MCC MATERIALS
CHARACTERIZATION CENTER

**Approved Reference and
Testing Materials for Use in
Nuclear Waste Management
Research and Development
Programs**

G. B. Mellinger
J. L. Daniel

December 1984

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

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I. SUMMARY

This document, addressed to members of the waste management research and development community, summarizes reference and testing materials available from the Nuclear Waste Materials Characterization Center (MCC). These materials are furnished under the MCC's charter to distribute reference materials essential for quantitative evaluation of nuclear waste package materials under development in the U.S.

Reference materials with known behavior in various standard waste management related tests are needed to ensure that individual testing programs are correctly performing those tests. Approved testing materials are provided to assist the projects in assembling a materials data base of defensible accuracy and precision.

This is the second issue of this publication. Eight new Approved Testing Materials are listed, and Spent Fuel is included as a separate section of Standard Materials because of its increasing importance as a potential repository storage form. A summary of current characterization information is provided for each material listed. Future issues will provide updates of the characterization status of the materials presented in this issue, and information about new standard materials as they are acquired.

II. INTRODUCTION

In this section, the objectives of the Materials Characterization Center (MCC) are described, and the structure and functions of the Nuclear Waste Materials Characterization Organization (MCO) (of which the MCC is a part) are briefly outlined. The purpose for and information contained in this listing of approved reference and testing materials are described. Two classifications of standard materials available from the MCC are defined, and the archiving and distribution of the materials are discussed.

The Objective of the Materials Characterization Center

The MCC was created by the U.S. Department of Energy (DOE) at the Pacific Northwest Laboratory (PNL)^(a) in 1980. The objective of the MCC is to assist the DOE projects responsible for nuclear waste form production, transportation, and disposal to assemble a materials database of defensible precision and accuracy. A major responsibility of the MCC is to arrange for the formulation, acquisition and distribution of reference and testing materials essential for quantitative evaluation of nuclear waste forms and repository systems under development in the U.S.

The Nuclear Waste Materials Characterization Organization

The MCO, created by DOE, coordinates the collection of a defensible materials property database. This database can be used as a recognized, referenceable source of data for waste management systems design, integration, and licensing.

The MCO is coordinated by the Materials Steering Committee (MSC) and consists of the Materials Integration Office (MIO), the MCC, and the Materials Review Board (MRB). The MCO is structurally arranged as shown in Figure 1. The direction of the MCO is determined by means of periodic meetings of the MSC in which issues affecting the overall program objectives are addressed and resolved.

Figure 1. The Structure of the Materials Characterization Organization

The MIO functions to integrate the activities of the MCC and the MRB to ensure that the test methods and materials data needed by the waste management community are available when required.

This Document

The purpose of this document, which is updated periodically, is to inform members of the nuclear waste management research and development community about the reference and testing materials available from the MCC. The fabrication and compositions of these materials are reported. Also reported are summaries of any completed characterization and the intended uses for these materials. New materials that are being acquired or are under consideration are also described.

(a) Operated for the DOE by Battelle Memorial Institute.

Classifications of Standard Materials

MCC standard materials are intended to provide a basis for comparison of data quality obtained in repository development work by the DOE projects, and to assist in verifying the accuracy and precision of the data obtained. For that purpose, two classifications of standard materials are available from the MCC. These are Approved Reference Materials (ARMs) and Approved Testing Materials (ATMs). These two types of materials are described in this section.

Approved Reference Materials

The primary use of ARMs is as standard reference and calibration materials, similar to that of the Standard Reference Materials (SRMs) of the United States National Bureau of Standards (NBS). The characterization of each ARM (composition, homogeneity, and behavior under specific MCC test conditions) is conducted by MCC and supporting laboratories such as NBS to a high level of accuracy and precision. The ARMs are intended especially for field calibration of MCC test methods, and for verification by test method users that they are conducting the test procedure in a controlled, reproducible manner. Therefore, the primary requirement for each ARM is a well defined, uniform composition representing a class of waste form rather than a specific formulation.

One ARM is currently available. The MCC plans the production of an additional ARM which will contain actinide dopants.

Approved Testing Materials

The purpose of ATMs is to serve as common testing materials, officially endorsed by DOE, for use in the DOE nuclear waste repository development projects. ATMs represent specific formulations of typical waste forms, or of other components of proposed repository systems. Each ATM will be characterized appropriately by MCC for composition, homogeneity and behavior under specified test conditions. The primary use of ATMs in a repository development testing program is to develop a defensible database of known accuracy and precision using these testing materials of recognized quality.

A sufficient amount of each ATM will be made to allow controlled testing under all reasonable conditions required by the DOE repository development projects. The ATMs may be produced by the MCC or by the waste-form producer. In every case the MCC will conduct sufficient characterization to validate the use of the material as an ATM.

Archiving and Distribution of Standard Materials

An important function of the MCC is the maintenance of a complete archive of all MCC reference and testing materials used in the nuclear repository development programs, and of the characterization documentation for those materials. Sufficient quantities of these materials will be stored by the MCC at PNL to ensure their future availability in reasonable quantities for additional testing or resolution of important questions raised in scheduled tests and experiments.

The MCC will be responsive to the needs of the waste management community for high quality reference and testing materials. Readers interested in obtaining any of the items listed in this document, or additional materials not listed, should communicate their needs to the MCC. Requests for existing or new standard materials should be addressed to:

J. E. Mendel, Manager
Materials Characterization Center
Pacific Northwest Laboratory
P.O. Box 999
Richland, Washington 99352

III. SUMMARY OF STANDARD MATERIALS

In this section, the materials available from the MCC are summarized in tabular form. The MCC's policies for acquiring, characterizing and distributing the materials are outlined. The MCC's capabilities in the preparation of special sample forms (i.e., forms other than cast bars or sections of spent fuel rods) to meet customers' needs are also discussed.

Inventory of Standard Materials

Table 1 provides a summary of the reference and testing materials currently available from the MCC. The MCC carefully plans the use of its manpower and funding to maximize the number and quality of reference and testing materials. In addition, funding is allotted to a careful characterization of each material consistent with its intended use. This characterization is an essential step in certifying with confidence that the material is suitable for use as a standard to verify test performance, or as a reference point to compare materials or test conditions.

Further acquisitions are planned. Users are encouraged to communicate their needs to the MCC.

Materials Policies

The MCC acquires and distributes reference and testing materials that are of wide use to the nuclear waste management research and development community. These materials are provided without charge, in reasonable amounts, to DOE programs. Others, such as the U.S. Nuclear Regulatory Commission (NRC) users, will pay prorated production costs.

The MCC will characterize all reference and testing materials and provide characterization results to the users. As a minimum, the composition and homogeneity will be determined. Microstructure and phase analyses will be conducted on solid materials. Statistical methods will be applied to the evaluation of uncertainty in the analytical data.

Table 1. MCC Reference and Testing Materials

Designation	Type	Quantity Fabricated/ Obtained
ARM-1	Reference waste glass, radioactive	255 kg
ATM-1	76-68 glass, U-doped	6 kg
ATM-2	76-68 glass, Am-doped	0.45 kg
ATM-3	76-68 glass, Np-doped	0.45 kg
ATM-4	76-68 glass, Pu-doped	0.45 kg
ATM-5	76-68 glass, fully radioactive	3 kg
ATM-6	Barnwell glass, radioactive dopants	3 kg
ATM-8	76-68 glass, radioactive dopants	3 kg
ATM-9	SRP glass, radioactive dopants	3 kg
ATM-11	SRP glass, radioactive dopants	3 kg
ATM-12	Aged 76-68 glass, radioactive dopants	3 kg
ATM-MCC-B77-260	Barnwell glass, radioactive dopants	2.5 kg
MCC-76-68	76-68 glass, nonradioactive	200 kg
ATM-101	Spent fuel, typical PWR	9 pins
ATM-301	ASTM A27 cast steel	~1.3 kg
ATM-401	Basalt (Cohasset)	8 kg
ATM-402	Bentonite	12 kg

Additional characterization may be applied consistent with the material's intended use. For example, ARMs will be subjected to MCC leach tests to provide reference data for verification of users' test performance. If the requestor of a material wishes characterization beyond that planned by MCC, this may be provided by separate arrangements including necessary funding.

Documentation reports will be available for all reference and testing materials supplied by the MCC. These reports will include details of a material's fabrication and the results of its characterization. Also included, when available, will be a statistical analysis of the uniformity of the material's composition, phases, etc. These reports will be provided to the requestors of a reference or testing material, or to a program that needs to examine such a report before requesting a material.

In order to provide materials as quickly as possible, and because of the time required for adequate

characterization, materials are being made available before the characterization has been completed and the data compiled into a formal document. Additional characterization reports will be distributed as the information becomes available.

Preparation of Special Sample Forms

MCC standard materials are normally supplied to the user in the form in which the materials are produced (e.g., glass will be furnished as cast bars). Some test programs require use of the materials in special form (e.g., sized blended powders, specially shaped monoliths, or unique containment). Usually the MCC can arrange to supply the materials in the form required. Specimen forms that require significant additional time to prepare, or special materials such as platinum molds, can be provided at cost by making special arrangements with the MCC.

IV. STANDARD MATERIALS: GLASS WASTE FORMS

This section describes the presently available reference and testing glass waste form materials. Information on composition is presented and the methods of the materials fabrication, characterization, and reporting are outlined.

The homogeneity of standard glass materials is of particular importance, and at the same time is difficult to achieve with low concentrations of dopants added to bulk quantities of glass. In addition to the problem of thorough, uniform mixing of additives, some components of ATM glasses tend to volatilize, segregate, precipitate, or crystallize under glass-forming conditions. Characterization in progress on the ATM glasses includes a careful determination of material homogeneity. Where such information is already available it is included here in the narrative description of the standard material. Where final characterization of a material has not been completed, the compositional information listed is based on nominal values or initial analyses. This information will be updated as characterization work progresses.

ARM-1
Reference Waste Glass,
Nonradioactive

This material represents a generic borosilicate reference waste glass. It is nonradioactive. It was produced by Schott Optical Glass of Duryea, Pennsylvania in 1983, in the form of 6 x 7 cm bars.

Its composition is shown in Table 2, based on analyses by the NBS and the MCC. Refractive index measurements at the NBS confirmed the high homogeneity of the glass. A number of other analyses were performed by the NBS to confirm that the glass was sufficiently homogeneous, properly annealed and free from secondary phases. These analyses included measurements of refractive index, stress birefringence and striae grade, as well as of the amounts of bubbles and solid inclusions present.

Since the primary purpose of ARM-1 is for field calibration of the MCC leach test methods, the MCC is in the process of certifying the behavior of the ARM-1 in selected MCC tests. MCC-1 and -2 testing (static tests using monolithic samples) has been completed through 182 days. One-year tests will be completed and reported in 1985. MCC-3 testing (a static test using crushed material) is under way; testing through 182 days will be completed and reported in 1985.

Table 2. Composition of ARM-1 (Reference Waste Glass)

Oxide Component	NBS, wt%(a)	Standard Deviation	MCC, wt%(b)	Standard Deviation
Al ₂ O ₃	5.59	0.06	5.90	0.04
B ₂ O ₃	11.3	0.25	11.8	0.06
BaO	0.66	0.01	0.66	0.00
CaO	2.23	0.03	2.28	0.01
CeO ₂	1.51	0.04	1.37	0.01
Cs ₂ O	1.16	0.03	1.1	—
Li ₂ O	5.08	0.13	5.08	0.06
MoO ₃	1.67	0.03	1.88	0.02
Na ₂ O	9.67	0.11	9.82	0.08
Nd ₂ O ₃	5.96	0.20	5.83	0.04
P ₂ O ₅	0.65	0.03	0.57	0.01
SiO ₂	46.5	0.81	46.1	0.23
SrO	0.45	0.01	0.47	0.00
TiO ₂	3.21	0.05	3.43	0.02
ZnO	1.46	0.03	1.52	0.01
ZrO ₂	1.80	0.03	1.95	0.02
TOTAL	98.90		99.76	

(a) 10 samples in duplicate; flame atomic absorption and direct-current plasma atomic emission spectrometry.

(b) 3 samples in duplicate (except 1 analysis for Cs); inductively coupled atomic emission and atomic absorption spectrometry.

**ATM-1, -2, -3 and -4
76-68 Type Glass,
Actinide Dopants**

These materials represent borosilicate glasses that incorporate high-level wastes resulting from the reprocessing of commercial nuclear reactor fuel. Their compositions are based on 76-68 glass (Mendel et al. 1977). Each contains a single actinide dopant, either U, Am-241, Np-237 or Pu-239; no other radioactive species are present. Glass compositions are given in Tables 3 and 4.

These glasses were prepared at PNL in 1983 and 1984 from crushed MCC-76-68 glass to which dopants were added. Each batch was melted in platinum crucibles and bars were cast and annealed. The bars of ATM-1b are $\sim 2 \times 2.5 \times 17.5$ cm and weigh ~ 275 g each. The bars of ATM-1c are $\sim 2 \times 2 \times 15$ cm and weigh ~ 180 g each. ATM-1c was also produced in other forms such as cast cylinders, core-drilled cylinders and stainless steel-clad discs. These forms were requested by and furnished to the Nevada Nuclear Waste Storage Investigations (NNWSI). The bars of ATM-1a, -2, -3 and -4 are $\sim 1.3 \times 1.3 \times 7.6$ cm and weigh ~ 36 g each.

TABLE 3. Composition of ATM-1 (U-doped 76-68 Glass)(a)

Oxide	ATM-1a(b)		ATM-1b(c)		ATM-1c(d)	
	wt%	Standard Deviation	wt%	Standard Deviation	wt%	Standard Deviation
Al ₂ O ₃	0.64	0.03	0.85	0.02	0.58	0.02
B ₂ O ₃	8.47	0.31	8.55	0.08	9.07	0.07
BaO	0.50	0.02	0.62	0.003	0.54	0.003
CaO	1.99	0.99	2.11	0.03	2.23	0.02
CeO ₂	0.88	0.03	0.97	0.09	0.90	0.03
Cr ₂ O ₃	0.39	0.02	0.45	0.04	0.42	0.005
Cs ₂ O	0.71	0.04	0.77	0.02	0.78	0.05
Fe ₂ O ₃	8.16	0.29	8.16	0.04	8.70	0.05
La ₂ O ₃	4.00	0.19	5.07	0.02	4.39	0.03
MoO ₃	1.72	0.08	1.99	0.03	1.82	0.01
Na ₂ O	10.14	0.43	9.66	0.08	10.51	0.10
Nd ₂ O ₃	1.34	0.05	1.61	0.03	1.42	0.01
NiO	0.18	0.01	0.22	0.03	0.20	0.005
P ₂ O ₅	0.63	0.05	0.60	0.06	0.60	0.06
SiO ₂	38.73	1.35	40.50	0.28	41.2	0.03
SrO	0.37	0.01	0.46	0.01	0.40	0.005
TiO ₂	2.62	0.09	2.60	0.01	2.82	0.02
UO ₂	3.98	0.11	4.16	0.08	4.02	0.08
ZnO	4.15	0.15	4.34	0.03	4.46	0.04
ZrO ₂	1.46	0.05	1.88	0.06	1.54	0.09

(a) Based on analyses of 12 random samples for each batch.

(b) Prepared from MCC-76-68 glass Lot 3 (see Table 12).

(c) Prepared from MCC-76-68 glass Lot 1 (see Table 12).

(d) Prepared from MCC-76-68 glass Lot 3 (see Table 12).

Table 3 shows the compositions of ATM-1a, -1b, and -1c. X-ray diffraction analyses of four samples of each material indicated that ATM-1c and -1b contain ~3-5 wt% iron-chrome spinel crystals. ATM-1a was found to have no detectable crystallinity; the crystallinity detection limit for these glasses is 3 to 5 wt%. The only features seen in the scanning electron microscopy (SEM) examination of these materials were a minor number of small (~1 μ m) bubbles.

Table 4 shows the nominal compositions of ATM-2, -3, and -4, based on the MCC-76-68, Lot 3, base glass composition, from which these materials were made, and the analyzed transuranium oxide contents of these ATMs. SEM analysis of these ATMs showed essentially featureless glasses; only a few small (~1 μ m) bubbles were present.

Alpha autoradiography has been performed on cut bar sections of ATM-2, -3 and -4. The Pu in ATM-4 was fairly uniformly distributed within the bar. There was some layering of Np within the ATM-3. This appears to have occurred during bar pouring. The Am in ATM-2 is very uniform in the center of the bar, but has a lower concentration around the bar's exterior surface.

Additional characterization of these glasses is in progress.

Table 4. Compositions of ATM-2, -3, and -4 (Transuranium-doped 76-68 Glasses)^(a)

Oxide	ATM-2		ATM-3		ATM-4	
	wt%	Standard Deviation	wt%	Standard Deviation	wt%	Standard Deviation
Al ₂ O ₃	0.59	0.02	0.59	0.02	0.59	0.02
²⁴¹ Am ₂ O ₃	5.6E-2	3.8E-3	—	—	—	—
B ₂ O ₃	9.06	0.01	9.06	0.01	9.06	0.01
BaO	0.55	0.00	0.55	0.00	0.55	0.00
CaO	2.37	0.04	2.37	0.04	2.37	0.04
CeO ₂	0.92	0.01	0.92	0.01	0.92	0.01
Cr ₂ O ₃	0.47	0.01	0.47	0.01	0.47	0.01
Cs ₂ O	1.11	0.06	1.11	0.06	1.11	0.06
Fe ₂ O ₃	9.56	0.13	9.56	0.13	9.56	0.13
La ₂ O ₃	4.16	0.05	4.16	0.05	4.16	0.05
MoO ₃	1.97	0.03	1.97	0.03	1.97	0.03
Na ₂ O	12.77	1.21	12.77	1.21	12.77	1.21
Nd ₂ O ₃	1.41	0.02	1.41	0.02	1.41	0.02
NiO	0.23	0.01	0.23	0.01	0.23	0.01
²³⁷ NpO ₂	—	—	2.4E-1	2.2E-2	—	—
P ₂ O ₅	0.80	0.16	0.80	0.16	0.80	0.16
²³⁹ PuO ₂	—	—	—	—	6.2E-2	4.2E-3
SiO ₂	42.00	0.26	42.00	0.26	42.00	0.26
SrO	0.42	0.01	0.42	0.01	0.42	0.01
TiO ₂	3.08	0.05	3.08	0.05	3.08	0.05
ZnO	5.10	0.46	5.10	0.46	5.10	0.46
ZrO ₂	1.89	0.04	1.89	0.04	1.89	0.04

(a) Prepared from MCC-76-68 glass Lot 3; composition listed is that of base glass (see Table 12) except for the transuranium oxides for which analytical values are given.

ATM-5
76-68 Type Glass,
Fully Radioactive

This material represents a borosilicate glass which incorporates the high-level waste resulting from commercial nuclear fuel reprocessing. Its composition is based on 76-68 glass (Mendel et al. 1977). ATM-5 is fully loaded with actual waste from the reprocessing of commercial nuclear fuel. This waste was generated during the Nuclear Waste Vitrification Project (NWVP) at PNL (Wheelwright et al. 1979).

ATM-5 was fabricated at PNL in 1983. The nonradioactive ingredients were combined, melted and crushed to form a base glass. All subsequent processing was performed in a hot cell. Dried and powdered NWVP waste was added to the base glass. The powdered waste was made by heating NWVP waste solution to drive off water and NO_x . Oxides of Np, Pu and U were added to the batch to bring their levels to those in the 76-68 composition. The glass was produced in the form of cast, annealed bars $\sim 2 \times 2 \times 18$ cm weighing ~ 180 g each.

The anticipated composition of ATM-5 is shown in Table 5. This is based on analyses of the powdered waste and nonradioactive base glass. Analysis of actual glass composition, crystallinity, homogeneity and phases is in progress.

A report is presently available which covers the fabrication of ATM-5.

**Table 5. Anticipated Composition of ATM-5
(Fully-loaded 76-68 Glass)^(a)**

Oxide	wt%
Glass Additives	
B ₂ O ₃	9.5
CaO	2.0
Na ₂ O	13.0
SiO ₂	40.0
TiO ₂	3.0
ZnO	5.0
Waste Components	
Ag ₂ O	<0.1 ^(b)
BaO	0.8
CdO	<0.1 ^(b)
CeO ₂	1.0
Cr ₂ O ₃	0.5
Cs ₂ O	1.0 ^(b)
Eu ₂ O ₃	<0.1 ^(b)
Fe ₂ O ₃	7.6
Gd ₂ O ₃	<0.1
La ₂ O ₃	0.5
MoO ₃	1.2
Na ₂ O	5.5
Nd ₂ O ₃	1.8
NiO	0.3
P ₂ O ₅	0.5
PdO	0.5 ^(b)
Pm ₂ O ₃	<0.1 ^(b)
Pr ₆ O ₁₁	0.5 ^(b)
Rb ₂ O	0.1 ^(b)
Rh ₂ O ₃	0.2
RuO ₂	0.6
Sm ₂ O ₃	0.3 ^(b)
SrO	0.3
Tc ₂ O ₇	0.5 ^(b)
TeO ₂	0.2
Y ₂ O ₃	0.2 ^(b)
ZrO ₂	1.8 ^(b)
Other	1.2 ^(c)
Actinides	
Am ₂ O ₃	0.2
Cm ₂ O ₃	<0.1
NpO ₂	0.3
PuO ₂	<0.1
U ₃ O ₈	4.2

(a) Based on analyses of batch components; analyses of ATM-5 not yet completed. Oxides shown at <0.1% are expected to be present at low concentrations.

(b) Component of NWVP Waste that has not yet been analyzed. Anticipated amount in ATM-5 based on composition of PW-8 Waste (Mendel et al. 1977).

(c) Minor impurities in NWVP Waste; Al₂O₃, B₂O₃, CaO, MgO, MnO₂, SiO₂, TiO₂, ZnO.

ATM-6
Barnwell Type Glass,
Radioactive Dopants

This material represents a borosilicate glass that incorporates the anticipated high-level waste from the Barnwell Nuclear Fuel Plant (BNFP) (Anderson et al. 1982). The glass was requested by the Basalt Waste Isolation Project (BWIP) for use in its repository interactions testing programs. The types and levels of radioactive dopants that it contains were those specified by the BWIP. The composition of the glass-former mix (type 83-B-15) to which the simulated waste was added was developed by the Commercial Waste Treatment Program at PNL in 1983.

ATM-6 was fabricated at PNL in 1983. It was produced in a hot cell. Radioactive dopants were mixed with a premelted and crushed glass that contained the nonradioactive components. The dopants used included depleted U, Cm-244, Th-232, Np-237, Pu-238, -239 and -240, Tc-99, Cs-137 and Se-75. The glass was produced as cast, annealed bars ~2 x 2 x 18 cm, weighing ~180 g each. A portion of this glass was crushed into two size fractions, -60 +115 and -115 +250 Tyler mesh, using a motor-driven Al₂O₃ mortar and pestle. Most of this crushed material was furnished to BWIP; however, a few grams are still available for distribution.

Table 6 compares the compositions of the bar and crushed materials. It can be seen that except for Na₂O and Tc₂O₇ there is no significant difference between them. This indicates that no impurity was introduced by the crushing operation, nor did any significant segregation occur during sieving. The reason for the Na₂O and Tc₂O₇ differences is being investigated.

ATM-6 has been examined using a SEM/microprobe. Overall, the material was uniform in appearance and composition. No evidence of crystallinity was seen. One small bubble, ~300 μm in diameter, was found in the specimen examined; flakes of Ru metal were found on its interior surface. This was the only evidence of inhomogeneity in the material.

Further characterization of this material is in progress. A report is currently available for ATM-6 which covers its fabrication and initial characterization. A supplement to this report, covering the completed characterization of ATM-6, is in preparation.

Table 6. Composition of ATM-6 (Radioactively-doped Barnwell-type Glass)

Oxide	Composition, wt%(a)				
	Bars(b)		Powder(c)		
	Average	Standard Deviation	Tyler Mesh Size		
			-60+15	-115+250	-250
Glass Additives					
Al ₂ O ₃	5.64	0.21	5.42	5.54	5.52
B ₂ O ₃	9.19	0.41	9.09	9.36	8.72
Li ₂ O	4.38	0.17	4.21	4.38	4.24
Na ₂ O(d)	14.4	1.3	17.8	17.9	14.6
SiO ₂	49.0	2.4	46.7	47.8	46.1
Waste Components					
Ag ₂ O					
BaO					
CaO	0.40	0.08	0.63	0.56	0.38
CdO					
CeO ₂	1.06	0.07	0.51	0.77	0.84
Cr ₂ O ₃	0.11	0.01	0.11	0.11	0.10
Cs ₂ O	0.74	0.04			
Fe ₂ O ₃	0.53	0.03	0.55	0.66	0.48
Gd ₂ O ₃					
MnO ₂	0.12	0.02	0.15	0.15	0.12
MgO	0.22	0.05	0.35	0.33	0.23
MoO ₃	1.54	0.07	1.48	1.50	1.42
Na ₂ O	(included above)				
NaCl					
Na ₂ SO ₄					
Nd ₂ O ₃	1.62	0.06	1.26	1.27	1.44
NiO	nd		nd	nd	nd
P ₂ O ₅					
PbO					
PdO					
Rb ₂ O					
RuO ₂	0.27	0.15	0.29	0.33	0.34
SeO ₂					
Sm ₂ O ₃					
SnO ₂					
SrO	0.29	0.02	0.28	0.23	0.27
TeO ₂	0.13	0.01	0.14	0.12	0.13
TiO ₂	0.02	0.01	nd	nd	nd
Y ₂ O ₃					
ZnO	0.09	0.09	0.10	0.10	0.10
ZrO ₂	0.64	0.36	0.15	0.15	0.15
Radioactive Dopants					
²⁴⁴ Cm ₂ O ₃	6.5E-5	2.E-6	5.6E-5	6.4E-5	6.3E-5
¹³⁷ Cs ₂ O	3.0E-3	3.E-4	3.0E-3	3.3E-3	3.1E-3
²³⁷ NpO ₂	0.358	0.025	0.312	0.368	0.360
²³⁸ PuO ₂	2.5E-3	1.E-4	2.5E-3	2.7E-3	2.5E-3
²³⁹ + ²⁴⁰ PuO ₂	2.0E-2	2.E-3	2.0E-2	2.2E-2	2.0E-2
⁷⁵ SeO ₂	1.9E-7	6.E-9	1.6E-7	1.6E-7	1.3E-7
⁹⁹ Tc ₂ O ₇ (d)	0.128	0.008	0.308	0.305	0.289
U ₃ O ₈ (e)	2.4	0.1			
²³² ThO ₂	1.1E-2	4.E-3			

(a) Based on initial analyses. Data omissions in the table indicate that the component is expected to be present but analyses are not yet complete.

(b) From an analysis of three samples taken during bar pouring.

(c) From an analysis of a single sample of each size fraction.

(d) Analytical discrepancy between bars and powder is under investigation.

(e) Depleted U.

nd = not detected.

ATM-8
76-68 Type Glass,
Radioactive Dopants

This material represents a borosilicate glass which incorporates the high-level waste resulting from commercial nuclear fuel reprocessing. Its composition is that of 76-68 glass (Mendel et al. 1977). This material was requested by the Nevada Nuclear Waste Storage Investigations (NNWSI) for use in its repository testing programs. The types and levels of radioactive dopants which it contains were those specified by the NNWSI.

ATM-8 was fabricated at PNL in 1984. It was produced in a glove box. Dopants were mixed with crushed MCC-76-68 Lot 1 base glass (see Table 11). The radioactive dopants included Tc-99, depleted U, Np-237 and Pu-239. Nonradioactive additives included Pd, Ru, and Rh. Three kg of the glass were made. The glass was produced as bars and in a number of other forms, including cast cylinders (1.5 cm dia. x 2 cm tall); core-drilled and 304L stainless steel-clad cylinders (1 cm dia. x 1 cm tall); core-drilled and 304L stainless steel-clad discs (1 cm dia. x 3 mm thick); crushed and sieved powder; and cast bars (2 x 2 x 10 cm).

Table 7 shows the anticipated composition of ATM-8, based on the composition of the base glass and additives used in ATM-8 fabrication.

Characterization of ATM-8 is in progress.

Table 7. Anticipated Composition of ATM-8
(Radioactively-doped 76-68 Glass)^(a)

Oxide	wt%
Al ₂ O ₃	0.8
B ₂ O ₃	8.4
BaO	0.6
CaO	2.2
CdO	<0.1
Cr ₂ O ₃	0.5
Cs ₂ O	1.2
Dy ₂ O ₃	<0.1
Eu ₂ O ₃	<0.1
Fe ₂ O ₃	8.9
Gd ₂ O ₃	<0.1
K ₂ O	<0.1
La ₂ O ₃	4.8
MgO	0.2
MnO ₂	<0.1
MoO ₃	2.1
Na ₂ O	11.3
Nd ₂ O ₃	1.6
NiO	0.2
P ₂ O ₅	0.6
PdO	0.5
Rh ₂ O ₃	0.2
RuO ₂	1.0
SiO ₂	39.4
SrO	0.5
TiO ₂	2.8
ZnO	4.6
ZrO ₂	2.3
Radioactive Dopants	
⁹⁹ Tc ₂ O ₇	0.5
UO ₂	4.0
²³⁷ NpO ₂	0.4
²³⁹ PuO ₂	0.1

(a) Based on analyses of batch components; complete analysis is in progress. Oxides shown at <0.1% are expected to be present at low concentrations.

ATM-9
Defense Waste (SRP) Glass,
Radioactive Dopants

This material is representative of glass which will be produced by the Defense Waste Processing Facility (DWPF) at Savannah River Plant (SRP), Aiken, South Carolina. The glass was requested by the Office of Nuclear Waste Isolation (ONWI) for use in its salt repository development programs.

ATM-9 was fabricated at PNL in 1984. It was produced in a glove box. The base glass used in its manufacture was Savannah River Laboratory (SRL) type 165 glass supplied to the MCC by SRL as a crushed powder. This material simulates waste glass that contains all of the major nonradioactive components of the DWPF glass and corresponds to a waste loading (by weight of oxides) of 29 wt%. Radioactive and nonradioactive dopants were added to this material to represent certain radionuclides present in the actual DWPF glass. The types and levels of dopants that ATM-9 contains were those agreed upon by MCC and ONWI personnel. The nonradioactive dopants were those elements that will be present in the actual DWPF product in concentrations greater than $5\text{E-}4$ g/g glass. These included Zr, Mo, Cs, Ba, and Nd (Nd was substituted on a mole basis for Ce, Pr, Sm, and Eu). The radioactive dopants included depleted U, Pu-239, Am-243, Np-237, and Tc-99. Graphite was added to the glass during melting to control the glass oxidation state.

ATM-9 was produced and supplied to ONWI in the form of bars $\sim 2 \times 2 \times 10$ cm and $\sim 1.3 \times 1.3 \times 10$ cm. Crushed and sieved material has also been provided to the BWIP.

The anticipated composition of ATM-9 is shown in Table 8, based on analyses of the SRL-165 base glass and the dopants added.

Characterization of ATM-9 is in progress.

Table 8. Anticipated Composition of ATM-9
(Radioactively-doped SRP-type Glass)^(a)

Oxide	wt%
Al ₂ O ₃	4.3
B ₂ O ₃	6.9
BaO	0.1
CaO	1.6
Cs ₂ O	<0.1
Fe ₂ O ₃	11.8
K ₂ O	0.2
Li ₂ O	4.8
MgO	0.6
MnO ₂	2.8
MoO ₃	<0.1
Na ₂ O	10.8
Nd ₂ O ₃	0.2
NiO	0.8
P ₂ O ₅	0.3
SiO ₂	51.7
TiO ₂	0.2
ZnO	<0.1
ZrO ₂	0.9
Radioactive Dopants	
U ₃ O ₈	1.9
²³⁹ PuO ₂	2.5E-3
²⁴³ Am ₂ O ₃	6.3E-4
²³⁷ NpO ₂	1.1E-2
⁹⁹ Tc ₂ O ₇	1.0E-2

(a) Based on analysis of SRL-supplied base glass; complete analysis is in progress. Oxides shown at <0.1% are expected to be present at low concentrations.

ATM-11
Defense Waste (SRP) Glass,
Radioactive Dopants

This material is representative of glass that will be produced by the Defense Waste Processing Facility (DWPF) at Savannah River Plant (SRP), South Carolina. The glass was requested by the BWIP for use in its repository interactions testing programs.

ATM-11 was fabricated at PNL in 1984. It was produced in a glove box. The base glass used in its manufacture was Savannah River Laboratory (SRL) type 165 glass supplied to the MCC by SRL as a crushed powder. This material simulates waste glass that contains all of the major nonradioactive components of the DWPF glass and corresponds to a waste loading (by weight of oxides) of 29 wt%. Radioactive and nonradioactive dopants were added to this material to represent certain radionuclides present in the actual DWPF glass. The types and levels of dopants that ATM-11 contains were those specified by BWIP. The nonradioactive dopants were those elements that will be present in the actual DWPF product in concentrations greater than 1E-5 g/g glass. The radioactive dopants included depleted U, Pu-239, Am-241, Np-237, Tc-99 and Sm-151. Graphite was added to the glass during melting to control the glass oxidation state.

ATM-11 was produced in the form of bars ~2 x 2 x 10 cm. Crushed and sieved material has been provided to the BWIP.

The anticipated composition of ATM-11 is shown in Table 9, based on analyses of the SRL-165 base glass, and the dopants added.

Characterization of ATM-11 is in progress.

Table 9. Anticipated Composition of ATM-11
(Radioactively-doped SRP-type Glass)^(a)

Oxide	wt%
From SRL-Supplied Base Glass	
Al ₂ O ₃	4.3
B ₂ O ₃	6.8
BaO	<0.1
CaO	1.6
Fe ₂ O ₃	11.7
K ₂ O	0.2
Li ₂ O	4.8
MgO	0.6
MnO ₂	2.8
Na ₂ O	10.8
NiO	0.8
P ₂ O ₅	0.3
SiO ₂	51.6
TiO ₂	0.2
ZnO	<0.1
ZrO ₂	0.7
Nonradioactive Dopants	
BaO	1.1E-1
Cs ₂ O	4.2E-2
MoO ₃	8.1E-2
Nd ₂ O ₃	2.4E-1
NiO	1.9E-3
PdO	9.6E-3
Rb ₂ O	7.3E-3
RuO ₂	4.9E-2
SrO	1.6E-2
TeO ₂	7.3E-3
Y ₂ O ₃	1.3E-2
ZrO ₂	1.6E-1
Radioactive Dopants	
U ₃ O ₈	1.9
²³⁹ PuO ₂	2.5E-3
²⁴¹ Am ₂ O ₃	6.4E-5
²³⁷ NpO ₂	1.7E-2
⁹⁹ Tc ₂ O ₇	1.9E-2
¹⁵¹ Sm ₂ O ₃	9.5E-6

(a) Based on analysis of SRL-supplied base glass; analysis of ATM-11 not yet completed. Oxides shown at <0.1% are expected to be present at low concentrations.

ATM-12
76-68 Type Glass
Composition at 300 Years,
Radioactive Dopants

This material represents a borosilicate glass that incorporates the high-level waste resulting from commercial nuclear fuel reprocessing. Its composition is that predicted for 76-68 glass at an age of 300 years. This material was requested by the Nevada Nuclear Waste Storage Investigations (NNWSI) for use in its repository testing programs. Its composition and the types and levels of radioactive dopants that it contains were those specified by NNWSI.

ATM-12 was fabricated at PNL in 1984. It was produced in a glove box. The nonradioactive components of ATM-12 were premelted to form a base glass to which the radioactive dopants were added, including Tc-99, depleted U, Np-237, Pu-239, and Am-241. Three kg of the glass were made. The glass was produced as bars and in a number of other forms, including cast cylinders (~1.5 cm dia. x 2 cm tall); core-drilled and 304L stainless steel-clad cylinders (~1 cm dia. x 1 cm tall); core-drilled and 304L stainless steel-clad discs (~1 cm dia. x 3 mm thick); crushed and sieved powder; and cast bars (~2 x 2 x 10 cm).

Table 10 shows the anticipated composition of ATM-12, based on an analysis of three samples of the nonradioactive base glass taken during fabrication activities.

Characterization of ATM-12 is in progress.

Table 10. Anticipated Composition of ATM-12 Glass
(Radioactively-doped 76-68 Glass)^(a)

Oxide	wt%
B ₂ O ₃	9.3
BaO	1.0
CaO	2.0
CdO	<0.1
CeO ₂	1.0
Cr ₂ O ₃	0.4
Cs ₂ O	0.5
Eu ₂ O ₃	<0.1
Fe ₂ O ₃	9.5
Gd ₂ O ₃	<0.1
La ₂ O ₃	0.4
MoO ₃	1.7
Na ₂ O	12.6
Nd ₂ O ₃	1.7
NiO	0.2
P ₂ O ₅	0.6
PdO	0.6
Pr ₆ O ₁₁	0.5
RbO	0.1
Rh ₂ O ₃	0.2
RuO ₂	1.0
SiO ₂	40.6
Sm ₂ O ₃	0.4
SnO ₂	<0.1
SrO	0.1
TeO ₂	0.2
TiO ₂	3.0
Y ₂ O ₃	0.2
ZrO ₂	1.8
Radioactive Dopants	
⁹⁹ Tc ₂ O ₇	0.8
UO ₂	4.0
²³⁷ NpO ₂	0.2
²³⁹ PuO ₂	<0.1
²⁴¹ Am ₂ O ₃	0.1

(a) Based on analyses of batch components during fabrication; complete analysis is in progress. Oxides shown at <0.1% are expected to be present at low concentrations.

ATM-MCC-B77-260
Barnwell Type Glass,
Radioactive Dopants

This material represents a borosilicate glass that incorporates the anticipated high-level waste that would have been produced by the Barnwell Nuclear Fuel Plant (BNFP). Its composition is that of 77-260 glass (Ross et al. 1978). The types and levels of radioactive dopants that it contains were those specified by the BWIP.

This ATM was fabricated by PNL for the BWIP in 1982. It was produced in a glove box. Initially, a base stock glass was made from the nonradioactive components. This was crushed and the radioactive dopants were added including depleted U, Pu-239, Am-241, Np-237, and Tc-99. The glass was produced in the form of air-quenched material (the molten glass was poured into a room-temperature stainless steel plate and allowed to fracture and cool). The cooled material was crushed and sieved into three size fractions: -60+115, 115+250, and -250 Tyler mesh.

Table 11 shows the anticipated composition of ATM-MCC-B77-260, based on analyses of the nonradioactive base stock glass, and the radioactive dopant additions.

Table 11. Anticipated Composition of ATM-MCC-B77-260 (Radioactively-doped Barnwell-type Glass)^(a)

Oxide	wt%
Al ₂ O ₃	2.0
B ₂ O ₃	9.0
BaO	<0.1
CaO	2.0
CeO ₂	1.2
CuO	2.7
Cs ₂ O	1.2
Fe ₂ O ₃	0.6
Gd ₂ O ₃	10.6
K ₂ O	2.0
MnO ₂	<0.1
MoO ₃	2.0
Na ₂ O	10.4
Nd ₂ O ₃	2.8
P ₂ O ₅	1.9
PdO	0.4
Rh ₂ O ₃	0.2
RuO ₂	1.1
SiO ₂	34.5
SrO	0.3
TeO ₂	0.3
TiO ₂	6.2
Y ₂ O ₃	0.3
ZrO ₂	1.5
Radioactive Dopants	
U ₃ O ₈	5.2
⁹⁹ Tc ₂ O ₇	0.7
²³⁹ PuO ₂	<0.1
²³⁷ NpO ₂	0.2
²⁴¹ Am ₂ O ₃	<0.1

(a) Based on analysis of nonradioactive base glass. Oxides shown at <0.1% are expected to be present at low concentrations.

**MCC-76-68 -
76-68 Type Glass,
Used for Selected
Applications**

This material represents a borosilicate glass that incorporates the high-level waste resulting from reprocessing of commercial nuclear reactor fuel. This glass is nonradioactive. Its composition is based on that of 76-68 glass (Mendel et al. 1977).

MCC-76-68 was fabricated by Penberthy Electromelt of Seattle, Washington, in 1980. It was supplied in the form of cast, annealed bars, 2.5 x 2.5 x 30 cm. Three lots were produced; the compositions of these lots, as determined by inductively coupled plasma spectrometry (ICP) is given in Table 12. The observed variation in composition of random specimens of this material is as much as 10% for some elements. The MCC recommends that use of this material be limited to applications in which this inhomogeneity is acceptable. One use of this material is as a feed stock for the production of doped ATMs based on 76-68 glass, such as ATM-1c and ATM-8. In this application the inhomogeneity is essentially eliminated because the bar material is crushed and blended before the addition of dopants.

Table 12. Composition of MCC-76-68 (Borosilicate Glass)

Oxide	Compositions, wt%(a)					
	Lot 1		Lot 2		Lot 3	
	wt%	Standard Deviation ^(b)	wt%	Standard Deviation ^(b)	wt%	Standard Deviation ^(b)
Al ₂ O ₃	0.84	0.03	0.63	0.03	0.59	0.02
B ₂ O ₃	8.65	0.06	8.99	0.15	9.06	0.01
BaO	0.62	0.01	0.54	0.02	0.55	0.00
CaO	2.29	0.04	2.22	0.11	2.37	0.04
CdO	0.05	0.01	0.05	0.01	0.05	0.01
CeO ₂	<0.02	—	0.82	0.11	0.92	0.01
Cr ₂ O ₃	0.50	0.02	0.47	0.01	0.47	0.01
Cs ₂ O	1.21	0.08	1.14	0.01	1.11	0.06
Dy ₂ O ₃	0.01	0.00	0.01	0.00	0.01	0.00
Eu ₂ O ₃	0.01	0.00	0.01	0.00	0.01	0.00
Fe ₂ O ₃	9.08	0.12	9.52	0.17	9.56	0.13
Gd ₂ O ₃	0.03	0.01	0.02	0.00	0.02	0.00
K ₂ O	0.09	0.03	0.27	0.06	<0.06	—
La ₂ O ₃	4.89	0.06	4.33	0.24	4.16	0.05
MgO	0.18	0.01	0.14	0.01	0.16	0.01
MnO ₂	0.06	0.00	0.06	0.01	0.06	0.01
MoO ₃	2.17	0.01	1.96	0.05	1.97	0.03
Na ₂ O	11.60	0.95	11.30	0.20	12.77	1.21
Nd ₂ O ₃	1.65	0.01	1.47	0.08	1.41	0.02
NiO	0.25	0.03	0.22	0.02	0.23	0.01
P ₂ O ₅	0.56	0.08	0.66	0.11	0.80	0.16
SiO ₂	40.33	0.81	40.73	0.32	42.00	0.26
SrO	0.49	0.01	0.42	0.01	0.42	0.01
TiO ₂	2.86	0.04	3.04	0.03	3.08	0.05
ZnO	4.75	0.08	4.76	0.05	5.10	0.46
ZrO ₂	2.33	0.04	1.79	0.07	1.89	0.04
TOTAL	95.50		95.57		98.76	

(a) Based on analyses of three bars for each lot.

(b) Standard deviation of a single analysis.

1000

1000

1000

V. STANDARD MATERIALS: SPENT FUEL WASTE FORMS

This section describes the presently available spent fuel ATMs. Information on irradiation history, physical and chemical characteristics, and homogeneity are provided in referenced reports to the extent that such information is available for each ATM.

One spent fuel ATM is available at present. This one, and others which are being sought, are selected on the basis of their being representative of spent fuels which might be submitted for storage in the U.S. nuclear waste repository systems now under development (Barner 1984a).

ATM-101

H. B. Robinson Spent Fuel, Typical PWR

This material represents the class of spent commercial nuclear reactor fuel characterized by moderate burnup and low in-reactor fission gas release. This fuel came originally from the H. B. Robinson PWR. The fuel's nominal burnup is 30 MWd/kgM. It was removed from the reactor in 1973, and received by the MCC from EG&G Idaho in November 1983.

ATM-101 characterizations completed to date include fission gas release (~0.2% released); longitudinal and transverse ceramography; comparisons of analytical and calculated radionuclide inventories for U-235, Pu-239, Cs-137, Np-237 and Tc-99; burnup analyses; and axial gamma scanning. The ceramography and analytical characterizations have been completed only on material from the high-power region. Characterization of material from lower-power regions is planned. Analytical results were within 10% of the calculated values, indicating that the calculated values can be used to determine the inventory for any radionuclide of interest for any sample/specimen of a known burnup. A summary of representative data describing ATM-101 is given in Table 13.

The report *Characterization of a LWR Spent Fuel MCC-Approved Testing Material ATM-101* (Barner 1984b) describes the characterizations completed to date and provides tables of calculated inventories of radionuclides as functions of the burnup and decay period. The latter can be used to determine radionuclide inventories for samples/specimens. This report will be updated as additional characterization data are obtained from work in progress.

Table 13. Representative Data Describing ATM-101 (PWR Spent Fuel)^(a)

Reactor Source:	H.B. Robinson, Unit 2 (PWR)
Fuel:	Solid dished UO ₂ pellets, 9.3 mm d x 15.2 mm l
Cladding:	Zircaloy-4, 10.7 mm O.D., 9.46 mm I.D.
Irradiation history:	Est. peak-pellet burnup = 31.36 MWd/kgM Est. assembly-average burnup = 28.03 MWd/kgM
Fission gas release (rod N-9):	371 cm ³ (STP) = 0.19%
Fuel grain size (section N-9C-C):	Centerline, 9.1 μm Edge, 6.1 μm
Fuel surface area including cracks (section N-9C-C):	Est. 152 mm ² /mm rod length
Chemical analysis (sample N-9C-J):	²³⁵ U, 6.18 x 10 ⁻³ wt% (oxide) ²³⁹ Pu, 4.55 x 10 ⁻³ wt% (oxide) ²³⁷ Np, 2.97 x 10 ⁻⁴ wt% (oxide) ¹³⁷ Cs, 6.27 x 10 ⁻² Ci/g (oxide) ⁹⁹ Tc, 8.95 x 10 ⁻⁵ Ci/g (oxide)

^(a) Selected data from Barner 1984b.

VI. STANDARD MATERIALS: WASTE PACKAGE AND REPOSITORY RELATED MATERIALS

This section describes the presently available reference and testing materials related to the MCC's nuclear waste package and repository test development program. Information on composition is presented, as well as a general discussion of each material.

These materials are acquired by the MCC during development and evaluation of MCC tests, in conjunction with the repositories. Each material generally will be related to a specific repository, and usually is supplied or specified by that repository. The MCC serves as an archive storage center for the test materials, and also uses the materials in its benchmark testing in cooperation with the respective repositories.

ATM-301
ASTM A27 Cast Steel

This material is a cast steel. It has been used in benchmark MCC-105.1 corrosion testing in basalt repository applications.

ATM-301 was obtained from the BWIP in 1983 in the form of a 38 x 38 x 13 cm plate. Its composition is given in Table 14. The results of a grain size analysis are given in Table 15.

Table 14. Chemical Composition of ATM-301 (Cast Steel)

Element	wt%	
	Mean ^(a)	Standard Deviation
Al	0.092	0.003
C	0.25	0.004
Cr	0.20	—
Cu	0.13	0.005
Fe	Balance	
Mn	0.70	0.013
Mo	0.03	0.013
N	0.0067	0.001
Ni	0.12	—
P	0.028	0.0004
S	0.018	0.002
Si	0.50	0.01
Sn	0.011	0.001
V	0.011	0.001

(a) Mean of analyses of 2 specimens cut from the plate.

Table 15. Grain Size Analysis of ATM-301 (Cast Steel)

Sample ^(a)	Mean Grain Size, mm		Volume Fraction	
	α -Fe	Pearlite	α -Fe	Pearlite
1	0.054	0.51	0.56	0.44
1	0.053	0.55	0.62	0.38
2	0.66	0.66	0.64	0.36
2	0.50	0.76	0.62	0.38
3	0.51	0.66	0.66	0.34
3	0.50	0.60	0.63	0.37
Average	0.054	0.062	0.62	0.38
Standard Deviation	0.006	0.009	0.03	0.03

(a) Each sample was measured in two orthogonal orientations.

ATM-401
Basalt

This material represents a reference basalt repository material. It came from the Cohasset entablature in southeast Washington State. It has been used for benchmark MCC-105.1 corrosion testing in basalt repository applications.

ATM-401 was obtained from the BWIP in 1983 as 3 kg of -12+230 mesh powder and 5 kg of -1/2+1/4 mesh material. The phases present in this basalt are shown in Table 16. The compositions of the two phases that make up the majority of the basalt are shown in Table 17.

Table 16. Phases Present in ATM-401 (Basalt)

Phase	Vol%	
	Sample 1	Sample 2
Plagioclase	36.5	37.3
Pyroxene	20.6	21.0
Mesostasis glass	30.5	32.5
Titaniferous magnetite	3.70	4.60
Apatite	Trace	Trace
Alteration products	8.30	5.03
TOTAL	99.6	100.4

Table 17. Composition of Plagioclase and Mesostasis Glass Phases of ATM-401

Oxide	wt% in Phase			
	Plagioclase		Mesostasis Glass	
	wt%	Standard Deviation	wt%	Standard Deviation
SiO ₂	53.2	0.9	65.1	3.2
TiO ₂	—	—	1.0	0.6
Al ₂ O ₃	28.5	0.6	14.0	2.1
FeO	0.8	0.1	5.4	2.4
MnO	—	—	0.4	0.1
MgO	0.2	0.1	0.5	0.8
CaO	11.8	0.8	3.1	1.4
Na ₂ O	4.6	0.5	4.2	0.9
K ₂ O	0.3	0.1	3.4	1.0
P ₂ O ₅	—	—	0.6	0.2
TOTAL	99.4		97.7	

ATM-402
Bentonite

ATM-402 represents a bentonite backfill material. It has been used for benchmark MCC-105.1 corrosion testing in basalt repository applications.

ATM-402 was obtained from the BWIP in 1983 as 2.6 kg of -400 mesh powder; an additional 9-kg piece was obtained subsequently. This ATM, mainly a sodium montmorillonite, contains the phases shown in Table 18. Its composition is shown in Table 19.

Table 18. Phases Present in ATM-402 (Bentonite)

Phase	wt%
Montmorillonite	85
Quartz	5
Feldspars	5
Cristobalite	2
Illite	2
Calcite and gypsum	1
TOTAL	100

Table 19. Composition of ATM-402 (Bentonite)

Component	wt%
SiO ₂	55.44
Al ₂ O ₃	20.14
Fe ₂ O ₃	3.67
CaO	0.49
MgO	2.49
Na ₂ O	2.76
K ₂ O	0.60
Bound water	5.50
Moisture released at 220°F	8.00
TOTAL	99.09

VII. PLANNED ACQUISITIONS

Additional standard materials are expected to be acquired during 1985.

a. Reference Leachates

Two reference leachates will be specified which will approximate the leachates resulting from MCC leach tests conducted using deionized water and brine leachants.

b. Spent Fuels

MCC will acquire ATM-102, a moderate-burnup, low-releasing (fission products in-reactor) BWR spent fuel; and ATM-103, a high-burnup or high-releasing (fission products in-reactor) PWR spent fuel.

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