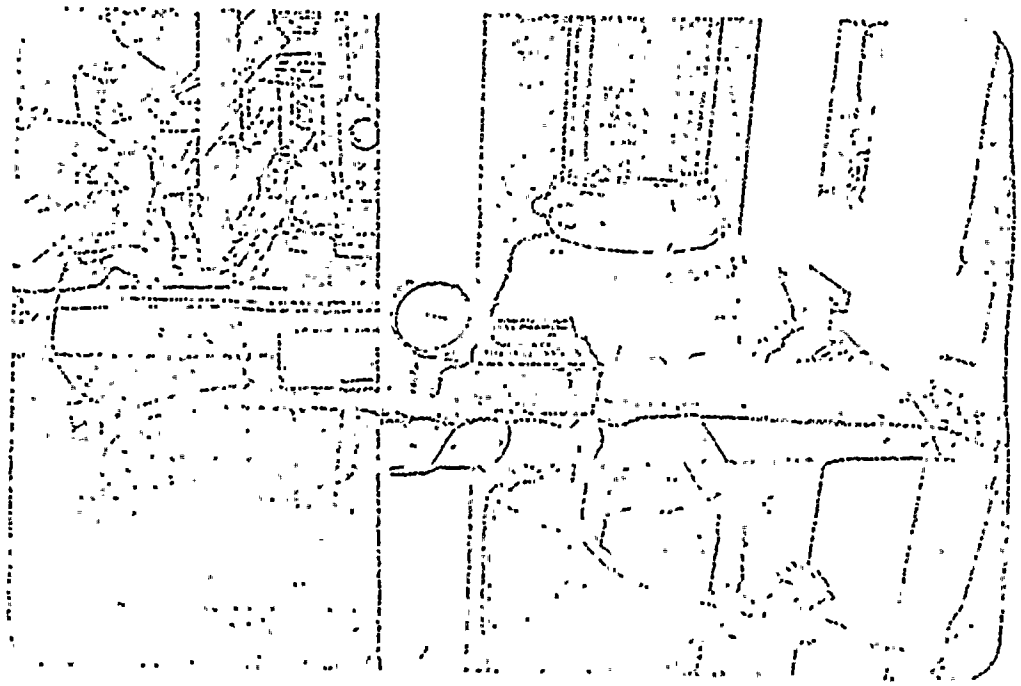


Figure 3
pressurized test chamber

1	1.25	1.25	30.35	.01756		30.35	.01756	
2	1.20	2.45	27.14	.01686		57.48	.03342	
3	1.0	3.45	24.23	.01405		83.76	.04846	
4	1.0	4.45	24.23	.01405		108.04	.06253	
5	.95	5.40	23.01	.01335		131.11	.07588	
6	.95	6.35	23.01	.01335		154.17	.08922	
7	.95	7.30	23.01	.01335		177.24	.10257	
8	.90	8.2	21.85	.01265		199.09	.11522	
9	.90	9.1	21.85	.01265		220.94	.12787	
10	.90	10.0	21.85	.01265		242.79	.14051	
11	.85	10.85	20.63	.01194		263.43	.15246	
12	.80	11.65	19.42	.01124		283.85	.16370	
13	.80	12.45	19.42	.01124		303.28	.17494	
14	.80	13.25	19.42	.01124		321.7	.18618	
15	.75	14.00	18.21	.01054		338.91	.19672	
16	.75	14.75	18.21	.01054		356.12	.20725	
17	.70	15.45	17.00	.00984		373.12	.21709	
18	.70	15.95	17.00	.00984		392.11	.22693	
19	.70	16.55	17.00	.00984		409.11	.23676	
20	.70	17.25	17.00	.00984		426.11	.24660	
21	.70	17.95	17.00	.00984		443.10	.25643	
22	.70	18.65	17.00	.00984		460.09	.26627	
23	.65	19.3	15.78	.00913		475.87	.27540	
24	.65	19.95	15.78	.00913		491.65	.28454	
25	.70	20.65	17.00	.00984		508.65	.29437	
26	.70	21.35	16.99	.00984		525.64	.30421	
27	.65	22.00	15.78	.00913		541.43	.31334	
28	.65	22.65	15.78	.00913		557.21	.32247	
29	.70	23.35	17.00	.00984		574.20	.33231	
30	.65	24.00	15.78	.00913		589.99	.34144	
31	.65	24.65	15.78	.00913		605.77	.35057	
32	.65	25.3	15.78	.00913		621.05	.35971	
33	.65	25.9	15.78	.00913		636.33	.36884	
34	.65	26.55	15.78	.00913		652.11	.37798	
35	.65	27.2	15.78	.00913		667.89	.38711	
36	.65	27.85	15.78	.00913		683.68	.39624	
37	.65	28.5	15.78	.00913		700.46	.40538	
38	.65	29.15	15.78	.00913		716.24	.41451	
39	.60	29.75	14.57	.00843		730.81	.42294	
40	.60	30.35	14.57	.00843		745.37	.43137	

DAY	DAY	ACCUM	IN³	FT³	IN³	FT³
41	.65	31.00	15.78	.00913	761.16	.44050
42	.60	31.6	14.57	.00843	775.72	.44893
43	.65	32.25	15.78	.00913	791.51	.45807
44	.60	32.85	14.57	.00843	806.08	.46665
45	.60	33.45	14.57	.00843	820.65	.47493
46	.60	34.05	14.57	.00843	835.21	.48336
47	.69	34.70	15.78	.00913	850.99	.49249
48	.65	35.35	15.78	.00913	866.78	.50163
49	.60	35.95	14.57	.00843	881.34	.51006
50	.60	36.55	14.57	.00843	895.91	.51849
51	.60	37.15	14.57	.00843	910.48	.52692
52	.65	37.8	15.78	.00913	926.26	.53605
53	.65	38.45	15.78	.00913	942.04	.54517
54	.60	39.05	14.58	.00843	956.61	.55362
55	.60	39.65			971.18	.56205
56	.60	40.25			985.75	.57048
57	.60	40.85			1000.31	.57891
58	.60	41.45			1014.88	.58734
59	.60	42.05			1029.45	.59577
60	.60	42.65			1044.02	.60420
61	.65	43.3	15.78	.00913	1059.80	.61333
62	.60	43.9	14.58	.00843	1074.37	.62176
63	.55	44.45	13.35	.00773	1087.72	.62947
64	.55	45.00	13.35	.00773	1101.07	.63722
65	.60	45.6	14.57	.00843	1115.64	.64565
66	.55	46.15	13.35	.00773	1128.99	.65338
67	.55	46.70			1142.35	.66111
68	.55	47.25			1155.70	.66884
69	.60	47.85	14.57	.00843	1170.27	.67727
70	.65	48.5	15.78	.00913	1186.05	.68640
71	.60	49.1	14.57	.00843	1200.62	.69483
72	.55	49.65	13.35	.00773	1213.97	.70256
73	.55	50.2	13.35	.00773	1227.32	.71029
74	.55	50.75	13.35	.00773	1240.67	.71802
75	.50	51.3	12.14	.00703	1252.82	.72507
76	.55	51.85	13.35	.00773	1266.17	.73280
77	.51	52.4	13.05	.00756	1279.52	.74050
78	.49	52.9	12.44	.00720	1291.64	.74752
79	.55	53.45	13.35	.00773	1305.01	.75525
80	.55	54.	13.35	.00773	1318.37	.76300

91	.55	54.55	13.80	.00773	1831.73	.77071	
92	.38	55.05	12.14	.00703	1543.51	.77773	
93	.55	55.60	13.55	.00773	1357.22	.78546	
94	.38	56.10	12.14	.00703	1369.36	.79249	
95	.38	56.6	12.14	.00703	1381.50	.79951	
96	.60	57.1	14.57	.00843	1396.07	.80794	
97	.50	57.6	12.14	.00703	1408.21	.81497	
98	.38	58.1	?	?	1420.34	.82199	
99	.50	58.6			1432.48	.82902	
90	.55	59.15	13.35	.00773	1445.83	.83675	
91	.50	59.65	12.14	.00703	1457.97	.84377	
92	.50	60.15	?	?	1470.11	.85080	
93	.50	60.65			1482.25	.85782	
94	.45	61.10	10.93	.00632	1493.18	.86415	
95	.45	61.55	?	?	1504.10	.87047	
96	.45	62.00			1515.03	.87679	
97	.40	62.4	9.71	.00562	1524.74	.88241	
98	.45	62.85	10.93	.00632	1535.67	.88873	
99	.50	63.35	12.14	.00703	1547.81	.89576	
100	.55	63.9	13.35	.00773	1561.16	.90348	
101	.55	64.45	13.35	.00773	1574.51	.91121	
102	.55	65.0	13.35	.00773	1587.86	.91894	
103	.50	65.5	12.14	.00703	1600.00	.92597	
104	.55	66.05	13.35	.00773	1613.35	.93337	
105	.50	66.55	12.14	.00703	1625.49	.94040	
106	.45	67.00	10.93	.00632	1636.42	.94672	
107	.45	67.45	10.93	.00632	1647.34	.95304	
108	.50	67.95	12.14	.00703	1659.48	.96007	
109	.45	68.4	10.93	.00632	1670.41	.96671	
110	.50	68.9	12.14	.00703	1682.55	.97374	
111	.45	69.35	10.93	.00632	1693.48	.98006	
112	.40	69.75	9.72	.00563	1703.21	.98569	
113	.40	70.15	9.71	.00562	1713.19	.99150	
114	.45	70.6	10.93	.00632	1724.12	.99783	
115	.50	71.1	12.14	.00703	1736.26	1.00485	
116	.40	71.5	9.71	.00562	1745.97	1.01048	
117	.40	71.9	9.71	.00562	1755.68	1.01611	
118	.45	72.35	10.93	.00632	1766.61	1.02244	
119	.45	72.8	10.93	.00632	1777.53	1.02876	
120	.40	73.2	9.71	.00562	1787.24	1.03439	

DAY	DIFF	ACCUM	10^3	FT^3	10^3	FT^3
121	.40	73.6	9.71	.00582	1796.95	1.03778
122	.40	74.0	9.71	.00582	1806.67	1.04360
123	.45	74.45	10.93	.00632	1817.59	1.05172
124	.45	74.9	10.93	.00632	1828.52	1.05809
125	.40	75.3	9.71	.00562	1838.23	1.06371
126	.40	75.7	〃	〃	1847.94	1.06933
127	.40	76.1	〃	〃	1857.65	1.07495
128	.45	76.55	10.93	.00632	1868.58	1.08127
129	.40	76.95	9.71	.00562	1878.29	1.08689
130	.40	77.35	〃	〃	1888.00	1.09251
131	.45	77.80	10.93	.00632	1898.93	1.09884
132	.40	78.2	9.71	.00562	1908.64	1.10446
133	.40	78.6	〃	〃	1918.35	1.11008
134	.45	79.05	10.93	.00632	1929.28	1.11640
135	.45	79.5	〃	〃	1940.20	1.16772
136	.40	79.9	9.71	.00562	1949.91	1.17334
137	.50	80.4	12.14	.00703	1962.05	1.18037
138	.55	80.95	13.35	.00773	1975.41	1.18820
139	.40	81.35	9.71	.00562	1985.12	1.19372
140	.40	81.75	〃	〃	1994.83	1.19934
141	.40	82.15	〃	〃	2004.54	1.20996
142	.35	82.50	8.50	.00491	2013.04	1.20987
143	.40	82.9	9.71	.00562	2022.75	1.21550
144	.45	83.35	10.93	.00632	2033.68	1.22182
145	.45	83.8	〃	〃	2044.60	1.22814
146	.40	84.2	9.71	.00562	2054.32	1.23376
147	.40	84.6	〃	〃	2064.03	1.23938
148	.45	85.05	10.93	.00632	2074.95	1.24571
149	.35	85.40	8.50	.00492	2083.45	1.25062
150	.35	85.75	〃	〃	2091.95	1.25554
151	.40	86.15	9.71	.00562	2101.66	1.28616
152	.35	86.5	8.50	.00492	2110.16	1.30108
153	.40	86.9	9.71	.00562	2119.87	1.30670
154	.35	87.25	8.50	.00492	2128.37	1.31162
155	.35	87.6	〃	〃	2136.87	1.31724
156	.40	88.0	9.71	.00562	2147.15	1.32286
157	.40	88.4	〃	〃	2157.50	1.32848
158	.35	88.75	8.50	.00495	2165.99	1.33343
159	.35	89.10	〃	〃	2174.49	[illegible]
160	.35	89.45	[illegible]	[illegible]	[illegible]	[illegible]

DAY	DAY	ACCUM	IN³	FT³		IN³	FT³
161	.40	89.8	9.71	.00456		2191.49	1.3822
162	.40	90.2	"	"		2201.20	1.39388
163	.30	90.5	7.28	.00421		2208.48	1.39809
164	.30	90.8				2215.77	1.40231
165	.30	91.1				2223.05	1.40653
166	.30	91.4				2230.33	1.41074
167	.35	91.75	8.50	.00412		2238.83	1.41486
168	.30	92.05	7.28	.00338		2246.12	1.41824
169	.35	92.4	8.50	.00412		2254.61	1.42479
170	.40	92.8	9.71	.00458		2264.32	1.43041
171	.35	93.15	8.50	.00415		2272.82	1.43536
172	.30	93.45	7.28	.00422		2280.10	1.43958
173	.30	93.75				2287.39	1.44317
174	.30	94.05				2294.67	1.44701
175	.30	94.35				2301.95	1.45233
176	.30	94.65				2309.23	1.46647
177	.35	95.0	8.50	.00972		2317.73	1.46137
178	.30	95.3	7.28	.00422		2325.01	1.46660
179	.35	95.65	8.50	.00482		2333.51	1.47052
180	.35	96.0				2342.01	1.47534
181	.35	96.35				2350.51	1.48036
182	.20	96.55	4.86	.00283		2355.36	1.48319
183	.25	96.8	6.07	.00351		2361.43	1.48676
184	.35	97.15	8.49	.00492		2369.93	1.49162
185	.35	97.5	8.50	.00492		2378.43	1.49653
186	.40	97.9	9.71	.00562		2388.14	1.50215
187	.35	98.25	8.50	.00351		2396.64	1.50566
188	.40	98.65	9.71	.00456		2406.35	1.51087
189	.40	98.95	9.71	.00458		2416.06	1.51691
190	.35	99.3	8.50	.00492		2424.56	1.52183
191	.35	99.65	"	"		2433.06	1.52674
192	.30	99.95	7.28	.00422		2440.34	1.53096
193	.25	100.2	6.07	.00351		2446.41	1.53447
194	.40	100.6	9.71	.00563		2456.12	1.54010
195	.20	100.8	4.86	.00283		2460.98	1.54293
196	.35	101.15	8.50	.00351		2469.48	1.54784
197	.25	101.40	6.07	.00351		2475.55	1.55135
198	.40	101.80	9.71	.00563		2485.26	1.55698
199	.35	102.15	8.50	.00492		2493.76	1.56190
200							

$ID = 5.56''$

$AREA = \left(\frac{5.56}{2}\right)^2 \pi = 24.279 \text{ in}^2$

VOL/INCH $= 24.279 \text{ in}^3$

$= 0.014051 \text{ ft}^3$

INCREMENT inch	VOLUME in^3	VOLUME ft^3
1.00	24.28	.0141
.90	21.85	.0126
.80	19.42	.0112
.70	17.00	.00984
.60	14.57	.00843
.50	12.14	.00703
.40	9.71	.00562
.30	7.28	.00422
.20	4.86	.00281

0	1	10.8 x 3.6 x .210	258.41	115.645		
	2	10.8 x 3.6 x .218	258.52	114.771		
	3	10.8 x 3.6 x .220	257.15	114.417		
	4	10.8 x 3.6 x .217	256.19	114.433		
	5	10.8 x 3.6 x .219	258.49	114.171		
	6	10.8 x 3.6 x .220	257.21	114.455		
42	1	10.8 3.6 .218	257.55	115.613	0	+0.22
	2	10.8 3.6 .219	257.53	115.275	+0.25	+0.90
	3	10.8 3.6 .222	257.21	114.964	+0.91	+0.91
	4	10.7 3.6 .212	252.91	116.322	+2.06	+1.03
	5	10.7 3.6 .219	251.02	116.114	+2.42	+0.79
	6	10.7 3.6 [illegible]	251.87	116.317	+0.49	+0.01
84	1	10.7 3.6 .212	257.11	116.33	-0.18	[illegible]
	2	10.7 3.6 .219	257.26	116.08	-0.93	[illegible]
	3	10.7 3.6 .221	258.98	116.71	[illegible]	+1.36
	4	10.7 3.6 .218	256.10	116.08	+0.47	+0.73
	5	10.7 3.6 .218	251.13	116.55	-0.91	+0.64
	6	10.8 3.6 .220	258.47	115.85	0	-.03
130	1	10.7 3.5 .217	256.91	116.94	-4.12	-.51
	2	10.7 3.5 .217	257.91	116.43	-4.13	-.41
	3	10.7 3.5 .217	258.07	116.63	-3.14	-.52
	4	10.7 3.5 .219	256.67	115.94	-3.27	-.59
	5	10.7 3.5 .218	257.73	116.26	-3.62	-.48
	6	10.7 3.5 .219	256.37	115.67	-4.6	-.93
171	1	10.7 3.5 .216	256.62	120.78	-4.16	+0.47
	2	10.7 3.5 .216	257.63	120.15	-4.56	+0.40
	3	10.7 3.5 .217	259.02	114.75	-4.12	+0.35
	4	10.7 3.5 .217	256.11	113.43	-3.69	+0.86
	5	10.7 3.5 .215	257.45	114.44	-3.62	+3.27
	6	10.7 3.5 .219	256.07	115.57	-4.75	-0.46

bisco

brand industrial services, inc.
1420 renaissance drive, park ridge, illinois 60068, (312) 298-1200, telex 282-482
a subsidiary of brand insulations, inc.

Job 1047
2-15-78

ATTACHMENT 7

TYPE TEST PROGRAM

ON

NEUTRON SHIELDING MODELS

ATTACHMENT 7 JOB 1047
2-24-78

WYLE LABORATORIES
SCIENTIFIC SERVICES AND SYSTEMS GROUP
EASTERN OPERATIONS
FACILITIES LOCATED AT
HUNTSVILLE, ALA. AND HAMPTON, VA.

TYPE TEST PROGRAM

ON

NEUTRON SHIELDING MATERIAL

TEST REPORT

5.0 TEST REQUIREMENTS.

5.1 Steam Impingement Test

One sample shall be exposed to 600°F steam jet impinging for 180 seconds normal to the as-molded free surface. The steam jet shall be approximately 1/4-inch diameter and the exit nozzle located 6 inches from the sample surface. The sample shall be evaluated after the test for any erosion, melting or dissolving of the sample material.

5.2 Borated Water Submersion Test

All four samples shall be submerged in borated water in a pressure tight container maintained at 280°F for 30 days. The borated water shall contain the following constituents:

0.28 Molar (17,300 PPM) Boric Acid-H_3BO_3 (3000 PPM Boron)

NaOH (Sodium Hydroxide) as required to maintain initial pH of 9.0 to 9.5 at room temperature

At the end of the 30-day submersion test, the gas shall be analyzed for evolution of hydrogen and methane gases. The samples shall be evaluated for any physical change, i.e., dissolving, deformation or weight change.

6.0 TEST PROCEDURES AND RESULTS

6.1 Steam Impingement Test

6.1.1 Steam Impingement Test Procedure

A 1/4-inch fitting for an exit nozzle was located 6 inches from the Shielding Material sample surface. A 1/4-inch line from a high pressure, high temperature steam source with a valve for regulating the flow furnished the steam supply to the exit nozzle. A bleed valve was provided upstream of the flow regulating valve to condition the steam in the line prior to starting the impingement. A thermocouple was installed in the steam flow approximately 18 inches upstream of the exit nozzle for measuring the steam temperature. The test setup is shown in Photograph 1. The Shielding Material sample was weighed as a control. The weight was 2.591 pounds.

The Shielding Material sample was located under the exit nozzle, the bleed valve opened to condition the steam, the flow control valve opened and the 600°F steam allowed to impinge on the sample for 180 seconds. Photographs 2 and 3 show the Steam Impingement Test in progress. Both the as-molded free surface and the opposite surface were exposed to the 180-second impingement.

Test Report

REPORT NO. 45[illegible]-1

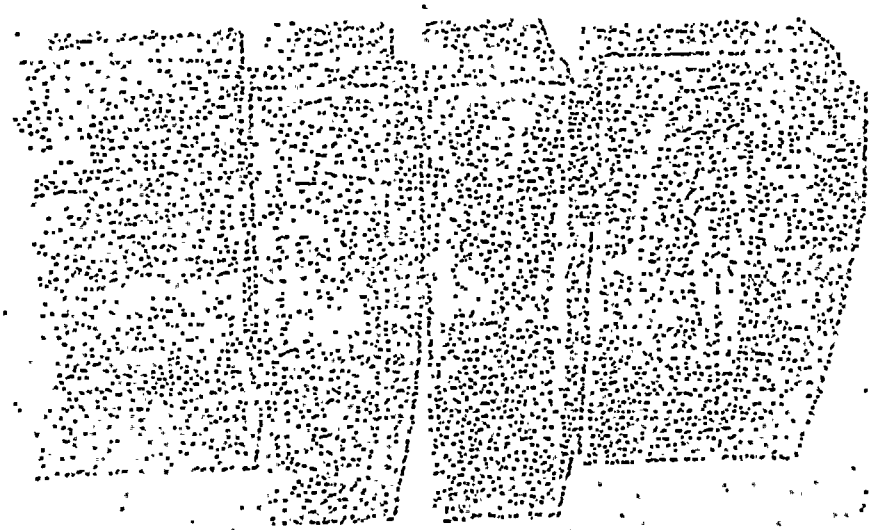
WYLE JOB NO. 45[illegible]

CUSTOMER P.O. NO. [illegible]

DATE February 22, 197[illegible]

SPECIFICATION(S) Sec Ref[illegible]

In Section 7.0



3.0 CUSTOMER Risol Industrial Services, Inc. (RISCO)

ADDRESS Elk Grove Village, IL 60007

4.0 TEST SPECIMEN Four 2"x6"x12" Neutron Shielding Material Samples

5.0 MANUFACTURER RISCO

6.0 SUMMARY

The Neutron Shielding Material (silicone resin containing boron carbide) was subjected to Nuclear Power Plant Loss-of-Coolant-Accident (LOCA) simulations to qualify the Shielding Material for Nuclear Power Plant application. The test program was performed as required by the RISCO Purchase Order Number 1731 and Wyle Laboratories Test Plan 545/539/CP, Revision A.

The Shielding Material showed absolutely no detrimental effects from the 300°F Steam Impingement Test. The exposure to submersion in borated water at 280°F for 31 days resulted in only small quantities of hydrogen and methane off-gassing.

STATE OF ALABAMA } ss
COUNTY OF MADISON }

Alabama Professional Engineer License No. 6753

[illegible] being duly sworn deposes and says: The information contained in this report is the result of [illegible] and to the best of his knowledge [illegible]

TEST BY Special Projects

PROJ. ENGINEER [illegible]

WYLE LABORATORIES [illegible]

6.0 TEST PROCEDURES AND RESULTS (Continued)

6.2 Borated Water Submersion Test (Continued)

6.2.2 Borated Water Submersion Test Results (Continued)

After the fifteenth day, the liquid sampling valve indicated the liquid/gas interface was at that level. Inspection of the container revealed an apparent pin hole leak in the bottom cap weld. Approximately 600 cubic inches of borated water were added to the container with a pump while the container remained pressurized and at 260°F.

The two gas sample analyses in percent by volume were as follows:

	Hydrogen	Methane	Ethane
After 28-day exposure:	0.03	0.27	0.07
After 31-day exposure:	0.14	1.83	1.60

The letter certifying the analysis is contained in Appendix H.

The Shielding Material control sample was weighed after removal of the samples from the borated water following the 31 days of exposure. The control sample weight was 8.650 pounds, an increase of 0.050 pounds. All four samples appeared to be unchanged in all other physical aspects. Photograph 7 shows the four Shielding Material samples immediately after removal from the borated water. The test data sheets are contained in Appendix I.

7.0 REFERENCES

7.1 Brand Industrial Services, Inc. Purchase Order Number 1731.

7.2 Wyle Laboratories Type Test Plan 545/5507/07.

6.0 TEST PROCEDURES AND RESULTS (Continued)

6.1 Steam Impingement Test (Continued)

6.1.2 Steam Impingement Test Results

Inspection of the Shielding Material sample surface immediately following the steam impingement revealed no changes or effects; therefore, weight was not checked. Photograph 4 shows the Shielding Material sample after exposure to the Steam Impingement Test.

6.2 Borated Water Submersion Test

6.2.1 Borated Water Submersion Test Procedures

The four samples were placed in an approximately 1.5 cubic-foot container and filled with the specified borated water to approximately 75% of the container volume, the remaining 25% available for gas evolution sampling. The borated water was mixed in accordance with Paragraph 5.2 except the sodium hydroxide (NaOH) was not added as the pH after Boric Acid (H_3BO_3) mixing resulted in a room temperature pH of 9.7.

The container was sealed and a gas sampling line containing a hand valve, pressure gage and relief valve was attached to a fitting penetrating the gas volume. A sampling line and valve were attached to the container below the liquid/gas interface and above the shielding samples to assure borated water always covered the shielding samples. The container was placed in an environmental chamber to maintain the 240°F temperature for 31 days. A thermocouple was attached to the container exterior for recording container borated water temperature. Photographs 5 and 6 show the container setup and the environmental chamber.

Gas samples were extracted after 24 and 31 days of exposure and gas chromatography analysis performed to determine hydrogen and methane gas content. The gas chromatography was performed by Southern Research Institute, Birmingham, Alabama.

6.2.2 Borated Water Submersion Test Results

After the environmental chamber temperature stabilized at 240°F, 8 hours were required to stabilize container/borated water temperature at 240°F. During the initial stabilization, the container pressure increased from 3½ to 5½ psig (well above the expected saturated steam pressure of 10 psig) and was vented to prevent overpressurization several times to a pressure equal to or less than the expected saturated steam pressure of 10 psig. After the third day, the pressure stabilized at 15 to 16 psig.

6.0 TEST PROCEDURES AND RESULTS (Continued)

6.2 Borated Water Submersion Test (Continued)

6.2.2 Borated Water Submersion Test Results (Continued)

After the fifteenth day, the liquid sampling valve indicated the liquid/gas interface was at that level. Inspection of the container revealed an apparent pin hole leak in the bottom cap weld. Approximately 400 cubic inches of borated water were added to the container with a pump while the container remained pressurized and at 240°F.

The two gas sample analyses in percent by volume were as follows:

	Hydrogen	Methane	Ethane
After 24-day exposure:	0.03	0.27	0.67
After 31-day exposure:	0.14	1.83	11.6

The letter certifying the analysis is contained in Appendix II.

The Shielding Material control sample was weighed after removal of the samples from the borated water following the 31 days of exposure. The control sample weight was 8.640 pounds, an increase of 0.049 pound. All four samples appeared to be unchanged in all other physical aspects. Photograph 7 shows the four Shielding Material samples immediately after removal from the borated water. The test data sheets are contained in Appendix I.

7.0 REFERENCES

7.1 Brand Industrial Services, Inc. Purchase Order Number 1733.

7.2 Wyle Laboratories Type Test Plan 545/5397/CP.

bisco

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1420 renaissance drive, park ridge, illinois 60068, (312) 298-1200, telex 282-482
a subsidiary of brand insulations, inc.

Job 1047
2-15-78

ATTACHMENT 8

NEUTRON & GAMMA

Attenuation tables for

various Boroflex compounds.

BISCO SAMPLE [illegible] TEST MEASUREMENT

Sample Identification	Sample Description	Attenuation Measurements					
		Neutron < 0.55 eV			Gamma 1.2 MeV		
		Attenuation, A	Thickness, T (in)	Attenuation Factor, μ (in^{-1})	Attenuation, A	Thickness, T (in)	Attenuation Factor, μ (in^{-1})
6 - 1	6% B_4C	.1248	.240	8.68			
6 - 2	6% B_4C	.1284	.240	8.54			
6 - 3	6% B_4C	.1348	.240	8.34			
10/100 - G	10% B_4C, < 100 mesh	.3202	.270	4.23			
25/100 - O	25% B_4C, < 100 mesh	.0398	.135	23.88			
40.6/100 - A	40.6% B_4C, < 100 mesh	.0069	.135	36.89			
40.6/100 - B	40.6% B_4C, < 100 mesh	.0086	.135	35.22			
40/220 - E	40% B_4C, < 220 mesh	.0041	.135	40.77			
40/220 - F	40% B_4C, < 220 mesh	.0073	.125	39.38			
60/100 - C	60% B_4C, < 100 mesh	.0033	.135	42.41			
60/100 - D	60% B_4C, < 100 mesh	.0054	.120	43.52			
SF150L/158.6		.2306	.525	2.79	.797	.525	.432
143IL/60 - 1		.1852	.570	2.96	.803	.570	.385
143IL/60 - 2		.2098	.525	2.97	.802	.525	.420
176.7ILL - 3		.2462	.540	2.59	.772	.540	.479
176.7ILL - 4		.2957	.475	2.56	.791	.475	.493

Equations: Attenuation = Transmitted Beam/Incident Beam

$= A$

$= e^{-\mu T}$

$\mu = 1/T \ln (1/A)$

ATTACHMENT 8 Job 1047 2-24-78

THE UNIVERSITY OF MICHIGAN
PHOENIX MEMORIAL LABORATORY
FORD NUCLEAR REACTOR
ANN ARBOR, MICHIGAN 48105

File

April 8, 1977

Mr. Jim Sherwood
Brand Industrial Services, Inc.
630 Bonnie Lane
Elk Grove Village, Illinois 60007

Dear Jim:

Enclosed is a neutron and gamma attenuation table for the samples you provided. Values of the attenuation factor, μ, give relative abilities to attenuate neutrons and gammas.

You can plug into the formula

$$A = e^{-\mu T}$$

to calculate attenuation, A, for a given thickness, T, or the formula

$$T = 1/\mu \ln (1/A)$$

to calculate the thickness required to provide a desired attenuation.

Sincerely,

Bob Burn

Reed R. Burn
Reactor Manager

Enclosure

RRB:jab

bisco

brand industrial services, inc.
1420 renaissance drive, park ridge, illinois 60068, (312) 298-1200, telex 282-482
a subsidiary of brand insulations, inc.

Job 1047
2-15-78

ATTACHMENT 9

The Effect of Combined Gamma and Neutron Radiation on the Hydrogen Content of BISCO NS-II Neutron Shielding Material

bisco
brand industrial services, inc.
1420 renaissance drive, park ridge, illinois 60068, (312) 298-1200, telex 282-482
a subsidiary of brand insulations, inc.

Job 1047
2-15-78

ATTACHMENT 10

The Reactor Cavity Annular Gap Shield Design - Using NS II Material at Arkansas Nuclear One Unit Two

BISCO Project #1006-60

Warranty

BISCO warrants to the purchaser that the work provided under this contract will be free from defects in material, workmanship, and title, and will meet the specifications contained in the Contract of Sale.

BISCO shall be responsible for any repairs or replacement caused by defective materials or workmanship which shall become necessary during a period of one year from and after the date of initial acceptance of the work by this contract. If certain portions are shown to be defective within the original warranty period, then the warranty period on the repaired portion shall be extended one year from and after such time that all defects are corrected.

If any repairs or replacements are necessary, BISCO will undertake, with due diligence, to make the aforesaid repairs or replacements within 10 days after receiving written notice that such repairs or replacements are required. If BISCO should fail to begin such repairs or replacements within this period, or in the case of emergency wherein, in the judgment of the purchaser, delay would cause serious loss or damage, the repairs and/or replacements may be made by the purchaser and charged to BISCO, provided the purchaser obtains BISCO's prior written consent.

The guarantee furnished herein by BISCO will be rendered void if the work is damaged by others, or if it is subjected to improper operation or temperatures. If and when the above condition occurs, repairs will be provided by BISCO under the normal unit cost provisions for time and material, and only after the rework is accepted by the customer and paid for, will BISCO extend a warranty on the products and services.

Correction of non-conformities of the materials and services provided by BISCO under this contract shall constitute the entire liability of BISCO with respect to such work, whether in contract, tort, or otherwise, unless otherwise agreed to and expressly provided in this contract.

THE WARRANTY FURNISHED BY BRAND IN THIS ARTICLE IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES (INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS OF PURPOSE), EXCEPT THAT OF TITLE, WHETHER WRITTEN, ORAL, OR IMPLIES, IN FACT OR IN LAW.