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INVESTIGATIONS OF RADIOACTIVE
FUEL-BEARING GLASSES

Contract AT-(30-1)-2489
May 1, 1960 - March 31, 1961

P. A. Lockwood **MASTER**

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INVESTIGATIONS OF RADIOACTIVE FUEL-BEARING GLASSES

May 1, 1960 - March 31, 1961

by

P. A. Lockwood

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INVESTIGATIONS OF RADIOACTIVE FUEL-BEARING GLASSES

by

P. A. Lockwood

Abstract

A series of glass compositions containing uranium oxide were investigated to determine fiberizability and physical properties of resultant fibers. The basic properties to be determined were (1) the maximum U_3O_8 content in a fiberizable glass and (2) the maximum service temperature of the fibers. Glasses containing 60 weight per cent U_3O_8 were fiberizable; the fibers had strengths of 100,000 psi at 1600°F.

Fiber-forming equipment was installed at Mound Laboratory to produce glass fibers containing PuO_2 . Fibers were successfully formed in the first trials. For additional work at Mound Laboratory a series of base glasses were provided affording a wider range of both PuO_2 solubility and physical properties.

Samples were prepared for use by Rensselaer Polytechnic Institute and Cleveite Corporation for experimentation on the utilization of fuel-bearing glasses in chemo-nuclear and power reactors.

INVESTIGATIONS OF RADIOACTIVE FUEL-BEARING GLASSES

INTRODUCTION

For several years Owens-Corning Fiberglass Corporation has supplied Rensselaer Polytechnic Institute with fuel-bearing glasses for experimentation with chemical reactions energized by atomic fission energy. In 1958 and 1959, Owens-Corning operated under a subcontract from Rensselaer in order to expedite research on glass fibers containing fuel materials.¹ New concepts for utilization of fuel-bearing glasses have emerged from this research and to investigate them prime contract AT-(30-1)-2489 was awarded to Owens-Corning Fiberglass Corporation in 1960 by the AEC covering:

- Task Order No. 1 Supplying samples to Clevite Corporation for the development of a power reactor fuel element.
- Task Order No. 2 Supplying samples to Rensselaer Polytechnic Institute for chemo-nuclear research and radiation tests on unique combinations and configurations of fuel-bearing glasses.
- Task Order No. 3 Studies concerned with problems encountered in Task Orders 1 and 2 and consultation with the AEC and its contractors on the utilization of fuel-bearing glass fibers.

¹"Investigation of Radioactive Fuel-Bearing Glasses," Rensselaer Polytechnic Institute Subcontract, RPI 441.37-1, First and Second Annual Reports, 1958 and 1959.

SUMMARY

All samples requested in Task Orders 1 and 2 were supplied with the exception of two items. The samples comprised a wide variety of fiber configurations. The work entailed determining fiber-forming potentials of a series of high temperature urania-bearing glasses and the physical properties of those fibers formed.

Glasses studied contained up to 75 weight per cent U_3O_8 . At 60 weight per cent U_3O_8 fibers exhibited good physical properties up to 1800°F. Leaching and firing yielded binary component silica-urania glasses of inherently greater refractoriness and not directly formable into fibers. Mats of leached and fired fibers were handleable after heating at various temperatures up to 2300°F.

Differences in devitrification characteristics of glasses made with depleted U_3O_8 versus enriched U_3O_8 appear to be majorly the consequence of about one per cent higher uranium atom content obtained with the lower atomic weight enriched urania when the glasses are batched on the same weight per cent basis. Uranium-oxygen stoichiometry also may have an effect on devitrification behavior. Determination of the oxidation state of the uranium in various glasses is in progress to check that point.

Analytical procedures for determining the uranium content of aluminum-coated urania-bearing glasses have been refined to the point where reproducible results are obtainable on single specimens but the problem of sampling a complete production run to obtain reliable results has not been solved.

Fiber-forming equipment was installed at Mound Laboratory to produce glass fibers containing PuO_2 . Fibers were successfully formed in the first trials. Since that time, Owens-Corning has consulted with Mound Laboratories several times and has provided them with a series of base glasses affording a wider range of both PuO_2 solubility and physical properties.

Clevite Corporation received over 28 pounds of aluminum-coated RX-70 glass (50 weight per cent depleted U_3O_8) and over 11 pounds of aluminum-coated RX-70E glass (50 weight per cent, 93 per cent enriched U_3O_8) for the development of an MTR reactor fuel element.

Rensselaer Polytechnic Institute received a variety of samples for use in its chemo-nuclear experiments and various irradiation tests.

Eight AEC contractors were consulted on possible ways of utilizing fuel-bearing Fiberglas.

DISCUSSIONBasic Research Investigations of Glass CompositionsHigh Temperature Urania-Bearing Glasses

Glass composition work under Contract AT-(30-1)-2489 differed from the earlier work under the RPI subcontract in that the primary objective was glasses having acceptable properties at high temperatures. A study was made of the ternary system urania-silica-alumina with emphasis on achieving the highest possible urania content. The high melting temperatures of the glasses studied necessitated use of screening and selection techniques different from those described in the subcontract reports.²

Small batches of the material were mixed as had been done in the earlier work and heated to 2850°F. For many of the batches, this was a sintering operation rather than a melting operation and the result was a cinder-type material rather than a glass. On other occasions glasses formed but often they were incompletely melted or were considerably devitrified. A small grain of the resultant material was then heated on a high temperature metallic strip in an argon atmosphere to check fiber-forming properties. To help in determining these properties, a 25X binocular microscope was utilized. The first property determined was the temperature at which the material melted completely. This temperature was measured with an optical pyrometer sighted on the melt. The melting temperatures and compositions for Glasses RX-254 - RX-357 are shown in

²Ibid., First Annual (1958), pp. 4 - 7, 22.

Table I and Figure 1. It should be noted that the melting temperature was not precisely determined because the temperature of the strip was raised in small increments, not continuously. Additionally, the optical readings were not corrected for emissivity of the material. The main objectives were to determine which compositions would melt at too low a temperature to be interesting and which would melt at too high a temperature to permit fiber-forming in the available equipment.

The fiberizability of the glass was determined by dipping a wire into the melt and attempting to draw short fibers. A good estimate of the probability of being able to draw continuous fibers from a fiber-forming bushing can be made by an experienced technician with this technique. These data are also noted in Table I.

When changing temperature to determine optimum fiber-forming conditions, the melts frequently would devitrify. The compositions which devitrified before suitable fiber-forming viscosity was reached are indicated in Table I. The speed of devitrification and approximate devitrification temperature obtained by this method were considered in evaluating the glasses during fiber-forming studies.

Surface tension of the glasses was qualitatively determined by observing how the different melts of glass wet the metal of the heated strip. The amount of wetting is related to surface tension and has a bearing on the way the glass will fiberize in a bushing. Note was made of the wetting characteristics of the various glasses as shown in Table I. Those glasses which wet the metal poorly and drew up into beads are described as having high surface tension whereas those which wet the metal and spread over the

surface are described as having low surface tension. It is recognized that these categories are not entirely accurate in all cases but they are adequate for the purposes of screening and selecting glasses for further work and for determining optimum fiber-forming conditions.

Several of the glasses selected were fiberized in a special high temperature bushing developed through OCF corporate research. The bushing is considerably more complicated than those used in the subcontract work and thus it will probably be difficult to scale up to a major production system. It is felt, however, that these high temperature bushings will probably be suitable for small quantity production of fuel-bearing fibers.

For fiber studies the compositions were divided into two groups:

1. Glasses likely to have high temperature properties and showing a fair degree of promise for fiberization.
2. Glasses containing large amounts of urania up to the maximum tolerable in a fiberizable glass.

It was felt that considerable modification of the forming process might be necessary to form fibers of this latter group. Several modifications were made at Owens-Corning expense but none of them improved fiberization capabilities of the glasses studied over what had been accomplished with the standard forming techniques.

Performance of the selected high temperature glasses in the one hole bushing is tabulated in Table II. The forming temperatures given in those cases where fibers formed were not corrected for emissivity at the bushing; hence the actual temperatures may be as much as 400°F higher.

It should be noted also that the fibers obtained were often of poor quality, they were produced at low speeds, and the forming conditions were extremely critical; however, it seems probable that techniques can be devised for producing high temperature fibers containing 50 to 60 per cent U_3O_8 on a semi-commercial scale. There is also some possibility of producing fibers containing above 60 per cent U_3O_8 , but due to equipment difficulties toward the end of this contract period only intermittent success was attained in forming fibers of these compositions.

When fibers were obtained from any of the experimental compositions, samples were tested for tensile strength at room temperature and elevated temperatures. Results are tabulated in Table III. Of the compositions listed in Table III, RX-70 and RX-78 can be fiberized in ordinary platinum alloy bushings and the fibers have tensile strengths comparable to those expected of commercial fibers. The high temperature fibers were produced by the special techniques, and the lower strengths obtained at room temperature for these fibers are believed to be due to the method of forming rather than to an inherent weakness of the glass. RX-255 glass containing 50 per cent U_3O_8 and RX-308 glass containing 60 per cent U_3O_8 show the most promise as high temperature materials. Glass RX-350 which contains 75 per cent U_3O_8 is an apparent anomaly in that the highest strengths are found at the highest temperature. The fibers tested at the highest temperature were the smallest in diameter, and it is believed that the higher strengths reflect a difference in quality rather than an increase in strength as a result of the higher temperature. Glass RX-350 was difficult to fiberize; but if reproducible results can be obtained, this glass, or glasses similar to it in composition,

appear very promising for making high temperature nuclear-material-bearing fibers. At the present time, we have nuclear-material-bearing glasses with usable strengths up to 1800°F. These glasses appear to have a reasonable possibility of fiberization on a limited commercial scale. It should be noted that nothing is known about the effect of long-time exposure to high temperatures on either the maximum strength or yield strengths of the glasses. Future work will be done on glasses having even higher temperature resistance and higher urania content.

RX-70 glass containing 50 weight per cent U_3O_8 and RX-78 glass containing 35 weight per cent U_3O_8 (Table IV) have been used for a considerable number of experimental trials. In order to better understand these glasses, several properties were measured and are reported in Table V. Of particular interest are the tensile strengths of the fibers at room temperature and 1000°F. Softening point and liquidus temperatures were determined in order to estimate the upper working temperature limit of the glasses as solid materials and to define the lower working temperature as true liquids. In general, the upper working temperature limit as a solid is some 300 - 400°F lower than the softening point. The lower working limit of the glasses as a liquid material is, of course, the liquidus temperature. The specific gravities of these glasses were determined for use in certain of the experimental calculations in reactor studies.

Leached Glasses

Leaching experimentation was described in considerable detail in the First and Second Annual Reports of the Rensselaer Polytechnic Institute Subcontract. It was desirable to continue a certain amount of this leaching

experimentation to verify some of the earlier results. Several small samples of RX-137 glass which originally contained 20 per cent by weight U_3O_8 were leached and then fired to form a new glass composition. The composition of RX-137 is given in Table IV and the details of the leaching and firing procedure are listed in Table VI. All samples were flexible and reasonably strong after processing but those with leaching losses under 27 per cent seemed weaker than the other fibers.

The term leaching when applied to glasses refers to the specific process whereby certain constituents are preferentially dissolved. With most glasses, exposure to acids, other than hydrofluoric, simply causes a general deterioration of the surface of the glass, the rate being dependent upon the composition of the glass, the temperature, and the nature of the acid. With certain special glasses only constituents other than silica are attacked by the acid. Objects made from such glasses can be leached to essentially pure silica while they retain their original shape. The structure at this stage is open and porous very like that of silica gel. Subsequent firing at temperatures considerably under usual working temperatures for silica causes the structure to contract and revitrify to a point where the temperature resistance is very nearly that of pure silica.

Further experimentation has determined that leaching will remove constituents selectively. It is possible to leach out one constituent, then another, and later on still another. This stepwise leaching technique does not result in sharp clean removal of only one constituent at a time, there being some small overlap, but it is of practical interest in leaching the urania-bearing glasses. Starting with a silica-urania-soda ternary

composition, it is possible to preferentially leach out the soda before very much of the urania is removed. The effect is to increase both silica and urania contents of the composition. The net result is an essentially binary component glass which could not be fiberized under normal conditions.

Ideally, only the Na_2O would be removed in the leaching process, but as mentioned above this is not a completely selective stepwise process and therefore some of the U_3O_8 is also removed. From the weight losses of the RX-137 glass after leaching, a theoretical reduction of 24 per cent by weight would be obtained if only the soda was removed. However, the loss is greater than this, so there is some removal of urania and/or SiO_2 . Analysis of the leach liquor indicates that only 0.3 per cent SiO_2 has been removed; therefore, the increase above 24 per cent in weight loss must be loss of urania. Actually, up to one per cent of the Na_2O is still present in the glass after leaching which means the loss of urania is slightly greater than the difference between the observed and calculated weight losses. The urania from these leached solutions could easily be recovered if this process were to be considered for production purposes.

By this process several glass fiber compositions which will withstand temperatures of 2300°F are possible which could not be formed directly. The fibers were leached in mat form and it was therefore not possible to obtain their physical properties. The mats were handleable for all practical purposes after heating to 2300°F.

Devitrification

One of the problems encountered in the production of samples (reported in detail beginning on page 15) was the devitrification behavior of glasses

containing enriched U_3O_8 , which was different from the behavior of the same glasses compounded with depleted U_3O_8 . The glasses containing enriched U_3O_8 devitrified at a faster rate at the fiber-forming temperature than did the glasses containing depleted U_3O_8 . A comparison of the liquidus temperatures and devitrification rates was made by the gradient method in which the glasses were heat treated in a long, narrow platinum boat in a furnace with a temperature gradient from one end of the boat to the other. The tests were run in a double boat with RX-70 glass, made with depleted U_3O_8 , disposed on one side and RX-70E glass, made with enriched U_3O_8 , on the other. For a short holding time, RX-70E appeared to have a higher devitrification rate and a liquidus temperature approximately $40^\circ F$ higher than for RX-70. For long heating periods, i.e. up to six hours, the devitrification rate difference was only slightly higher for the enriched material and the liquidus temperature difference had dropped to about $10^\circ F$. This difference does not seem to be significant and may be due to the fact that the batches are compounded on a weight per cent basis. The atomic weight differences between U_{235} and U_{238} result in a yield of approximately one per cent more uranium atoms from the enriched material than from the depleted material for the same weight U_3O_8 . As RX-70 glass contains very close to the solubility limit of U_3O_8 at the operating temperature, it may be taking longer for the additional one per cent of uranium atoms to be dissolved into the enriched urania glass (RX-70E). This additional one per cent of uranium atoms may also be responsible for slight alteration of the properties as indicated by the six-hour liquidus temperature measurements.

As noted earlier, the problem of devitrification seems to extend beyond the difference in numbers of uranium atoms present. Consecutive melts of RX-70 or RX-78 containing depleted urania were found to have slightly different forming characteristics, for which there appeared to be no simple explanation. It was also found that the product of devitrification when the devitrification rate was abnormally high was UO_2 instead of a U_3O_8 -silica complex normally obtained. It is therefore suspected that in the forming procedure U_3O_8 is being reduced to UO_2 and that UO_2 is not as soluble in the melt as U_3O_8 . Study of this matter indicates that heat transfer within the dark colored, high urania content glasses is very poor due to much higher infrared absorptivity. The net result is that melts of these glasses stay hot longer, that is, cool slowly enough to permit devitrification to occur. The melts are made in platinum alloy crucibles in gas-fired furnaces and quenched by placing the crucibles in cold water immediately on removal from the furnace. To bypass the problem, melts were limited to 100 grams. It was felt that the interiors of larger melts would cool so slowly that devitrification could proceed in the central portions.

Further investigation in this area indicates that the Ames Laboratory at Iowa State University³ has been producing glasses containing up to 45 per cent UO_2 that do not devitrify very readily. If this is true, the problem is to find out why the small percentage of UO_2 produced in the

³C. D. Wirkus and D. R. Wilder, "Uranium Silicate Glasses," Ames Laboratory, Iowa State University, Ames, Iowa.

first melting operation due to decomposition of U_3O_8 causes so much devitrification. After consulting with Dr. Wilder of the Ames Laboratory, it was determined that in melting his glasses he may possibly have been converting UO_2 to U_3O_8 . If this is true, it is necessary to determine what effect the exact ratio of oxygen to uranium in the batch material and in the finished glass has on the devitrification rate of the glass.

Initial efforts in the study of the oxygen-uranium ratio in the glasses are attempts to determine ultraviolet, visible, and infrared absorption spectra of several uranium-bearing glasses. Other investigators have shown that uranium ions in true liquids, such as aqueous solutions, have absorption peaks determined by the ionic states of the uranium. Glass can be considered as a true solution of infinitely high viscosity and thus it may also be possible to measure the actual distances between atoms of oxygen and uranium in different ionic states by recently developed X-ray diffraction techniques. At the present time all of the work in this area is preliminary. If the methods under investigation prove successful, it will be possible to melt glasses using various batch materials and under various atmospheric conditions, determine the oxygen/uranium ratio during the melting and fiber forming operations, and, finally, determine how changes in this ratio affect the devitrification rate of the glasses.

Aluminum Coating

In supplying aluminum-coated fibers to various contractors (reported in detail beginning on page 15), it was found that the uranium glass was not coated with as much aluminum by weight or volume as some of the earlier uranium-free glasses. Efforts were made to improve the coating technique.

There was some improvement in the aluminum-to-uranium ratio, but it did not become equal to that obtained with the non-fuel-bearing fibers. It was found that the urania glass was unusual in that fiber diameter had an effect on the amount of aluminum coated onto the fibers. This had not been found true of the coatings on earlier commercial glass fibers. Small diameter urania glass fibers were found to have heavy coatings of aluminum, some of them greater than 60 per cent by volume. With slightly coarser fibers, i.e. 0.6 mil diameter, the maximum obtainable ranged 45 to 50 per cent by volume. The only explanation seems to be that the urania glass fibers of larger diameter cool slower and thereby reduce the amount of aluminum adhering to the fiber as it is drawn through the molten metal.

Uranium Content Analysis

Cooperative work was done with the Cleveite Corporation to develop an analytical procedure for uranium which yields reproducible results. Several systems of analysis and modifications of these systems were tried before suitable analyses were made by wet chemical methods that were reproducible within 0.1 per cent. Based on samples analyzed with this method, a master sample of known uranium content was made up for use as a standard in the X-ray fluorescence technique. The major difficulty with the analyses now lies with the fact that the aluminum coating is not uniform on the fibers (Figure 2) and thus sampling a tube of the fiber to obtain a representative sample becomes a major problem. Variations of one to two per cent in uranium content still persist with the present sampling technique. At present no new methods are known which will reduce this sampling error. Therefore the major effort has been placed on improving

the coating technique to achieve a more uniform aluminum coating. At the present time, more uniform coatings have been produced but only with low percentages of aluminum. These lower percentages of aluminum are so much below the desired amount that it is not considered feasible to use them for sample production.

Plutonium Oxide Bearing Glasses

In May of 1960 equipment was shipped to the Mound Laboratory at Miamisburg, Ohio, for use in fiberizing glasses containing plutonium oxide. The Owens-Corning Fiberglas Corporation helped the Mound Laboratory personnel install this equipment and advised them on ways of modifying their present equipment for use in the production of plutonium oxide glass. Owens-Corning assisted in melting and fiberizing the first plutonium oxide-containing glass. Based on this experience the Mound Laboratory personnel were able to continue further fiberizing experiments with the equipment.

The Owens-Corning Fiberglas Corporation has consulted with the Mound Laboratory on what properties were desired from the glasses. As a result of these discussions, OCF has supplied ten more glass compositions to serve as base glasses for plutonium glass systems. These compositions are given in Table VII. The Mound Laboratory will report the PuO_2 concentrations added to these glasses and the properties found.

Production of Samples for AEC Contractors

Clevite Corporation

Samples were produced for the Clevite Corporation of Cleveland, Ohio, for development trials in the production of an MTR fuel element. These

fuel elements were to be made with a glass-fiber-metal composite material for the core and a suitable cladding material with glass-fiber-metal composites being a candidate material for the cladding as well. The core material would be made with an aluminum-coated glass fiber which contained 50 per cent U_3O_8 in the glass. The clad material would be made with uranium- and boron-free glass fibers. The major items for this task consisted of 28 pounds of aluminum-coated glass fibers containing 50 weight per cent depleted uranium oxide and 11 pounds of aluminum-coated glass fibers containing 50 weight per cent enriched uranium oxide. The glass fibers containing depleted U_3O_8 were to be used in the development work whereas the enriched uranium oxide glass fibers were to be used for irradiation testing work.

Approximately 60 volume per cent of the coated fibers was to be aluminum coating and the glass fiber diameter was to be normally 0.6 mil. It was found, however, that the 0.6 mil fiber could be coated with only 50 volume per cent of aluminum. The metal coating procedure was the same as that described in the First Annual subcontract report for Rensselaer Polytechnic Institute. It consisted of drawing the fiber through a meniscus of the molten metal during the forming process. The only difficulties found in producing this material were inability to get as much aluminum on the fiber as desired and sampling and analysis to determine the ratio of aluminum to glass and the uranium content of the glass.

Rensselaer Polytechnic Institute

Our second task order was to supply samples to the Rensselaer Polytechnic Institute of Troy, New York. The majority of the fibers requested were for various irradiation tests in the MIR and Brookhaven reactors. One set of

samples was to check on the possibility of an open mesh cloth type configuration for the fuel-bearing fibers.

One thousand feet of glass-coated uranium-glass fibers consisting of a core of 35 per cent U_3O_8 (93 per cent U_{235} enriched) were requested for burnup studies at MTR. The enriched fiber core was to be 140 microns in diameter overcoated with a 17 micron thick layer of uranium- and boron-free glass. These fibers were drawn from a bushing which melted both glasses simultaneously in separate compartments.

Another sample produced was five grams of 25-micron diameter fiber containing 20 per cent thorium oxide and 20 per cent U_3O_8 , enriched with 93 per cent U_{235} . These single filaments are to be used in radiation damage studies to assess the effect of the uranium oxide and the thorium oxide combination on fiber properties under irradiation and to scout the possibility of using this sort of material as a breeder type fuel. The sample was produced in a standard laboratory bushing position with no particular difficulty.

Samples of 0.6 mil diameter fibers drawn from a 35 per cent U_3O_8 (93 per cent U_{235} enriched) glass were also produced for physical property studies after irradiation at MTR. The fibers are to be wound on pins mounted in stainless steel tubes so that they can be removed and tested after irradiation. These fibers show some surface imperfections due to a slight amount of devitrification attributable to the slower cooling rates characteristic of the somewhat larger fiber diameter. The control samples tested indicated that these fibers were not quite as strong as other fibers produced of the same glass composition but it is not expected that this will seriously affect the overall test.

Five sets of samples were also returned from RPI after being tested in the Brookhaven reactor for irradiation burnup. The first set of samples were controls and showed a strength of 175,000 psi. The other four samples were in the reactor for varying lengths of time and had approximate burnups of 0.4 per cent, 0.8 per cent, 1.6 per cent, and 2.0 per cent of the available U_{235} . In the 0.4 per cent burnup group, all but one of the fibers were broken when the cans were examined; this fiber broke on handling. The remaining ends of the fibers appeared to be slightly curled. The fibers from the 0.8 per cent burnup cans were all broken although there were several long lengths of fibers remaining. These fibers appeared to be crystallized and some of them showed exaggerated curling. All attempts to handle the fibers to put them under a microscope caused immediate breakage of the fiber. The fibers in the 1.6 per cent burnup and 2.0 per cent burnup cans were completely gone. No trace of them could be found. There was corrosion on the cans. Whether this corrosion was due to the glass fibers or coating of the glass on the cans is unknown at this time.

Five grams of leached glass fibers were also requested which would have a softening point exceeding 1200°C . RX-137E, which was mentioned in the first part of the discussion, was used for this experimental work and leached and fired fibers were produced from it that would withstand 1260°C (2300°F). Five grams of glass fibers that could be directly drawn and would have a softening point above 1200°C were also requested. Although glasses have been developed which have a softening point above 1200°C , we are very close to the development of fibers that have appreciable strength in the 1200°C range. Therefore, instead of supplying the first

set of samples that were possible, action on the request was delayed to determine if fibers with strengths of 100,000 psi at 1200°C could be developed. The set of samples has not been shipped for that reason.

Another set of samples supplied to RPI was fibers, two microns in diameter, of RX-78 glass which contains 35 per cent depleted U_3O_8 . This material is to be put in cans similar to those for the RPI-Brookhaven Loop experiment at the Brookhaven reactor and is to be tested under environmental conditions similar to those in the Loop except that it will not be irradiated. These tests are to determine the maximum temperatures and pressures that the fibers will be able to withstand. Fine fibers of this type were blown into a mat form that showed excellent resilience and appeared to be suitable for the test.

The last sample requested by Rensselaer Polytechnic Institute was a cloth woven of RX-78 glass fibers in the 5 to 7 micron diameter range. Ten tubes of five-filament strands were sent to the Ashton Plant of the Owens-Corning Fiberglas Corporation to be woven into an open cloth. Efforts to weave this cloth were unsuccessful primarily because the five-fiber strand was too weak to withstand weaving stresses. Plans have been made to repeat this experiment using 15 to 25 micron diameter fibers.

Visitations and Consultations

The AEC requested that Owens-Corning Fiberglas consult with various AEC contractors in order to:

1. Inform these contractors of the progress Owens-Corning has made in research on fuel-bearing glasses.

2. Explore areas of utilization of these fuel-bearing glasses.
3. Determine if the individual contractors had immediate interest in the fuel-bearing glasses and to supply samples for their research.

Eight contractors were visited in the course of this consultation.

(See Table VIII)

The following uses were proposed for fuel-bearing glass fibers:

1. Fine fibers to obtain fission fragment energy for chemo-nuclear processes.
2. Aluminum-glass fiber composites for fuel element cores for power and test reactors.
3. High temperature metal-glass fiber composite fuel element cores for power reactors.
4. Graphite-glass fiber composites for gas-cooled power reactors.
5. Large, glass-clad glass fibers for gas-cooled power reactors and organic moderated reactors.

The consensus of opinion was that, if fuel-bearing fibers are to be used, it will probably be for chemo-nuclear process reactors. The only contractor interested in experimenting in this field besides Rensselaer Polytechnic Institute is the Brookhaven National Laboratory. The Brookhaven National Laboratory is requesting samples for trials in the Brookhaven reactor.

The use of aluminum-glass fiber composites for fuel element cores will be limited to the material testing type reactors since all future power reactors will use higher melting materials than aluminum. Most of the high

temperature power reactors will have cylindrical shaped fuel elements with a very high fuel density. High temperature metal-glass fiber composites in plate shapes will probably not be satisfactory as the core material in high temperature reactors due to low fuel densities.

The use of graphite-glass fiber composites and glass-clad glass fibers in gas-cooled power reactors is possible for some of the low temperature reactors that are presently under design but all future ones are expected to be higher temperature systems. While the glass would give better heat transfer due to more surface area, it produces problems in coolant flow and fuel element breakage. Glass-clad glass fuel elements could possibly be used in organic moderated reactors, but the future of this type reactor does not seem too promising.

There is considerable interest in using glass in the bulk form as a high temperature solid (above its annealing range) or as a very viscous liquid. Glass converted to a fine grained crystalline structure similar to that of Pyrocera^m could also be used at high temperatures.

The major problem with using glass for a fuel element material is that no data are available concerning property changes due to irradiation at high levels for long periods of time. The major questions to be answered are:

1. What is the effect of high burnup of the fissionable material?
2. What strains are placed on the glass by the fission process and fission by-products?
3. Do the devitrification rate and temperature range change?
4. Do the inert gases migrate through the glass?

Without these answers the value of fibrous glass in reactors is an unknown quantity. From present data, fibers at temperatures below their annealing point should suffer greater damage than bulk glass irradiated at temperatures above its annealing point. Both strength loss and devitrification would be more severe in the fiber form.

Many people have discussed the use of glass fibers containing isotope materials where the present properties of the glass would be useful and no large change in properties of the glass would be expected from the radioactive decay. Mats, cloths, and tapes of fibers could all be used for applications such as luminescence sources, static eliminators, inexpensive fluoroscope sources, neutron sources, low level power sources, biological shielding and control materials.

FUTURE PLANS

1. Basic Research

- a. Explore glass compositions containing maximum amounts of uranium, thorium, and plutonium, or combinations of these, to determine their physical properties and to determine the feasibility of producing fibers from them.
- b. Explore glass compositions containing uranium and thorium to obtain maximum temperature resistance.
- c. Explore glass compositions containing uranium and thorium for evaluation of their resistance to adverse environmental conditions, i.e. hot gases, radiation, etc., by interested AEC contractors.

2. Applied Research

- a. Evaluate various types of fibrous glass materials such as mats, cloths, and strands for maximum utilization of the radioactive properties of the filaments and investigate other possible forms of glass.
- b. Investigate techniques for metal coating glass fibers to better control the uniformity and thickness of the coating.
- c. Investigate improved methods of sampling and analyzing glass-metal composite materials.
- d. Determine the feasibility of incorporating uranium- and thorium-containing glass fibers into high temperature metal-glass composite materials.

In connection with this program Owens-Corning will supply samples of uranium- and thorium-containing glass fibers to interested AEC contractors, i.e. Clevite Corporation, Rensselaer Polytechnic Institute, and possibly others.

·APPENDIX

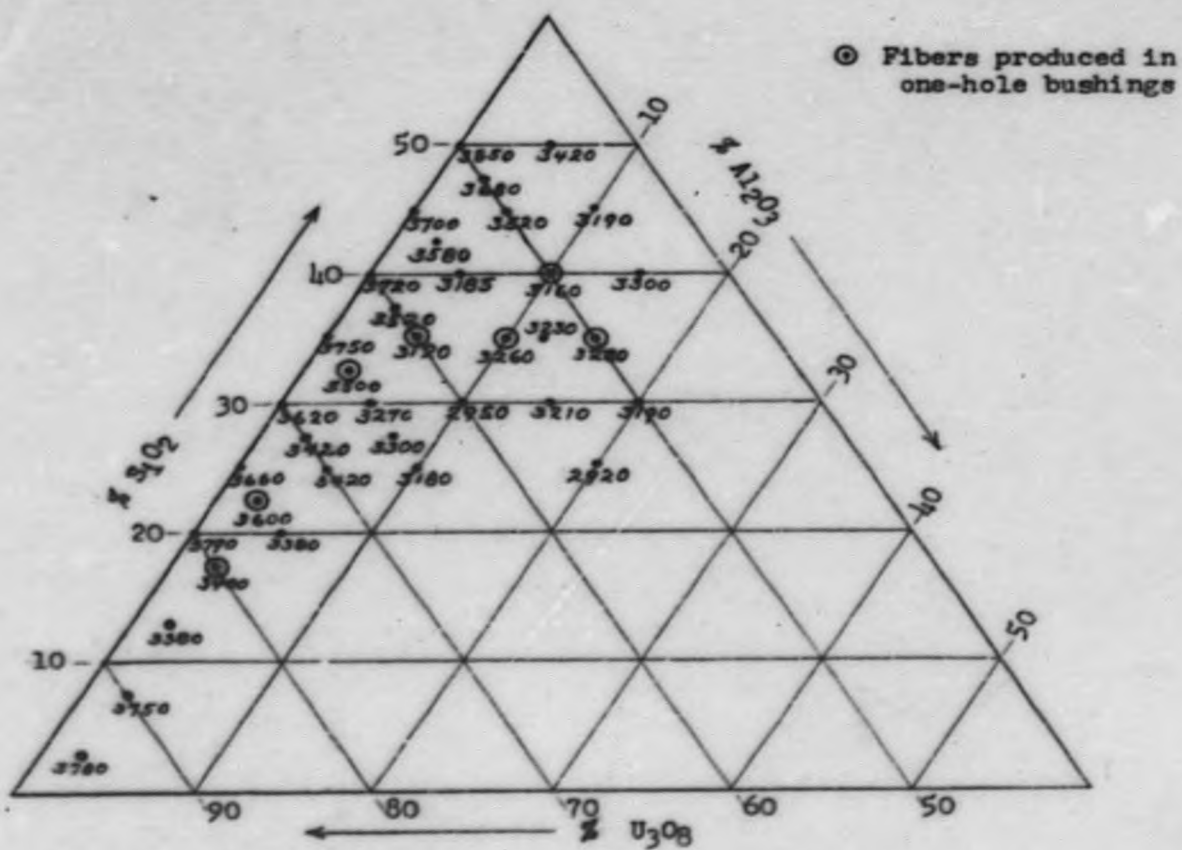


Fig. 1 - High temperature uranium-bearing glass compositions with batch melting temperatures ($^{\circ}\text{F}$).
Uncorrected optical.

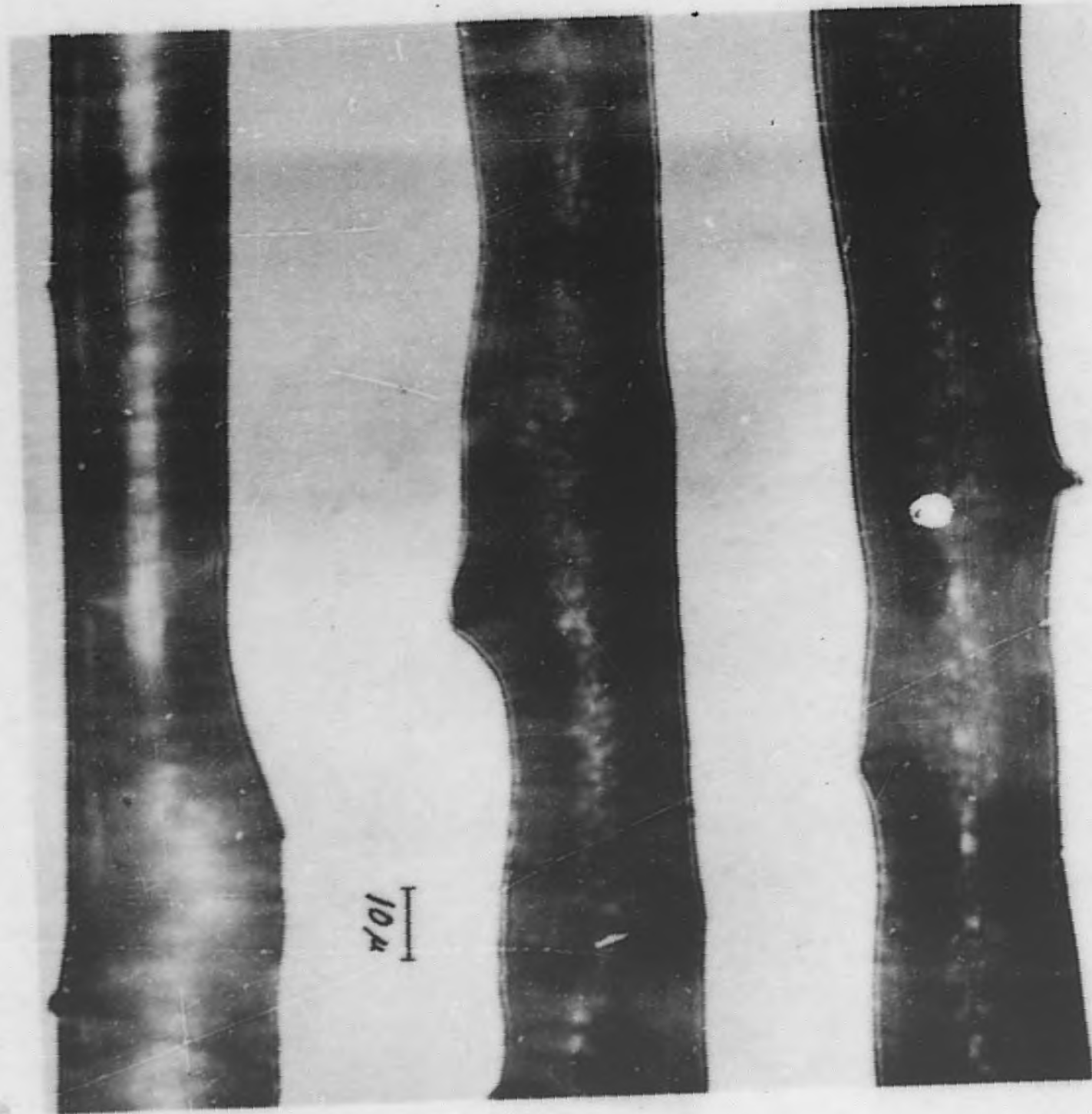


Figure 2. Photomicrograph of Aluminum-Coated RX-70 Fibers
Coated With a Maximum Amount of Aluminum

TABLE I

POTENTIAL HIGH TEMPERATURE, HIGH URANIA GLASSES INVESTIGATED

| Glass No. | RX-254 | RX-255 | RX-256 | RX-257 | RX-258 | RX-259 | RX-260 | RX-261 |
|-------------------------------------|----------------------|---|---|------------------|------------------|------------------|----------|----------------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 44.97 | 39.98 | 34.98 | 49.96 | 44.97 | 39.98 | 44.97 | 44.97 |
| Al ₂ O ₃ | 5.00 | 9.99 | 14.99 | 5.00 | 9.99 | 14.99 | 7.49 | 5.00 |
| U ₃ O ₈ | 49.96 | 49.97 | 49.97 | 44.96 | 44.97 | 44.97 | 44.97 | 44.97 |
| Fe ₂ O ₃ | 0.07 | 0.06 | 0.06 | 0.08 | 0.07 | 0.06 | 0.07 | 0.06 |
| MnO ₂ | - | - | - | - | - | - | 2.50 | 5.00 |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 3520°F | 3160°F | 3280°F | 3420°F | 3190°F | 3300°F | 3100°F | 3180°F |
| <u>Fiberizability</u> | Possible at 3520° | Possible at lower temp. | Fair at 2880° | Poor at 3420° | Poor at 2750° | Poor at 2750° | Possible | Couldn't fiberize |
| <u>Devitrification Tendency</u> | Fibers devit. | | | Fibers devit. | Fibers devit. | Fibers devit. | | |
| <u>Surface Tension</u> | | | | | | | | |
| <u>Comments</u> | | Ran in OHB see Tables III & IV | Ran in OHB see Tables III & IV | | | | | |
| | | Sp. G. = 3.70 | Sp. G. = 3.97 | | | | | |

TABLE I (Continued)

| Glass No. | RX-262 | RX-263 | RX-264 | RX-265 | RX-266 | RX-267 | RX-268 | RX-269 |
|---------------------------------|-------------------|--------|--------|--------|---------------|---|---------------|-----------------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 44.97 | 52.84 | 50.85 | 48.87 | 39.97 | 34.98 | 34.98 | 29.99 |
| Al ₂ O ₃ | 2.50 | 0.21 | 0.21 | 0.20 | 5.00 | 9.99 | 11.99 | 14.99 |
| U ₃ O ₈ | 44.97 | 44.87 | 44.87 | 44.87 | 54.96 | 54.97 | 52.97 | 54.97 |
| Fe ₂ O ₃ | 0.07 | 0.09 | 0.08 | 0.08 | 0.07 | 0.06 | 0.06 | 0.05 |
| MnO ₂ | 7.49 | 1.99 | 3.99 | 5.98 | - | - | - | - |
| MgO | | | - | - | - | - | - | - |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 3400° | | | | 3185° | 3260° | 3230° | 3210° |
| <u>Fiberisability</u> | Couldn't fiberize | | | | Fair at 3185° | Good at 3005° | Fair at 3000° | Possible |
| <u>Devitrification Tendency</u> | | | | | | | | Fiberizes at liquidus |
| <u>Surface Tension</u> | | | | | Medium | Medium | Medium | Low |
| <u>Comments</u> | | | | | | Used in fiberization trials in Physics Lab. | | |

TABLE I (Continued)

| Glass No. | RX-270 | RX-271 | RX-272 | RX-273 | RX-274 | RX-275 | RX-276 | RX-277 |
|---------------------------------|-------------------|-----------------------|-------------|-----------------------|---------------|-------------------|-------------------|-------------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 24.96 | 29.99 | 37.47 | 34.98 | 32.48 | 39.97 | 39.97 | 39.97 |
| Al ₂ O ₃ | 19.99 | 19.99 | 9.99 | 9.99 | 9.99 | 7.49 | 5.00 | 2.50 |
| U ₃ O ₈ | 54.97 | 49.97 | 49.97 | 49.97 | 49.97 | 49.97 | 49.96 | 49.96 |
| Fe ₂ O ₃ | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 |
| MnO ₂ | | | | | | | | |
| MgO | - | - | 2.50 | 5.00 | 7.50 | 2.50 | 5.00 | 7.49 |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 2920° | 3190° | 3005° | 2700° | 2820° | 3200° | 3300° | 3575° |
| <u>Fiberizability</u> | Couldn't fiberize | Possible | Poor | Possible | Fair at 2750° | Couldn't fiberize | Couldn't fiberize | Fiberizes well |
| <u>Devitrification Tendency</u> | Devitrifies | Fiberizes at liquidus | Devitrifies | Fiberizes at liquidus | | Devitrifies | | Did not devitrify |
| <u>Surface Tension</u> | Low | Low | Low | Low | Medium | Low | High | Low |
| <u>Comments</u> | | | | | | | | |

TABLE I (Continued)

| Glass No. | RX-278 | RX-279 | RX-280 | RX-281 | RX-282 | RX-283 | RX-284 | RX-285 |
|-------------------------------------|----------------------|----------------------|---------------|------------------------------|--------|----------------------|--------|--------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 37.47 | 34.98 | 32.48 | 39.77 | 39.97 | 39.97 | 37.47 | 34.98 |
| Al ₂ O ₃ | 9.99 | 9.99 | 9.99 | 7.49 | 5.00 | 2.50 | 9.99 | 9.99 |
| U ₃ O ₈ | 49.97 | 49.97 | 49.97 | 49.77 | 49.96 | 49.97 | 49.97 | 49.97 |
| Fe ₂ O ₃ | 0.07 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | 2.50 | 5.00 | 7.50 | 2.50 | 5.00 | 7.49 | - | - |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | - | - | - | - | - | - | 2.50 | 5.00 |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 3280° | 3050° | Over 3350° | 3000° | 3300° | 3150° | 3140° | 3120° |
| <u>Fiberizability</u> | Couldn't fiberize | Couldn't fiberize | | Poor | Poor | Couldn't fiberize | Poor | Poor |
| <u>Devitrification Tendency</u> | | | | | | | | |
| <u>Surface Tension</u> | Low | Low | | Low | Low | Low | Low | Low |
| <u>Comments</u> | | | | Melt seemed inhomogeneous | | | | |

TABLE I (Continued)

| Glass No. | RX-286 | RX-287 | HX-288 | RX-289 | RX-290 | RX-291 | RX-292 | RX-293 |
|-------------------------------------|-------------|----------------|-----------------------|-------------------|-------------------------------|-------------------------------|------------------|------------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 32.48 | 39.97 | 39.97 | 39.97 | 37.47 | 34.98 | 32.48 | 39.97 |
| Al ₂ O ₃ | 9.99 | 7.49 | 5.00 | 2.50 | 9.99 | 9.99 | 9.99 | 7.49 |
| U ₃ O ₈ | 49.97 | 49.97 | 49.96 | 49.96 | 49.97 | 49.97 | 49.97 | 49.97 |
| Fe ₂ O ₃ | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.07 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SrO ₂ | - | - | - | - | 2.50 | 5.00 | 7.50 | 2.50 |
| PbO | | | | | | | | |
| ZnO | 7.50 | 2.50 | 5.00 | 7.49 | - | - | - | - |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 3130° | 3150° | 3350° | 3600° | 3130° | 3140° | 3070° | 3070° |
| <u>Fiberizability</u> | Fair | Fair | Fiberized at 3250° | Fiberized well | Fiberized well at 2890° | Fiberized well at 2870° | Fair at 2890° | Fair at 3070° |
| <u>Devitrification Tendency</u> | Devitrified | Some Devit. | | | | | Some Devit. | |
| <u>Surface Tension</u> | Low | Low | Low | Low | Medium | Medium | Low | Medium |
| <u>Comments</u> | | | | | | | | |

TABLE I (Continued)

| Glass No. | RX-294 | RX-295 | RX-296 | RX-297 | RX-298 | RX-299 | RX-300 | RX-301 |
|-------------------------------------|-------------------------|-----------------------------|------------------|------------------|------------------|-----------------------|--|------------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 39.97 | 39.97 | 37.47 | 34.98 | 32.48 | 39.97 | 39.97 | 39.97 |
| Al ₂ O ₃ | 5.00 | 2.50 | 9.99 | 9.99 | 9.99 | 7.49 | 5.00 | 2.50 |
| U ₃ O ₈ | 49.96 | 49.17 | 49.97 | 49.97 | 49.97 | 49.97 | 49.96 | 49.96 |
| Fe ₂ O ₃ | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SnO ₂ | 5.00 | 7.47 | - | - | - | - | - | - |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | - | - | 2.50 | 5.00 | 7.50 | 2.50 | 5.00 | 7.49 |
| <u>Melting Temp.</u> | 3180° | 3190° | 3212° | 3260° | 3270° | 3200° | 3270° | 3340° |
| <u>Fiberizability</u> | Good at 3250° | No fibers up to 3100° | Good at 3140° | Good at 2980° | Fair at 3080° | Very good at 2970° | Good at 3270° | Good at 3340° |
| <u>Devitrification Tendency</u> | Some devit. at 3180° | Devit. | | | | No devit. | Some devit. | |
| <u>Surface Tension</u> | Medium | Medium | Low | Medium | Medium | Medium | Medium | Medium |
| <u>Comments</u> | | | | | | | Glass worked better and had less devit. after stirring | |

TABLE I (Continued)

| Glass No. | RX-302 | RX-303 | RX-304 | RX-305 | RX-306 | RX-307 | RX-308 | RX-309 |
|-------------------------------------|------------------|----------------------|------------------------------|------------------|----------------------|----------------------|------------------|------------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 37.47 | 34.98 | 32.48 | 39.97 | 39.97 | 39.97 | 34.98 | 29.98 |
| Al ₂ O ₃ | 9.99 | 9.99 | 9.99 | 7.49 | 5.00 | 2.50 | 5.00 | 10.00 |
| U ₃ O ₈ | 49.97 | 49.97 | 49.97 | 49.97 | 49.97 | 49.97 | 59.96 | 59.97 |
| Fe ₂ O ₃ | 0.07 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.06 | 0.05 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | 2.50 | 5.00 | 7.50 | 2.50 | 5.00 | 7.49 | - | - |
| ZnO | | | | | | | | |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 3060° | 3070° | 3090° | 2980° | 3010° | 3200° | 3120° | 2950° |
| <u>Fiberizability</u> | Fair at 3070° | Possible at 2980° | Possible but difficult | Good at 3000° | Possible at 3020° | Couldn't fiberize | Good at 2890° | Fair at 2900° |
| <u>Devitrification Tendency</u> | | | Devit. | Devit. | Devit. | Devit. | | |
| <u>Surface Tension</u> | Low | Low | Medium | Medium | Medium | Medium | Low | Low |
| <u>Comments</u> | | | | | | | Run in OHB | |

TABLE I (Continued)

| Class No. | RX-310 | RX-311 | RX-312 | RX-313 | RX-314 | RX-315 | RX-316 | RX-317 |
|---------------------------------|-------------------|----------------------|---------------|-------------------|-------------------|-------------------|-------------------|---------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 29.23 | 25.99 | 39.91 | 34.93 | 37.42 | 33.73 | 29.98 | 35.97 |
| Al ₂ O ₃ | 8.99 | 8.00 | 0.16 | 0.14 | 0.15 | 8.99 | 8.00 | 2.25 |
| U ₃ O ₈ | 54.97 | 59.96 | 49.88 | 49.90 | 54.88 | 54.97 | 59.97 | 54.96 |
| Fe ₂ O ₃ | 0.06 | 0.05 | 0.07 | 0.06 | 0.07 | 0.06 | 0.05 | 0.07 |
| MnO ₂ | | | | | | | | |
| MgO | 6.75 | 6.00 | - | - | - | - | - | - |
| CaO | | | | | | | | |
| SnO ₂ | - | - | - | - | - | 2.25 | 2.00 | 6.75 |
| PbO | | | | | | | | |
| ZnO | - | - | 9.98 | 14.97 | 7.48 | - | - | - |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 2780° | 2740° | 3500° | 3520° | 3550° | 3020° | 3120° | 3500° |
| <u>Fiberizability</u> | Couldn't fiberize | Some fibers at 2820° | Good at 3520° | Possible at 3540° | Possible at 3640° | Possible at 3050° | Couldn't fiberize | Good at 3550° |
| <u>Devitrification Tendency</u> | Devit. | Devit. | | | | | | |
| <u>Surface Tension</u> | Medium | Low | Medium | Medium | Medium | Low | Low | High |
| <u>Comments</u> | | | | | Glass viscous | | | |

TABLE I (Continued)

| Glass No. | RX-318 | RX-319 | RX-320 | RX-321 | RX-322 | RX-323 | RX-324 | RX-325 |
|---------------------------------|--------------------|--|-------------------|---------------|---------------|-------------|-------------------------|---------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 31.98 | 35.97 | 31.98 | 33.73 | 29.98 | 29.23 | 25.99 | 35.97 |
| Al ₂ O ₃ | 2.00 | 2.25 | 2.00 | 8.99 | 8.00 | 8.99 | 8.00 | 6.75 |
| U ₃ O ₈ | 59.96 | 54.96 | 59.96 | 54.97 | 59.97 | 54.97 | 59.96 | 54.96 |
| Fe ₂ O ₃ | 0.06 | 0.07 | 0.06 | 0.06 | 0.05 | 0.06 | 0.05 | 0.07 |
| MnO ₂ | - | - | - | - | - | - | - | - |
| MgO | - | 6.75 | 6.00 | - | - | - | - | - |
| CaO | - | - | - | - | - | - | - | - |
| SnO ₂ | 6.00 | - | - | - | - | - | - | - |
| PbO | - | - | - | - | - | - | - | - |
| ZnO | - | - | - | - | - | - | - | - |
| BaO | - | - | - | 2.25 | 2.00 | 6.75 | 6.00 | 2.25 |
| <u>Melting Temp.</u> | 3520° | 3200° | 3230° | 3180° | 3280° | 3260° | 3180° | 3280° |
| <u>Fiberizability</u> | Fiberizes at 3600° | Possible at 3170° | Couldn't fiberize | Poor at 3100° | Poor at 3280° | Possible | Possible | Good at 3100° |
| <u>Devitrification Tendency</u> | May devit. | | Devit. | Devit. | Devit. | Some devit. | Some devit. | |
| <u>Surface Tension</u> | High | Medium | Medium | Medium | Low | Low | Medium | Medium |
| <u>Comments</u> | | Had to raise temp. over 3200° before fiberizing. | | | | | Glass fluid at liquidus | |

TABLE I (Continued)

| Glass No. | RX-326 | RX-327 | RX-328 | RX-329 | RX-330 | RX-331 | RX-332 | RX-333 |
|-------------------------------------|-----------------------|-----------------------|-------------------------|------------------|------------------|--------|--------|--------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 31.98 | 35.97 | 31.98 | 35.97 | 31.98 | 39.91 | 34.93 | 37.42 |
| Al ₂ O ₃ | 6.00 | 4.50 | 4.00 | 2.25 | 2.00 | 0.16 | 0.14 | 0.15 |
| U ₃ O ₈ | 59.96 | 54.97 | 59.96 | 54.96 | 59.96 | 49.88 | 49.90 | 54.88 |
| Fe ₂ O ₃ | 0.06 | 0.07 | 0.06 | 0.07 | 0.06 | 0.07 | 0.06 | 0.07 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | 2.00 | 4.50 | 4.00 | 6.75 | 6.00 | 9.98 | 14.97 | 7.48 |
| <u>Melting Temp.</u> | 3270° | 3350° | 3420° | 3510° | 3560° | 3200° | 3180° | 3280° |
| <u>Fiberizability</u> | Very good at 3180° | Very good at 3320° | Good at 3400° | Good at 3400° | Good at 3380° | Fair ? | Fair ? | Good |
| <u>Devitrification Tendency</u> | | | Possibly some devit. | | | | | |
| <u>Surface Tension</u> | High | High | Medium | Medium | Medium | Low | Low | Low |
| <u>Comments</u> | | Viscous | | Viscous | | | | |

TABLE I (Continued)

| Glaes No. | RX-334 | RX-335 | RX-336 | RX-337 | RX-338 | RX-339 | RX-340 | RX-341 |
|-------------------------------------|------------------|------------------|----------------------------------|------------------|------------------|--------|----------------------|--------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 29.98 | 32.48 | 24.98 | 27.48 | 24.99 | 19.99 | 27.99 | 27.99 |
| Al ₂ O ₃ | 5.00 | 2.50 | 10.00 | 7.50 | 5.00 | 5.00 | 5.25 | 1.75 |
| U ₃ O ₈ | 64.97 | 64.96 | 64.97 | 64.97 | 69.96 | 74.97 | 64.96 | 64.96 |
| Fe ₂ O ₃ | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 | 0.05 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | - | - | - | - | - | - | 1.75 | 5.25 |
| <u>Melting Temp.</u> | 3270° | 3500° | 3180° | 3300° | 3420° | 3380° | 3620° | 3510° |
| <u>Fiberizability</u> | Fair at 3320° | Good at 3610° | Poor. Some fibers at 3200° | Fair at 3280° | Fair at 3380° | Fair | Couldn't fiberize | Fair |
| <u>Devitrification Tendency</u> | | | | | | | Devit. | Devit. |
| <u>Surface Tension</u> | High | High | Medium | Medium | Low | Low | Low | Low |
| <u>Comments</u> | | Run in OHB | | | | | | |

TABLE I (Continued)

| Glass No. | RX-342 | RX-343 | RX-344 | RX-345 | RX-346 | RX-347 | RX-348 | RX-349 |
|---------------------------------|----------------------------|------------|---------------------|---------------------|---------------|---------------|---------------|---|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 17.49 | 12.50 | 7.50 | 2.50 | 47.46 | 42.47 | 37.47 | 27.49 |
| Al ₂ O ₃ | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| V ₂ O ₅ | 79.98 | 84.98 | 89.99 | 95.00 | 49.95 | 54.95 | 59.96 | 69.96 |
| Fe ₂ O ₃ | 0.03 | 0.02 | 0.01 | - | 0.09 | 0.08 | 0.07 | 0.05 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 3400° | 3380° | 3750° | 3780° | 3680° | 3580° | 3520° | 3420° |
| <u>Fiberizability</u> | Poor but possible at 3360° | Poor | Poor | Poor | Good at 3720° | Good at 3680° | Good at 3630° | Good at 3460° |
| <u>Devitrification Tendency</u> | | | Did not devit. | Did not devit. | | | | |
| <u>Surface Tension</u> | Low | Low | | | Medium | Medium | Medium | Medium |
| <u>Comments</u> | Fluid Tried to run in OHB. | Very fluid | Fluid down to 3300° | Fluid down to 3400° | Viscous | Viscous | Viscous | Viscous Would not run in OHB (Too fluid.) |

TABLE I (Concluded)

| Glass No. | RX-350 | RX-351 (X-875) | RX-352 | RX-353 | RX-354 | RX-355 | RX-356 | RX-357 |
|-------------------------------------|---|----------------------------------|----------------------------|-------------------|----------------------------|--------------------|---|--------------------|
| <u>Composition - %</u> | | | | | | | | |
| SiO ₂ | 22.49 | 49.86 | 44.88 | 39.91 | 34.93 | 29.95 | 24.96 | 19.98 |
| Al ₂ O ₃ | 2.50 | 0.20 | 0.18 | 0.16 | 0.14 | 0.12 | 0.10 | 0.08 |
| U ₃ O ₈ | 74.97 | 49.86 | 54.86 | 59.86 | 64.87 | 69.88 | 74.89 | 79.90 |
| Fe ₂ O ₃ | 0.01 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.05 | 0.04 |
| MnO ₂ | | | | | | | | |
| MgO | | | | | | | | |
| CaO | | | | | | | | |
| SnO ₂ | | | | | | | | |
| PbO | | | | | | | | |
| ZnO | | | | | | | | |
| BaO | | | | | | | | |
| <u>Melting Temp.</u> | 3600° | 3850° | 3700° | 3720° | 3750° | 3620° | 3660° | 3790° |
| <u>Fiberizability</u> | Possible at 3700° | Some fibers above 3850° | Some fibers at 3750° | Question- able | Possible above 3750° | Possible | Possible | Possible |
| <u>Devitrification Tendency</u> | | Devit. | Devit. | Devit. | Probably devit. | Probably devit. | Probably devit. | Probably devit. |
| <u>Surface Tension</u> | Medium | Medium | Medium | Medium | High | High | High | High |
| <u>Comments</u> | Viscous Ran in OHB but could not repeat. | | | | | | Burned out OHB in attempt to fiberize. | |

TABLE II

PERFORMANCE OF HIGH TEMPERATURE GLASSES IN THE ONE HOLE BUSHING

| <u>Glass No.</u> | <u>Temp., °F</u> | <u>Comments</u> |
|------------------|------------------|--|
| RX-255 | 3000-3050° | Ran fairly well |
| RX-256 | 2800-2900° | Produced fibers, but ran too poorly to produce test sample. Flooded tip. |
| RX-267 | 2910° | Produced sample to test |
| RX-308 | 3190° | Produced sample to test |
| RX-335 | 3450° | Ran only with larger bushing hole size, making coarse fibers. |
| RX-342 | 3500° | Produced fibers at times at very low speeds. Fibers flat and coarse. |
| RX-343 | -- | Could not fiberize in bushing |
| RX-349 | -- | Could not fiberize. Too fluid above liquidus. |
| RX-350 | 3580° | Produced fibers once, but could not duplicate. |
| RX-356 | -- | Fishing turned out. |

TABLE III

TENSILE STRENGTH AND YIELD STRESS OF FIBERS

| | Fiber Diameter* | Tensile Strength in psi at | | | | | | | |
|--------|-----------------|----------------------------|-------|---------|--------|---------|--------|---------|--------|
| | | 72°F | | 1600°F | | 1800°F | | 2000°F | |
| | | Maximum | Yield | Maximum | Yield | Maximum | Yield | Maximum | Yield |
| RX-70 | 42-43 | 352,000 | - | | | | | | |
| RX-78 | 42.5-45 | 420,000 | - | | | | | | |
| RX-255 | 47-68 | 156,000 | - | 116,000 | 98,000 | | | | |
| RX-267 | 38-43 | 209,000 | - | 50,000 | | | | | |
| RX-308 | 50 | 141,000 | - | 118,000 | 91,000 | 69,000 | 53,000 | | |
| RX-335 | 57-81 | 123,000 | - | 80,000 | 59,000 | 67,000 | 53,000 | | |
| RX-350 | 114-150 | | | 73,000 | - | 56,000 | - | 97,000 | 86,000 |

* In hundred thousandths of an inch.

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TABLE IV

COMPOSITION OF GLASSES RX-70, 78, AND 137

| | | RX-70 | RX-78 | RX-137 |
|---------------|--------------------------------|-------|-------|--------|
| Composition - | SiO ₂ | 39.98 | 49.96 | 55.95 |
| | Al ₂ O ₃ | 0.04 | 0.05 | 0.06 |
| | Na ₂ O | 9.99 | 9.99 | 23.98 |
| | U ₃ O ₈ | 49.97 | 34.97 | 19.98 |
| | CaO | - | 5.00 | - |
| | Fe ₂ O ₃ | 0.02 | 0.03 | 0.03 |

TABLE V

PROPERTIES OF URANIUM-BEARING GLASSES*

| | Type Glass | | |
|--|------------|-------|------|
| | RX-70 | RX-78 | "E" |
| Weight Percent U ₃ O ₈ | 50 | 35 | 0 |
| Tensile Strength | | | |
| Room Temperature - ksi | 352 | 420 | 500 |
| 1000°F - ksi | 166 | 115 | 250 |
| Specific Gravity | 3.66 | 3.22 | 2.55 |
| Liquidus Point - °F | 2370 | 2360 | 2035 |
| Softening Point - °F | 1540 | 1435 | 1555 |

* The RX-70 and RX-78 are used extensively for sample materials.
 "E" Glass is a commercial composition which is shown for comparison purposes.

TABLE VI

DATA ON LEACHING RX-137E

| | Acid Used | Acid Dilution | Leaching Time | Leaching Temp. | Washing Procedure | % Ignition Loss | Firing Time and Temp. |
|-------------|-----------|---------------|---------------|----------------|-------------------|-----------------|-----------------------|
| Sample #1 a | HCl | 1:1 | 1 hour | Reflux | 1 hr. reflux | 29.70 | 5 min. at 2300°F |
| Sample #1 b | HCl | 1:1 | 1 hour | Reflux | 1 hr. reflux | 29.11 | " |
| Sample #2 a | HCl | 2:1 | 1 hour | Reflux | 1 hr. reflux | 35.70 | " |
| Sample #2 b | HCl | 2:1 | 1 hour | Reflux | 1 hr. reflux | 33.24 | " |
| Sample #3 a | HCl | 1:1 | 1 hour | 90°C | Rinse three | 25.00 | " |
| Sample #3 b | HCl | 1:1 | 1 hour | 90°C | times in | 26.10 | " |
| Sample #3 c | HCl | 1:1 | 1 hour | 90°C | hot dist. | 25.55 | " |
| Sample #3 d | HCl | 1:1 | 1 hour | 90°C | water. | 27.91 | " |

TABLE VII

COMPOSITIONS SUBMITTED TO MOUND LABORATORY

| | X-811 | X-1211 | X-1212 | X-1225 | X-1226 | X-1227 |
|--------------------------------|-------|--------|--------|--------|--------|--------|
| SiO ₂ | 70 | 66.58 | 59.93 | 64.97 | 63.40 | 69.42 |
| Al ₂ O ₃ | | 5.55 | 4.99 | 5.41 | 5.29 | 2.56 |
| CaO | | 5.55 | - | 5.41 | 5.27 | 5.58 |
| MgO | | - | - | - | - | - |
| Na ₂ O | 30 | 16.65 | 14.98 | 16.24 | 15.86 | 16.73 |
| K ₂ O | | 5.55 | - | 5.41 | 5.29 | 5.58 |
| ZrO ₂ | | - | 4.00 | - | - | - |
| ZnO | | - | 11.99 | - | - | - |
| F ₂ | | - | 4.00 | 2.44 | 4.76 | - |
| Fe ₂ O ₃ | | 0.12 | 0.11 | 0.12 | 0.11 | 0.12 |
| BaO | | - | - | - | - | - |

| | X-1228 | X-1229 | X-1230 | X-1231 | X-1232 |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO ₂ | 63.75 | 64.08 | 66.58 | 66.58 | 65.59 |
| Al ₂ O ₃ | 9.57 | 5.55 | 5.55 | 5.55 | 5.47 |
| CaO | 5.31 | 5.55 | 4.00 | 4.00 | 3.94 |
| MgO | - | 2.50 | 1.55 | 1.55 | 1.53 |
| Na ₂ O | 15.94 | 16.65 | 11.65 | 20.20 | 16.40 |
| K ₂ O | 5.34 | 5.55 | 10.55 | 2.00 | 5.47 |
| ZrO ₂ | - | - | - | - | - |
| ZnO | - | - | - | - | - |
| F ₂ | - | - | - | - | - |
| Fe ₂ O ₃ | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| BaO | - | - | - | - | 1.48 |

TABLE VIII

AEC CONTRACTORS VISITED

Ames Laboratory - Iowa State University, Ames, Iowa

Dr. D. R. Wilder, Project Manager

Dr. C. D. Wirkus, Project Scientist

Also present

Dr. J. D. Fleming - Georgia Institute of Technology

Nuclear Materials and Equipment Corporation - Appolo, Pennsylvania

Dr. Z. Shapiro, President

Dr. Garber, Manager, Plutonium Division

Combustion Engineering Corporation - Winsor, Connecticut

Dr. R. Gail, Manager, Materials Development Laboratory

Mr. G. Zuromsky, Project Manager

Mr. M. A. Andrews, Design Engineer

Brookhaven National Laboratory - Upton, Long Island, New York

Dr. B. Manowitz, Department Manager

Dr. M. Steinberg, Project Manager

General Atomics Corporation - San Diego, California

Mr. J. Shumar, Director, Metallurgical Division

Mr. W. Wallace, Supervisor, Materials Development

Mr. D. Johnson, Materials Engineer

Mr. J. Quirk, Ceramic Engineer

General Electric Company

Vallecitos Laboratory - Pleasanton, California

Dr. B. Weidenbaum, Assistant Director, Vallecitos Laboratory

Atomic Power Equipment Department - San Jose, California

Mr. R. Voltz, Materials Engineer

Hanford Laboratories - Hanford, Washington

Dr. E. A. Evans, Chief of Ceramics Division

Mr. R. Anicetti, Ceramics Division

Mr. N. Roske, Ceramics Division

Mr. W. Wolfe, Ceramics Division

Dr. I. D. Thomas, Supervisor, Plutonium Fuels Development

Mr. G. Barton, Chemistry Research

Mr. R. E. Moore, Chemistry Research

END