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CHEMICAL AND PHYSICAL STABILITY OF REFRACTORIES FOR USE IN COAL GASIFICATION

Quarterly Progress Report, November 1, 1977—January 31, 1978

MASTER

By
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February 10, 1978

Work Performed Under Contract No. EY-76 S-02-2904

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I. OBJECTIVES

The basic objective of this investigation is to establish the corrosion resistance of refractories, especially the bond phases, to those high pressure/temperature gases and liquids that are typically present in coal gasification vessels.

The specific objectives are:

(1) to achieve an understanding of the general types of chemical reactions occurring in refractories when exposed to conditions representative of those at the cold face of the refractory lining in coal gasification vessels;

(2) to assess the relative importance of these reactions to those physical/chemical properties required for long-service life; and

(3) to identify those refractory systems providing optimum service performance, particularly in regard to the bond phases.

II. WORK COMPLETED

During this quarter, the 60-day long-term exposure in the ERDA + 1 Vol.% H_2S, and the 20-day exposure in CO/H_2O ratio = 3 + 1 Vol. % H_2S atmospheres were completed. The plan and schedule in Figure 1 is being followed and the work is on schedule. All exposure tests have been completed and specimen post-exposure characterization and analysis (XRD and DTA-TGA) is progressing satisfactorily.

III. EXPERIMENTAL PROCEDURE

A. Materials.

The refractories and cements investigated during this quarter are listed in Table I.

B. Test Atmosphere.

The exposure tests were performed in the ERDA* or CO-steam atmospheres containing 1 Vol.% H_2S at 1000 psia. The exposure conditions were as follows:

(1) 60-Day long-Term Exposure Test

Total pressure of ERDA* atmosphere = 1000 psia

Temperature of Unsaturated Vapor = 700°F

Temperature of Saturated Vapor = 447°F

(2) 20-Day CO/H_2O = 3.0 Exposure Test

Pressure of Steam = 247.5 psia

Pressure of CO = 742.5 psia

Pressure of H_2S = 10.0 psia

Temp. of Unsaturated Vapor = 1000°F

Temp. of Saturated Vapor = 400°F

Seven samples of each refractory were exposed to the unsaturated and saturated vapors and two samples were immersed in the water in the bottom of the steam vessel. The liquid in the bottom of the steam vessel is referred to as water although it contains dissolved gases.

C. Pre-and Post-Exposure Characterization and Procedure.

Specimen preparation, test systems, testing procedures, and pre- and post-exposure characterization were the same as described previously.

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*Composition is 18% CO, 12% CO_2, 24% H_2, 41% H_2O, 5% CH_4 (Vol.%) plus 1% H_2S.

IV. RESULTS AND DISCUSSION

Calcium Aluminate Cement-Bonded Refractories

(1) 20-Day CO/H_2O = 3.0 Exposure Test

A. Weight and Dimensional Changes.

Table II summarizes the weight changes* for the high alumina, intermediate alumina, and insulating castables exposed to the CO/H_2O = 0.1, 1.0, and 3.0 atmospheres. The weight changes at 1000°F (unsaturated vapor) in CO/H_2O = 3.0 were similar to those in CO/H_2O = 0.1 or 1.0. Similar weight changes were observed in previous exposures in the ERDA and CO-steam atmospheres at 1000°F. In the saturated vapor atmosphere, all samples either showed smaller weight losses or weight increases with the exception of UMR-4 and VSL-50. Unlike the CO/H_2O = 0.1 or 1.0 tests, all the samples immersed in water during the CO/H_2O = 3.0 test showed large weight losses. Comparison of the weight change data for the refractories immersed in water for the three CO/H_2O ratios indicates that weight loss increased with increasing CO content of the atmosphere.

The dimensional changes in both unsaturated and saturated atmospheres were similar to those observed in previous exposures and, in general, were below 1%. In the unsaturated atmosphere, there was generally a shrinkage, while a slight expansion occurred in saturated atmospheres.

B. Density and Porosity.

Unlike CO/H_2O = 0.1 or 1.0 atmospheres, the high and intermediate alumina castables in CO/H_2O = 3.0, in general, showed lower densities and higher porosities in the saturated (400°F) atmosphere as compared

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*as Cast and dried (230°F) is reference weight.

to the unsaturated atmosphere (1000°F), Table III. Samples immersed in water had the highest porosity. The higher porosities of the samples immersed in water is consistent with their larger weight losses. The density and porosity of the insulating castables, was essentially the same in both the unsaturated and saturated atmospheres.

C. Flexural Strength.

Figure 2 shows the MOR of the cement-bonded castables after exposure to the CO/H_2O = 3.0 atmosphere. For the purpose of comparison, the MOR of these compositions after exposure to CO/H_2O = 0.1 and 1.0 are shown in Figures 3 and 4, respectively. As was observed in previous exposures in the ERDA and CO/H_2O atmospheres, the high and intermediate alumina castables, in general, showed higher strengths in saturated atmospheres. This is attributed to the formation of boehmite ($Al_2O_3 \cdot H_2O$) in the samples during exposure. Similar to the CO/H_2O = 1.0 atmosphere, the flexural strength of the insulating castables generally increased slightly in the CO/H_2O = 3 atmosphere.

(2) 60-Day Long-Term Exposure Test

Table IV summarizes the properties after a 60 day exposure in the ERDA + 1% H_2S atmosphere. In the unsaturated atmosphere at 700°F, all samples lost weight of 1 to 2%. With the exception of UMR-1 and CERLITE # 75, samples exposed to the saturated vapor (447°F) again showed about the same weight losses as in the unsaturated vapor at 700°F. UMR-1 and CERLITE # 75 had weight increases of ~1%. Dimensional changes in the unsaturated and saturated vapors were small and, in general, below 1%. These weight and dimensional changes are similar to those observed in previous exposures in the ERDA and CO-steam atmospheres.

The weight change of samples immersed in water for 60 days at 447°F were significantly larger. All samples showed weight increases of over 4% with CERLITE # 75 as high as 19.6%. Large deposits of $CaCO_3$ crystals formed on the sample surfaces during exposure. (The weight change reported is after the crystals had been scrapped from the surface). Though these crystals were ~1mm in diameter and easily removed from the surface of high alumina samples, smaller crystals were also observed, especially in the insulating castables. These smaller crystals filled the surface pores and thereby increased the sample weight as well as decreasing the porosity. UMR-1 and CERLITE # 75 had a porosity of only 6 and 37%, respectively, which is considerably smaller than their porosity before exposure.

The flexural strenghts of the samples after the 60 day exposure were basically similar to those after the 10-30 day exposures in the ERDA and CO-steam atmospheres.

Phosphate-Bonded Ramming Mix

Table XV summarizes the data currently available for GREENPAK 90-P. Comparison of properties after exposure for 20 days in the various CO/H_2O atmospheres and for 60 days in the ERDA atmosphere are given in Tables III and IV, respectively.

Except for samples immersed in water during the CO/H_2O = 1.0 and 3.0 exposures, where weight gains of 2 to 3% were observed, all weight and dimensional changes in the three CO/H_2O atmospheres were below 1%. The density was higher and the porosity lower in the CO/H_2O = 1.0 atmosphere than in the CO/H_2O = 0.1 or 3.0 atmospheres.

Figure 5 summarizes the MOR after exposure for the various phosphate-bonded refractories, only GREENPAK 90-P was investigated

in the CO/H_2O exposure tests. The flexural strength in the unsaturated atmosphere (1000°F) at CO/H_2O = 1.0 was higher compared to either CO/H_2O = 0.1 or 3.0. As observed in previous exposure tests in the ERDA and CO-steam atmospheres, the MOR of each refractory was less in saturated atmospheres than the MOR of the control (as-fired in air) samples or samples exposed to unsaturated conditions. Of the three CO/H_2O tests, the MOR was lowest for CO/H_2O = 0.1 (532°F), where the steam pressure was highest (900 psia).

Table IV summarizes the property data for GREENPAK 90-P and BRIKRAM 90-R exposed to the saturated vapor (447°F) of the ERDA + 1 Vol.% H_2S atmosphere for 60 days. GREENPAK 90-P showed a weight increase of 1.3%, while there was a weight loss of 0.8% for BRIKRAM 90-R. Both refractories showed small dimensional changes, being generally below 1%. These weight and dimensional changes are similar to those in previous exposures for 30 days in the ERDA atmosphere with 1% H_2S.

Both GREENPAK 90-P and BRIKRAM 90-R had lower densities and higher porosities after the 60 day exposure in the saturated vapor (447°F) of the ERDA atmosphere compared to the previous ERDA and CO-steam exposure tests. The higher porosities in these refractories, however, did not indicate any failure or surface degradation. Moreover, the MOR for both GREENPAK 90-P and BRIKRAM 90-R was slightly higher in the saturated atmosphere (447°F) after the 60 day exposure as compared to the previous 30 day exposure in the ERDA atmosphere at the same temperature, see Fig. 5.

pH of Condensed Water

60 Day versus 30 Day in ERDA Atmosphere.

The pH of water collected from the steam condensor usually was

slightly alkaline (pH = 7-8) during the first few days of exposure and became more acidic with time. In both the 60 day and 30 day exposures the pH decreased to 4.5 within 10 days and remained constant until the end of 20 days. In the 60 day exposure, the pH of water continued decreasing and became 3.5 at the end of 30 days. Between 30 and 60 days, the pH decreased only slightly being 3.3 at 60 days. Distilled water (pH = 7) was used in all exposures.

CO/H$_2$O = 0.1, 1.0, and 3.0 Tests.

In the case of CO/H_2O = 0.1, the pH of the condensed water was above 7 for the first 10 days. Between the 10th and 15th day the pH varied between 4-6 and thereafter became constant at 4. In the CO/H_2O = 1.0 test, the pH of the water decreased more rapidly becoming 5 at the end of 5 days, 3.5 by the 10th day and remained constant thereafter. In the CO/H_2O = 3.0, the change toward acidity was not rapid. It remained at about 7 for the first 10 days, then varied between 4-6 becoming constant at 4 by the end of the exposure.

VI. CONCLUSIONS

The general conclusions given below are based on the results obtained to date in the three CO/H_2O and 60 day exposure tests.

A. CO/H_2O Tests

(1) Large weight losses were observed for refractory samples immersed in water in the CO/H_2O = 3 test compared to CO/H_2O = 0.1 or 1 tests and, in general, increased with increasing CO/H_2O ratio. This weight loss is most likely due to the dissolution of CaO from the refractories. Chemical analysis is in progress.

(2) The weight changes in the unsaturated (1000°F) and saturated (532, 466, and 400°F) vapors were basically the same in the three CO/H_2O tests.

(3) With the exception of UMR-6, UMR-7 and RC-3, the high and intermediate alumina refractories generally had the lowest porosity when exposed to the saturated atmosphere (vapor or liquid) at CO/H_2O = 0.1 and the highest when immersed in water at CO/H_2O = 3.0. UMR-6, UMR-7, and RC-3 had porosities ranging from 6-9% for samples exposed to the saturated vapor at CO/H_2O = 3.

(4) Porosities of high and intermediate alumina refractories in unsaturated atmospheres and insulating castables in saturated and unsaturated atmospheres generally remained nearly constant for CO/H_2O ratios of 0.1 to 3.

(5) The effect of saturation on the flexural strength of high and intermediate alumina was significant in all three CO/H_2O tests and, in general, the flexural strength increased by a factor of 2 compared with the unexposed samples or samples exposed to unsaturated conditions. The effect of saturation on the insulating castables was slightly beneficial at CO/H_2O = 1 and 3 where the flexural strength generally increased.

B. 60 Day versus 30 Day ERDA Tests

The changes in weight, dimension, density-porosity, and MOR of refractory samples after a 60 day exposure in the ERDA atmosphere were basically the same as observed in similar exposure conditions for 30 day lengths.

FUTURE WORK

XRD and DTA/TGA analyses of samples from the 60 day long-term exposure in the ERDA and 20 day CO/H_2O = 3 tests will continue and scheduled to complete in March 1978. Work is also continuing on thermal expansion measurements of exposed samples.

VI. PERSONNEL

During this quarter the following personnel worked on this project:

(a) Delbert E. Day, Principal Investigator

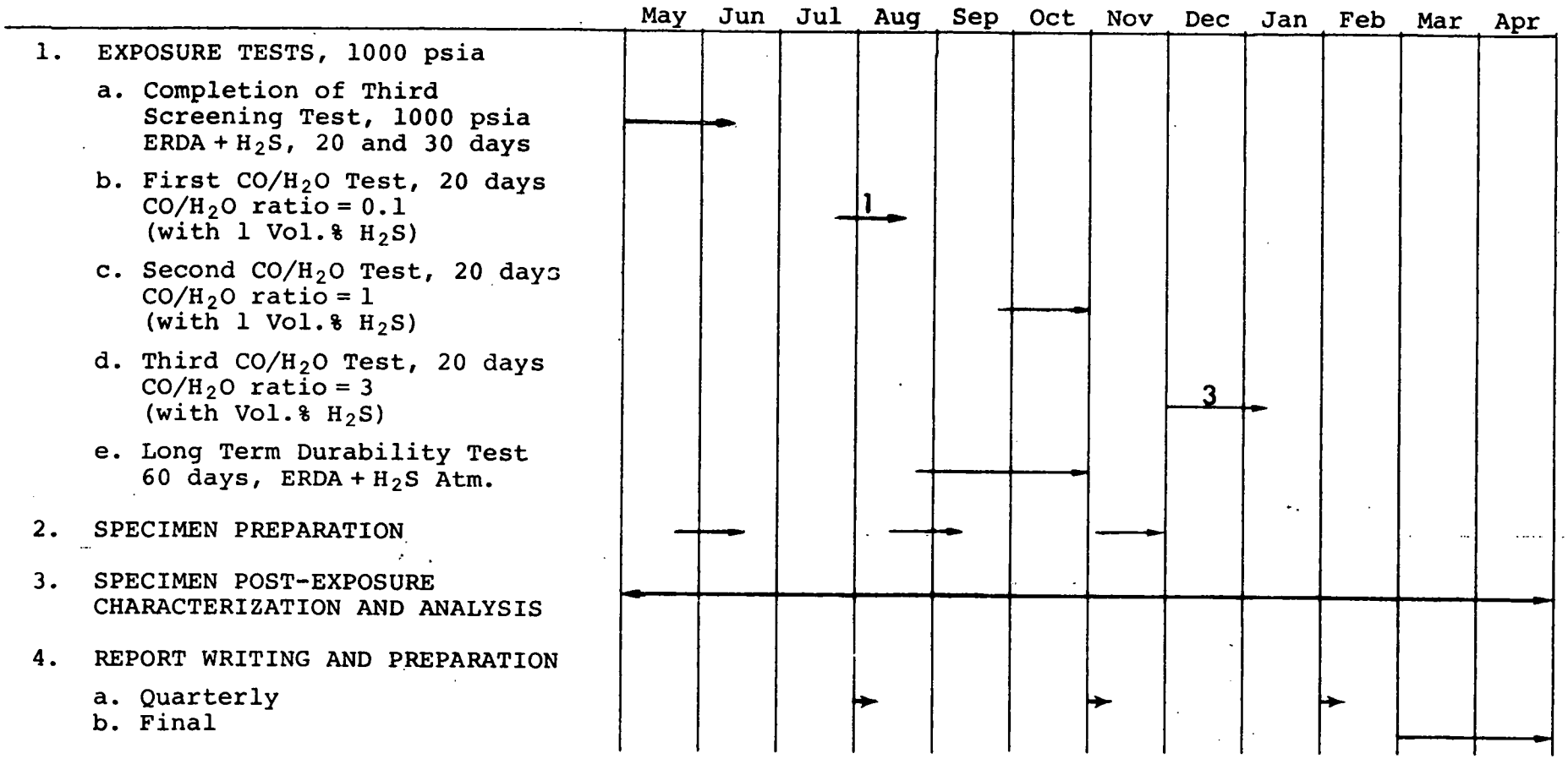
(b) Gordon Lewis, Co-Investigator

(c) Syed F. Rahman, Postdoctoral Fellow in Ceramic Engineering (full-time)

(d) Student Research Technicians (four, part-time)

(e) S. Sinharoy, Research Associate (half-time)

Fig. 1: Work Plan and Schedule, 1 May 1977 - 30 April 1978



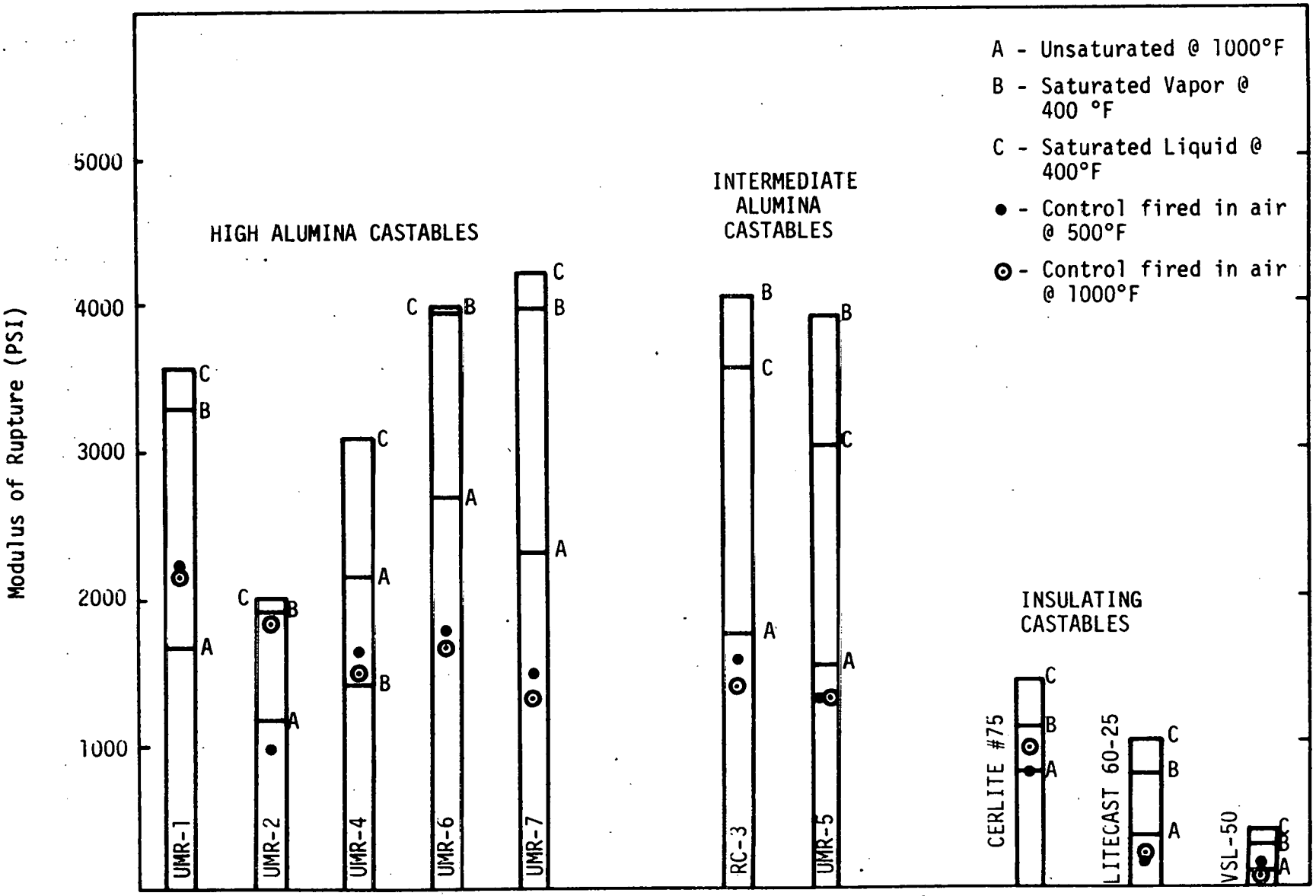


Figure 2. Room Temperature Modulus of Rupture of Castables Exposed to CO/H_2O = 3.0 + 1 Vol.% H_2S, 1000 psia, 20 days.

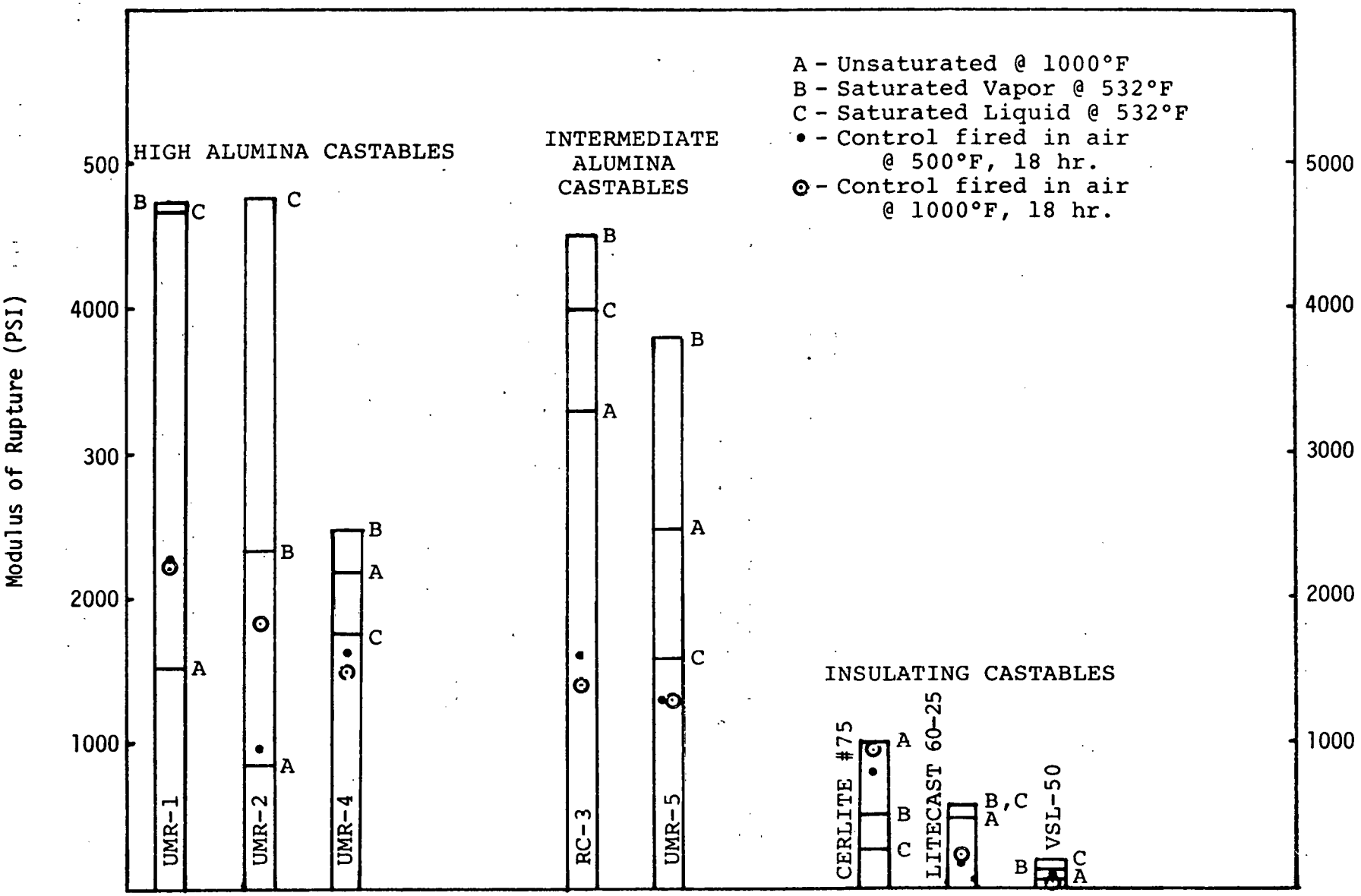


Figure 3. Room Temperature Modulus of Rupture of Castables Exposed to CO/H_2O = 0.1 + 1 Vol. % H_2S Atmosphere, 1000 psia, 20 days.

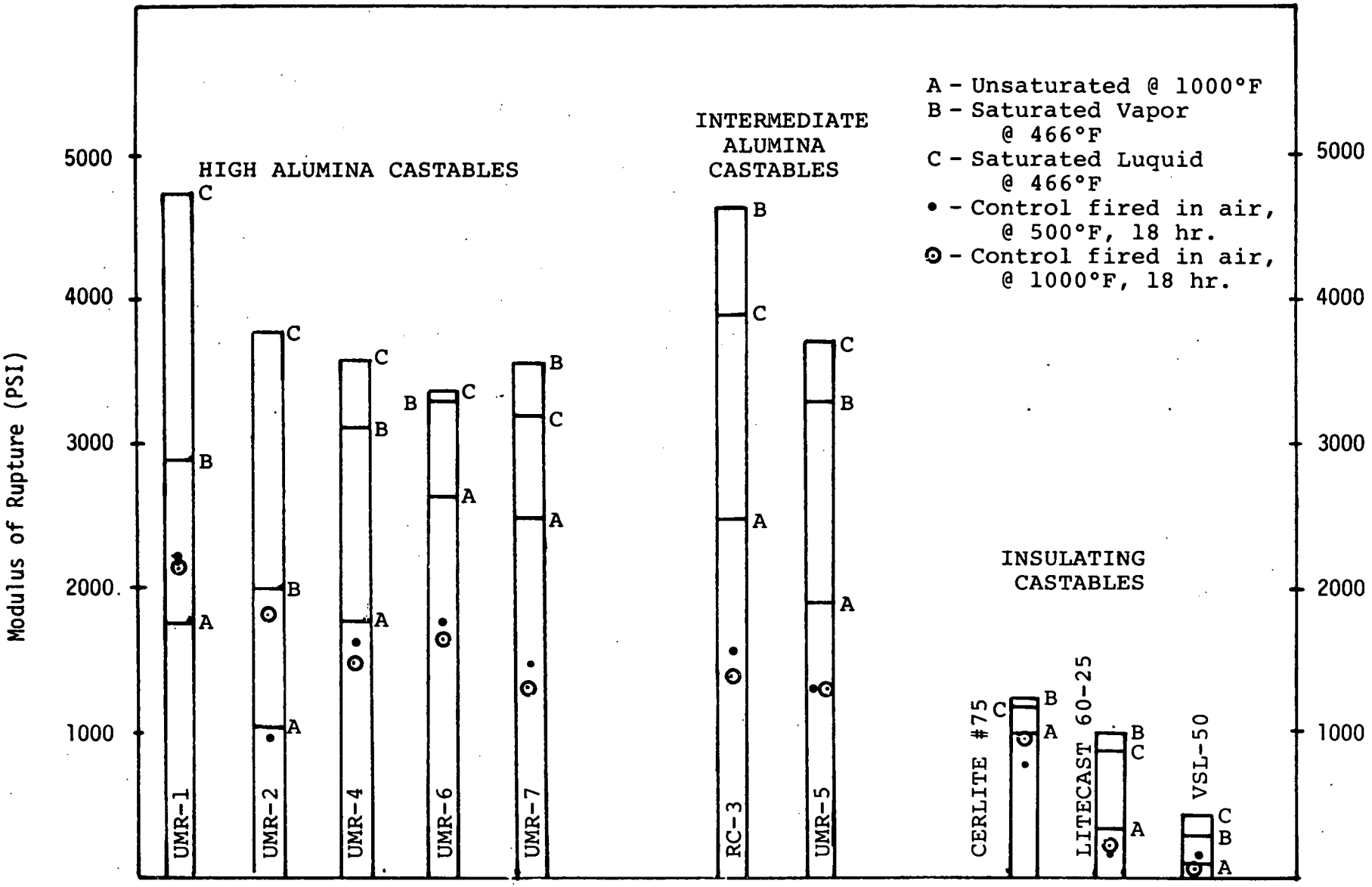


Figure 4. Room Temperature Modulus of Rupture of Castables Exposed to CO/H_2O = 1.0 + 1 Vol. % H_2S, 1000 psia, 20 days.

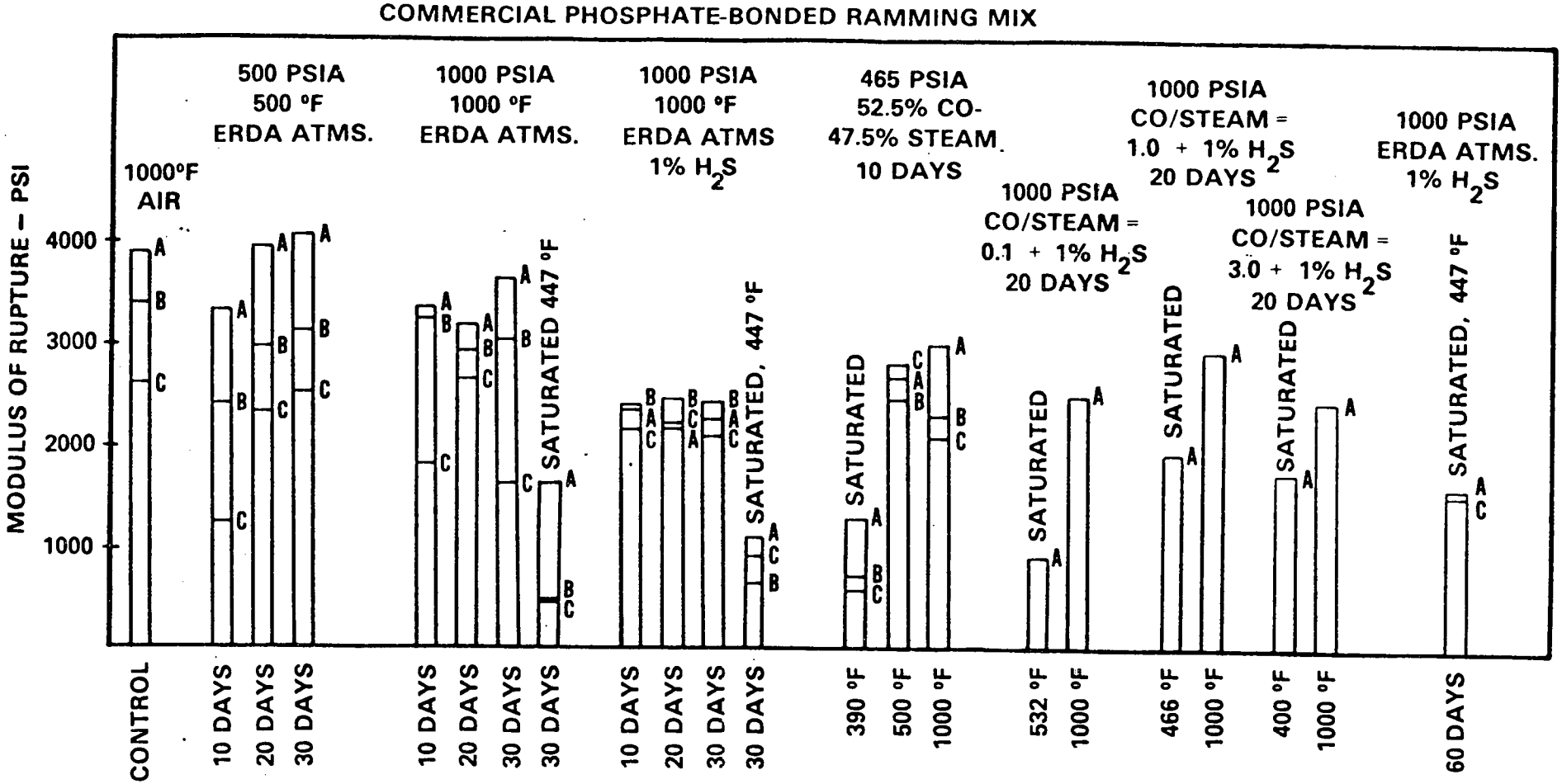


Figure 5. Room Temperature Modulus of Rupture of Commercial Phosphate-Bonded Ramming Mix.

A - GREENPAK 90-P
B - 90 RAM HS
C - BRIKRAM 90-R

Table I
Refractory Materials Used in Exposure Tests

Trade or Given Name	Manufacturer	Remarks
		Dense High Alumina Castable
UMR-1	University of Missouri	93% Al_2O_3 (70% of Tabular Al_2O_3* + 30% CA-25 cement**)
UMR-2	University of Missouri	91% Al_2O_3 (70% of Tabular Al_2O_3* + 30% Secar 250 cement**
UMR-4	University of Missouri	87.4% Al_2O_3 (70% of Tabular Al_2O_3* + 30% Refcon cement**)
UMR-6	University of Missouri	88 Al_2O_3 (UMR-1 with 5% SiO_2^+)
UMR-7	University of Missouri	84% Al_2O_3 (UMR-1 with 10% SiO_2^+)
		Intermediate Alumina Castable
RC-3	General Refractories	57% Al_2O_3, 34% SiO_2, CA-25 Cement
UMR-5	University of Missouri	50.4% Al_2O_3, 38.4% SiO_2 (75% of Mulcoa and Mul-grain 60*** + 25% Refcon Cement**)
		Insulating Castable
Cerlite #75	C. E. Refractories	54% Al_2O_3, 40% SiO_2, CA-25 Cement
Litecast 60-25	General Refractories	46.7% Al_2O_3, 40.2% SiO_2
VSL-50	A. P. Green	34.5% Al_2O_3, 52.5% SiO_2
Sauereisen No.72	Saureisen Cement Co.	
Penguard	Pennwalt Corporation	
		Dense High Alumina Phosphate-Bonded Ramming Mix
Greenpak 90-P	A. P. Green	95% Al_2O_3
		Calcium Aluminate Cements
CA-25	Aluminum Co. of America	79% Al_2O_3, 18% CaO
SECAR 250	Lone Star Lafarge Co.	72% Al_2O_3, 26% CaO
C-3	Babcock & Wilcox	72% Al_2O_3, 24.5% CaO
REFCON	Universal Atlas Cement	58% Al_2O_3 + TiO_2, 33% Cao
LUMNITE	Universal Atlas Cement	44% Al_2O_3 + TiO_2, 36% Cao

*Aluminum Company of America, Bauxite, Arkansas. Tabular alumina T-61, used as grog in the high alumina castables prepared in this laboratory, contained the following fractions (wt% of the total amount of castable):

Table I Continued

-8 to 14 mesh = 14%
-14 to 28 mesh = 13%
-28 to 48 mesh = 11%
-48 mesh = 32%

** Information on various cements appears elsewhere in this Table.

*** C-E Minerals, King of Prussia, Pennsylvania. Mulcoa 60 and Mulgrain M60 used as grog contained the following fractions (wt% of the total amount of castable).

4 mesh = 55%
8 mesh = 10%
20 mesh = 10%

+ 99.9% pure, bone dry Wedron Silica flour. Manufactured by Wedron Silica Division, Del Monte Properties Company, La Salle County, IL 60557.

Table II. Percent Weight Change After Exposure to CO-Steam + 1 Vol.% H_2S Atmosphere 20 Day Exposure at 1000 psia.

Sample Identification	CO/H_2O=0.1 + 1 Vol% H_2S 1000°F Unsaturated	CO/H_2O=0.1 + 1 Vol% H_2S 532°F Saturated**	CO/H_2O=1.0 + 1 Vol% H_2S 1000°F Unsaturated	CO/H_2O=1.0 + 1 Vol% H_2S 466°F Saturated**	CO/H_2O=3.0 + 1 Vol% H_2S 1000°F Unsaturated	CO/H_2O=3.0 + 1 Vol% H_2S 400°F Saturated**
Dense, High Alumina						
UMR-1 (CA-25)	-2.1	+1.9 (+4.1)	-2.3	-2.9 (-2.2)	-2.0	-1.0 (-5.5)
UMR-2 (Secar 250)	-3.6	+2.4 (+1.4)	-3.8	+0.7 (-3.9)	-4.0	+1.7 (-9.5)
UMR-4 (Refcon)	-2.4	+3.0 (+2.0)	-3.5	-0.3 (-1.4)	-3.3	+3.8 (-5.2)
UMR-6 (CA-25, 5% SiO_2)	Not Tested		-4.2	-3.2 (+0.7)	-3.4	-0.6 (-3.1)
UMR-7 (CA-25, 10% SiO_2)	Not Tested		-4.1	-0.9 (+0.6)	-3.6	-0.5 (-3.8)
Dense, Intermediate Alumina						
RC-3	-5.1	-2.8 (+1.6)	-3.8	-1.3 (-4.7)	-3.5	-0.3 (-5.3)
UMR-5 (Refcon)	-5.0	-1.1 (-0.7)	-4.0	-0.4 (-3.1)	-2.7	+0.8 (-3.0)
Insulating Castables						
Cerlite # 75	-3.2	-0.6 (+3.1)	-2.7	+0.5 (+5.5)	-2.6	-0.1 (-1.1)
Litecast 60-25	-6.7	-1.6 (+5.5)	-6.2	+0.4 (+7.3)	-6.2	+1.4 (-4.6)
VSL-50	-7.0	-7.7 (-5.2)	-6.1	-6.2 (-4.6)	-6.5	-6.6 (-4.6)
Phosphate-Bonded High Alumina						
Greenpak 90-P	-0.2	-0.7 (+0.6)	-0.2	-0.4 (+3.2)	-0.2	-0.4 (+2.0)

*Referenced to as-cast and dried (230°F) weight.

**Number without parentheses are for samples exposed to saturated vapor. Adjacent number in parentheses is for samples immersed in liquid (water) under the same exposure condition.

Table III. Comparison of Properties* After Exposure to Saturated Vapor or to Liquid (H_2O)
20 Day Exposure at 1000 psia.

Sample Identification	CO/H_2O=0.1 Atmosphere (532°F) Wt. Change %	Porosity %	MOR Psi	CO/H_2O=1.0 Atmosphere (466°F) Wt. Change %	Porosity %	MOR Psi	CO/H_2O=3.0 Atmosphere (400°F) Wt. Change %	Porosity %	MOR Psi
Dense, High Alumina									
UMR-1	+1.9 (+4.1)	13 (13)	4660 (4610)	-2.9 (-2.2)	26 (20)	2910 (4720)	-1.0 (-5.5)	22 (26)	3320 (3590)
UMR-2	+2.4 (+1.4)	15 (14)	2290 (4710)	+0.7 (-3.9)	22 (22)	2000 (3770)	+1.7 (-9.5)	22 (33)	1930 (2030)
UMR-4	+3.0 (+2.0)	19 (17)	2450 (1750)	-0.3 (-1.4)	26 (22)	3120 (3570)	+3.8 (-5.2)	23 (28)	4610 (3100)
UMR-6		Not Tested		-3.2 (+0.7)	23 (18)	3300 (3330)	-0.6 (-3.1)	8 (24)	3990 (3950)
UMR-7		Not Tested		-0.9 (+0.6)	18 (20)	3540 (3190)	-0.5 (-3.8)	6 (22)	3980 (4210)
Dense, Intermediate Alumina									
RC-3	-2.8 (+1.6)	17 (16)	4470 (3960)	-1.3 (-4.7)	18 (20)	4610 (3880)	-0.3 (-5.3)	9 (22)	4060 (3570)
UMR-5	-1.1 (-0.7)	16 (14)	3740 (1580)	-0.4 (-3.1)	17 (16)	3280 (3700)	+0.8 (-3.0)	13 (18)	3920 (3030)
Insulating Castables									
Cerlite # 75	-0.6 (+3.1)	52 (52)	490 (250)	+0.5 (+5.5)	51 (35)	1230 (1190)	-0.1 (-1.1)	51 (52)	1100 (1440)
Litecast 60-25	-1.6 (+5.5)	56 (51)	520 (520)	+0.4 (+7.3)	57 (45)	1000 (880)	+1.4 (-4.6)	56 (60)	785 (1010)
VSL-50	-7.7 (-5.2)	68 (64)	120 (170)	-6.2 (-4.6)	70 (67)	300 (420)	-6.6 (-4.6)	67 (69)	280 (390)
Phosphate-Bonded High Alumina									
Greenpak 90-P	-0.7 (+0.6)	23 (22)	920 (1080)	-0.4 (+3.2)	21 (19)	1920 (1910)	-0.4 (+2.0)	22 (22)	1760 (1550)

*Numbers without parentheses are for samples exposed to saturated vapor, average of seven samples. Adjacent numbers in parentheses are for samples immersed in liquid (water) under the same exposure conditions, average of two samples.

Table IV. Comparison of Properties* After Exposure to ERDA + 1 Vol.% H_2S Atmosphere
60 Day Long-Term Exposure at 1000 psia.

Sample Identification	Unsaturated @ 700°F Wt. Change# %	Density gm/cc	Porosity %	MOR Psi	Saturated @ 447°F** Wt. Change# %	Density gm/cc	Porosity %	MOR Psi
Dense, High Alumina								
Greencast 94	-1.9	2.72	26	1230	-1.4 (+4.5)	2.69 (2.72)	23 (18)	2790 (3210)
UMR-1 (CA-25)	-1.9	2.71	27	1750	+1.0 (+7.3)	2.72 (2.78)	21 (6)	4610 (5190)
UMR-2 (Secar 250)	-2.5	2.58	29	1580	-1.5 (+4.4)	2.54 (2.60)	23 (24)	3600 (2420)
UMR-3 (C-3)	-0.6	2.44	31	2110	-2.0 (+10.2)	2.35 (2.53)	32 (24)	1670 (2010)
UMR-6 (CA-25, 5% SiO_2)					(+4.2)	(2.77)	(16)	(4290)
UMR-7 (CA-25, 10% SiO_2)					(+6.0)	(2.72)	(14)	(4980)
Dense, Intermediate Alumina								
RC-3	-2.3	2.32	20	3560	-1.2 (+5.2)	2.28 (2.38)	19 (13)	3560 (4260)
UMR-5 (Refcon)					-2.2	2.40	17	3570
Insulating Castables								
Cerlite # 75	-1.4	1.51	52	1050	+1.2 (+19.6)	1.54 (1.78)	50 (37)	480 (1340)
Litecast 60-25					-2.1	1.19	57	510
Phosphate-Bonded High Alumina								
Greenpak 90-P					+1.3	2.89	21	1600
Brikram 90-R					-0.8	2.84	22	1520

*Blank space represents samples not tested in that exposure condition.

**Numbers without parentheses are for samples exposed to saturated vapor. Adjacent number in parentheses is for samples immersed in liquid (water), average of two samples.

#Referenced to as-cast and dried (230°F) weight.

TABLE V. Properties of UMR-1, CA-25 After Exposure

PROPERTY	Dried 230°F, 24 hr.	Fired 500°F, 18 hr.	Fired 1000°F, 18 hr.	ERDA Atmosphere, 500 psia, 500°F			ERDA Atmosphere 1000 psia, 1000°F			ERDA Atm. 1000 psia, 447°F, 30 Days (saturated) §
				10 Days	20 Days	30 Days	10 Days	20 Days	30 Days	
Weight Change, %*	---	-3.2	-5.0	-0.4	-1.6	-0.4	-2.5	-1.8	-2.0	+0.2
Dimensional Change,%**	---	-0.6	-0.3	+0.1	-0.6	-0.3	-0.1	-0.4	-0.2	+0.1
Density (gm/cc)	2.75	2.71	2.68	2.74	2.76	2.75	2.73	2.74	2.73	2.75
App. Porosity, %	16	20	23	23	22	21	24	24	26	11
MOR (PSI)***	2850±190	2220±170	2200±140	2680±870	2480±420	2860±600	1820±210	1920±30	1800±200	6630±35
XRD Analyses#										
Alumina	M			M	M	M	M			M
Boehmite	ud			M	m	M	ud			M
Calcite	ud			M	M	M	M			M
Gibbsite	ud			ud	ud	ud	ud			ud
CA	m			ud	ud	ud	ud			ud
CA_2	ud			ud	ud	ud	ud			ud
C_3AH_6	ud			ud	ud	ud	ud			ud
Aragonite	ud			ud	ud	tr	ud			ud
DTA-TGA Analyses										
%Weight Loss				5.5	4.4	5.7	3.9		3.9	7.5
%Boehmite				16.5	7.9	13.3	Nil		Nil	29.1
%Calcite				9.1	7.2	8.3	9.0		8.0	5.2
%CaO(Dry Weight Basis)				5.4	4.2	4.9	5.3		4.5	2.9

TABLE V. Continued

PROPERTY	47.5 Steam - 52.5 CO (vol. %) Atmos. 465 psia, 10 Days			ERDA Atmos. with H_2S 1000 psia, 1000°F			ERDA Atm. with H_2S, 1000 psia, 447°F, 30 Days (Saturated)
	390°F (saturated)	500°F	1000°F	10 Days	20 Days	30 Days	
Weight Change, %*	-0.2	-0.2	-2.6	-2.0	-2.2	-1.2	+0.5
Dimensional Change,%**	-0.2	-0.1	-0.2	-0.2	-0.2	-0.2	+0.3
Density (gm/cc)	2.72	2.74	2.73	2.70	2.76	2.78	2.73
App. Porosity, %	5	22	24	26	24	23	15
MOR (PSI)***	4830±330	2530±60	1620±190	1720±100	1750±95	2020±160	4870±210
XRD Analyses// Alumina	M	M	M	M	M	M	M
Boehmite	M	M	ud	ud	ud	ud	M
Calcite	m	M	M	M	M	M	M
Gibbsite	ud	ud	ud	ud	ud	ud	ud
CA	ud	ud	ud	ud	ud	ud	ud
CA_2	ud	ud	ud	ud	ud	ud	ud
C_3AH_6	ud	ud	ud	ud	ud	ud	ud
Aragonite	ud	ud	ud	ud	ud	ud	ud
DTA-TGA Analyses							
%Weight Loss	6.4	6.2	3.6	3.7	4.1	3.7	6.6
%Boehmite	19.1	14.4	Nil	Nil	Nil	Nil	29.1
%Calcite	3.5	8.7	7.1	7.5	9.4	7.8	5.1
%CaO(Dry basis)	2.1	5.2	4.1	4.3	5.5	4.5	3.1

Table V Continued

PROPERTY	CO/H_2O=0.1 + 1 Vol.% H_2S 1000 psia, 20 days			CO/H_2O=1.0 + 1 Vol.% H_2S 1000 psia, 20 days		
	1000°F Unsaturated	532°F Saturated	532°F § In Water	1000°F Unsaturated	466°F Saturated	466°F§ In Water
Weight Change, %*	-2.1	+1.9	+4.1	-2.3	-2.9	-2.2
Dimensional Change, %**	-0.1	Nil	+0.5	-0.1	-0.1	+0.6
Density (gm/cc)	2.71	2.76	2.77	2.72	2.64	2.67
App. Porosity, %	26	13	13	25	26	20
MOR (PSI)***	1520±70	4660±320	4610±630	1780±90	2910±310	4720±580
XRD Analyses#						
Alumina	M	M				
Boehmite	ud	M				
Calcite	M	M				
Gibbsite	ud	ud				
CA	ud	ud				
CA	ud	ud				
C AH	ud	ud				
Aragonite	ud	ud				
DTA-TGA Analyses						
% Weight Loss	4.1	8.4	9.5			
% Boehmite	Nil	30.0	25.3			
% Calcite	7.7	7.0	6.0			
% CaO (Dry Wt. Basis)	4.5	4.3	3.7			

Table V Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-2.0	-1.0	-5.5	-1.9	+1.0	+7.3
Dimensional Change, %**	-0.2	+0.5	+0.2	-0.2	+0.1	
Density (gm/cc)	2.71	2.69	2.53	2.71	2.72	2.78
App. Porosity, %	25	22	26	27	21	6
MOR (PSI)***	1680±210	3320±370	3590±230	1750±190	4610±880	5190±770
XRD Analyses#						
DTA-TGA Analyses						
% Weight Loss						
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE VI. Properties of UMR-2, Secar 250 After Exposure

PROPERTY	Dried 230°F, 24 hr.	Fired 500°F, 18 hr.	Fired 1000°F, 18 hr.	ERDA Atmosphere, 500 psia, 500°F			ERDA Atmosphere 1000 psia, 1000°F			ERDA Atm. 1000 psia, 447°F, 30 Days (saturated)§
				10 Days	20 Days	30 Days	10 Days	20 Days	30 Days	
Weight Change, %*	---	-4.3	-5.0	Nil	-1.8	-0.1	-3.7	-3.3	-3.6	
Dimensional Change,%**	---	-0.2	-0.1	Nil	Nil	-0.2	-0.1	-0.4	-0.5	
Density (gm/cc)	2.66	2.58	2.52	2.70	2.62	2.68	2.61	2.60	2.59	NO SPECIMEN TESTED
App. Porosity, %	16	24	28	22	23	22	26	27	27	
MOR (PSI)***	2930±340	970±180	1810±290	2930±430	1800±210	3120±160	700±75	640±65	660±80	
XRD Analyses#										
Alumina	M			M		M	M	M		
Boehmite	ud			M		M	ud	ud		
Calcite	ud			M		M	M	M		
Gibbsite	tr			ud		ud	ud	ud		
CA	m			ud		ud	ud	ud		
CA_2	ud			ud		ud	ud	ud		
C_3AH_6	tr			ud		ud	ud	ud		
Aragonite	ud			m		tr	tr	ud		
DTA-TGA Analyses										
%Weight Loss				8.4	6.5	8.3	4.6		4.9	
%Boehmite				24.5	15.9	24.1	Nil		Nil	
%Calcite				10.8	9.3	10.5	10.3		10.1	
%CaO(Dry Weight Basis)				6.7	5.5	6.3	6.1		6.0	

TABLE VI. Continued

PROPERTY	47.5 Steam - 52.5 CO (vol. %) Atmos. 465 psia, 10 Days			ERDA Atmos. with H_2S 1000 psia, 1000°F			ERDA Atm. with H_2S, 1000 psia, 447°F, 30 Days (Saturated)
	390°F (saturated)	500°F	1000°F	10 Days	20 Days	30 Days	
Weight Change, %*	-1.4	+0.7	-4.8	-4.2	-4.0	-4.0	-2.4
Dimensional Change, %**	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	+0.3
Density (gm/cc)	2.61	2.70	2.58	2.59	2.61	2.60	2.58
App. Porosity, %	7	21	26	27	26	27	18
MOR (PSI)***	3310±270	3040±280	1211±150	1125±150	880±185	1035±130	4050±560
XRD Analyses// Alumina	M	M	M	M	M	M	M
Boehmite	M	M	ud	ud	ud	ud	M
Calcite	m	M	M	M	M	M	M
Gibbsite	ud	ud	ud	ud	ud	ud	ud
CA	ud	ud	ud	ud	ud	ud	ud
CA_2	ud	ud	ud	ud	ud	ud	ud
C_3AH_6	ud	ud	ud	ud	ud	ud	ud
Aragonite	ud	ud	ud	ud	ud	ud	ud
DTA-TGA Analyses							
%Weight Loss	7.8	8.9	4.2	2.6	5.5	5.4	8.3
%Boehmite	20.0	24.7	Nil	Nil		Nil	37.3
%Calcite	3.8	11.7	7.3	4.3	10.8	10.94	5.2
%CaO(Dry basis)	2.3	7.2	4.3	2.5	6.4	6.5	3.2

Table VI Continued

PROPERTY	CO/H_2O=0.1 + 1 Vol.% H_2S 1000 psia, 20 days			CO/H_2O=1.0 + 1 Vol.% H_2S 1000 psia, 20 days		
	1000°F Unsaturated	532°F Saturated	532°F § In Water	1000°F Unsaturated	466°F Saturated	466°F§ In Water
Weight Change, %*	-3.6	+2.4	+1.4	-3.8	+0.7	-3.9
Dimensional Change, %**	-0.2	+0.2	+0.6	-0.4	+1.5	+0.5
Density (gm/cc)	2.59	2.65	2.63	2.56	2.51	2.55
App. Porosity, %	28	15	14	27	22	22
MOR (PSI)***	830±80	2290±560	4710±100	1780±90	2000±70	3770±78
XRD Analyses#						
Alumina	M	M				
Boehmite	ud	M				
Calcite	M	M				
Gibbsite	ud	ud				
CA	ud	ud				
CA_2	ud	ud				
C_3AH_6	ud	ud				
Aragonite	ud	ud				
DTA-TGA Analyses						
% Weight Loss	5.3	10.2	9.2			
% Boehmite	Nil	28.8	28.9			
% Calcite	10.9	8.4	6.0			
% CaO (Dry Wt. Basis)	6.5	5.3	3.7			

Table VI Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-4.0	+1.7	-9.5	-2.5	-1.5	+4.4
Dimensional Change, %**	-0.3	+1.4	+0.4	-0.3	+0.1	
Density (gm/cc)	2.62	2.61	2.38	-2.58	2.54	2.60
App. Porosity, %	25	22	33	29	23	24
MOR (PSI)***	1190±130	1930±570	2030±1	1580±100	3600±550	2420±310
XRD Analyses#						
DTA-TGA Analyses						
% Weight Loss						
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE VII. Properties of UMR-4, REFCON After Exposure

Property	Dried 230°F 24 hr.	Fired 500°F 18 hr.	Fired 1000°F 18 hr.	CO/H_2O = 0.1 + 1 Vol% H_2S 1000 psia, 20 days			CO/H_2O = 1.0 + 1 Vol% H_2S 1000 psia, 20 days		
				1000°F Unsaturated	532°F Saturated	532°F § (In Water)	1000°F Unsaturated	466°F Saturated	466°F § (In Water)
Weight Change, %*	-	-4.6	-5.8	-2.4	+3.0	+2.0	-3.5	-0.3	-1.4
Dimensional Change,%**	-	Nil	+2.7	-0.2	+0.7	+0.2	-0.2	+1.4	+0.3
Density (gm/cc)	2.64	2.58	2.55	2.61	2.60	2.66	2.60	2.52	2.59
App. Porosity, %	18	24	27	24	19	17	25	26	22
MOR (PSI)***	2260±170	1620±170	1490±70	2180±230	2450±330	1750±80	1790±150	3120±600	3570±210
XRD Analyses#									
Alumina	M			M				M	M
Boehmite	ud			ud				m	m
Calcite	ud			m				M	M
Gibbsite	ud			ud				ud	ud
C_3AH_6	m			ud				ud	ud
C_2AS	m			m				m	m
DTA-TGA Analyses									
%Weight Loss				4.1	8.6		7.7	8.1	
%Boehmite				Nil	23.9		23.5	16.6	
%Calcite				7.1	7.9		7.2	9.9	
%CaO(Dry Weight Basis)				4.2	4.8		4.4	6.1	

Table VII Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-3.3	+3.8	-5.2			
Dimensional Change, %**	-0.3	+2.4	Nil			
Density (gm/cc)	2.58	2.58	2.46	NOT TESTED		
App. Porosity, %	26	23	28			
MOR (PSI)***	2160±170	1410±390	3100±180			
XRD Analyses#						
DTA-TGA Analyses % Weight Loss % Boehmite % Calcite % CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE VIII. Properties of UMR-6, CA-25 with 5%SiO_2 After Exposure

Property	Dried 230°F 24 hr.	Fired 500°F 18 hr.	Fired 1000°F 18 hr.	CO/H_2O = 0.1 + 1 Vol% H_2S 1000 psia, 20 days			CO/H_2O = 1.0 + 1 Vol% H_2S 1000 psia, 20 days		
				1000°F Unsaturated	532°F Saturated	532°F § (In Water)	1000°F Unsaturated	466°F Saturated	466°F § (In Water)
Weight Change, %*	-	-4.0	-4.4				-4.2	-3.2	+.07
Dimensional Change,%**	-	Nil	Nil				-0.2	-0.1	-0.2
Density (gm/cc)		2.62	2.59	N O T	T E S	T E D	2.60	2.60	2.53
App. Porosity, %		22	27				25	23	18
MOR (PSI)***		1740±100	1630±80				2560±380	3300±320	3330±370
XRD Analyses #									
Alumina	M							M	
Boehmite	ud							m	
Calcite	ud							M	
α-Quartz	m							m	
C_3AH_6	tr							tr	
DTA-TGA Analyses									
%Weight Loss								5.4	
%Boehmite								10.8	
%Calcite								5.5	
%CaO(Dry Wt. Basis)								3.2	

Table VIII Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-3.4	-0.6	-3.1			+4.2
Dimensional Change, %**	-0.1	+0.4	+0.3	NOT TESTED		
Density (gm/cc)	2.62	2.65	2.56	NOT TESTED		2.77
App. Porosity, %	25	8	24			16
MOR (PSI)***	2690±160	3990±440	3950±180			4290±360
XRD Analyses#						
DTA-TGA Analyses % Weight Loss % Boehmite % Calcite % CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE IX. Properties of UMR-7, CA-25 with 10%SiO$_2$ After Exposure

Property	Dried 230°F 24 hr.	Fired 500°F 18 hr.	Fired 1000°F 18 hr.	CO/H_2O = 0.1 + 1 Vol% H_2S 1000 psia, 20 days			CO/H_2O = 1.0 + 1 Vol% H_2S 1000 psia, 20 days		
				1000°F Unsaturated	532°F Saturated	532°F § (In Water)	1000°F Unsaturated	466°F Saturated	466°F § (In Water)
Weight Change, %*	-	-3.7	-4.1				-4.1	-0.9	+0.6
Dimensional Change,%**	-	Nil	Nil				-0.3	+0.2	-0.3
Density (gm/cc)		2.58	2.54	N O T	T E S	T E D	2.53	2.53	2.62
App. Porosity, %		24	27				26	18	20
MOR (PSI)***		1440±130	1330±160				2500±340	3540±360	2190±290
XRD Analyses #									
Alumina	M							M	
Boehmite	ud							m	
Calcite	ud							tr	
α-Quartz	M							M	
C_3AH_6	tr							ud	
CA	tr							ud	
CA_2	ud							tr	
DTA-TGA Analyses									
%Weight Loss								5.3	
%Boehmite								9.7	
%Calcite								4.0	
%CaO(Dry Wt. Basis)								3.4	

Table IX Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-3.6	-0.5	-3.8			+6.0
Dimensional Change, %**	-0.1	+0.3	Nil	NOT TESTED		
Density (gm/cc)	2.56	2.54	2.51	NOT TESTED		2.72
App. Porosity, %	25	6	22			14
MOR (PSI)***	2310±180	3980±420	4210±350			4980±480
XRD Analyses#						
DTA-TGA Analyses						
% Weight Loss						
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE X. Properties of RC-3 After Exposure

PROPERTY	Dried 230°F, 24 hr.	Fired 500°F, 18 hr.	Fired 1000°F, 18 hr.	ERDA Atmosphere, 500 psia, 500°F			ERDA Atmosphere 1000 psia, 1000°F			ERDA Atm. 1000 psia, 447°F, 30 Days (saturated)§
				10 Days	20 Days	30 Days	10 Days	20 Days	30 Days	
Weight Change, %*	---	-3.2	-5.0	-0.8	-2.2	-1.1	-4.0	-4.2	-4.4	-5.2
Dimensional Change,%**	---	-0.1	-0.2	-0.1	Nil	-0.3	-0.1	Nil	-0.1	Nil
Density (gm/cc)	2.31	2.27	2.21	2.30	2.28	2.30	2.24	2.25	2.25	2.15
App. Porosity, %	16	19	23	19	21	20	22	22	22	22
MOR (PSI)***	2200±240 (1300-1500)	1570±230	1390±100	2770±900	2000±310	2130±340	2390±170	2730±240	2450±320	3330±830
XRD Analyses#										
Mullite	M			M		M	M	M		M
β-Cristoballite	M			M		M	M	M		M
Alumina	m			m		m	m	m		m
Boehmite	ud			m		m	ud	ud		m
Calcite	ud			m		m	m	m		m
CA	m			ud		ud	ud	ud		ud
Bayerite	ud			ud		ud	ud	ud		m
DTA-TGA Analyses										
%Weight Loss				5.7	3.6	5.3			2.3	5.3
%Boehmite				17.2	7.5	14.1			Nil	13.5
%Calcite				7.0	5.7	7.2			4.4	4.1
%CaO(Dry Weight Basis)				4.1	3.3	4.2			2.6	2.4

TABLE X. Continued

PROPERTY	47.5 Steam - 52.5 CO (vol. %) Atmos. 465 psia, 10 Days			ERDA Atmos. with H_2S 1000 psia, 1000°F			ERDA Atm. with H_2S, 1000 psia, 447°F, 30 Days (Saturated)
	390°F (saturated)	500°F	1000°F	10 Days	20 Days	30 Days	
Weight Change, %*	-1.6	-0.1	-4.5	-4.5	-4.0	-4.1	-2.7
Dimensional Change,%**	+0.1	+0.1	-0.1	-0.2	-0.1	+0.1	+0.2
Density (gm/cc)	2.31	2.34	2.24	2.24	2.25	2.24	2.26
App. Porosity, %	11	17	23	22	22	22	17
MOR (PSI)***	3280±400	3280±180	1760±280	2245±220	2140±140	2340±190	3920±385
XRD Analyses#							
Mullite	M	M	M	M	M	M	M
β-Cristobalite	M	M	M	M	M	M	M
Alumina	m	m	m	m	m	m	m
Boehmite	m	m	ud	ud	ud	ud	m
Calcite	tr	m	m	m	m	m	m
CA	ud	ud	ud	ud	ud	ud	ud
Bayerite	ud	ud	ud	ud	ud	ud	ud
DTA-TGA Analyses							
%Weight Loss	5.0	6.3	2.0	2.0	2.6	2.7	
%Boehmite	27.2	11.7	Nil	Nil	Nil	Nil	
%Calcite	2.0	7.4	3.43	3.9	5.0	4.4	
%CaO(Dry basis)	1.2	4.4	2.0	2.3	2.8	2.5	

Table X Continued

PROPERTY	CO/H_2O=0.1 + 1 Vol.% H_2S 1000 psia, 20 days			CO/H_2O=1.0 + 1 Vol.% H_2S 1000 psia, 20 days		
	1000°F Unsaturated	532°F Saturated	532°F § In Water	1000°F Unsaturated	466°F Saturated	466°F§ In Water
Weight Change, %*	-5.1	-2.8	+1.6	-3.8	-1.3	-4.7
Dimensional Change, %**	-0.1	Nil	+0.5	Nil	+0.1	+0.4
Density (gm/cc)	2.27	2.26	2.29	2.29	2.32	2.26
App. Porosity, %	22	17	16	20	18	20
MOR (PSI)***	3260±250	4470±640	3960±560	2480±400	4610±620	3880±370
XRD Analyses#						
Mullite	M	M			M	
α-Cristobalite	M				M	
Alumina	M	tr			m	
Boehmite	ud	M			m	
Calcite	tr	m			tr	
CA	ud	ud			ud	
Bayerite	ud	ud			ud	
DTA-TGA Analyses						
% Weight Loss	1.9	5.1	6.0			
% Boehmite	Nil	13.6	18.2			
% Calcite	3.0	2.1	4.2			
% CaO (Dry Wt. Basis)	1.7	1.2	2.5			

Table X Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-3.5	-0.3	-5.3	-2.3	-1.2	+5.2
Dimensional Change, %**	-0.2	+0.3	+0.3	Nil	+0.3	
Density (gm/cc)	2.24	2.29	2.15	2.32	2.28	2.38
App. Porosity, %	22	9	22	20	19	13
MOR (PSI)***	1770±120	4060±560	3570±250	3560±370	3560±420	4260±20
XRD Analyses#						
DTA-TGA Analyses % Weight Loss % Boehmite % Calcite % CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE XI. Properties of UMR-5, MULCOA/MULGRAIN with REFCON After Exposure

Property	Dried 230°F 24 hr.	Fired 500°F 18 hr.	Fired 1000°F 18 hr.	CO/H_2O = 0.1 + 1 Vol% H_2S 1000 psia, 20 days			CO/H_2O = 1.0 + 1 Vol% H_2S 1000 psia, 20 days		
				1000°F Unsaturated	532°F Saturated	532°F § (In Water)	1000°F Unsaturated	466°F Saturated	466°F § (In Water)
Weight Change, %*	-	-4.2	-4.7	-5.0	-1.1	-0.7	-4.0	-0.4	-3.1
Dimensional Change,%**	-	Nil	Nil	-0.2	+0.1	+0.6	-0.3	+0.5	+0.4
Density (gm/cc)	2.47	2.44	2.37	2.34	2.39	2.41	2.37	2.38	2.38
App. Porosity, %	11	16	19	22	16	14	19	17	16
MOR (PSI)***	2370±210	1290±120	1290±70	2470±340	3740±430	1580±100	1910±220	3280±630	3700±50
XRD Analyses #									
Mullite	M		M					M	
Alumina	tr		tr					m	
Boehmite	ud		ud					m	
Calcite	ud		ud					M	
Aragonite	ud		ud					ud	
C_3AH_6	tr		ud					ud	
C_2AS	m		m					ud	
DTA-TGA Analyses									
%Weight Loss				0.8	5.3	5.1		6.6	
%Boehmite				Nil	14.1	15.7		10.0	
%Calcite				1.1	3.0	3.7		7.5	
%CaO(Dry Wt. Basis)				0.6	1.8	2.2		4.5	

Table XI Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-2.7	+0.8	-3.0		-2.2	
Dimensional Change, %**	-0.3	+0.3	-0.1	NOT	+0.2	NOT
Density (gm/cc)	2.38	2.46	2.33	TESTED	2.40	TESTED
App. Porosity, %	18	13	18		17	
MOR (PSI)***	1550±240	3920±460	3030±40		3570±560	
XRD Analyses#						
DTA-TGA Analyses % Weight Loss % Boehmite % Calcite % CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE XII. Properties of CERLITE-75 After Exposure

PROPERTY	Dried 230°F, 24 hr.	Fired 500°F, 18 hr.	Fired 1000°F, 18 hr.	ERDA Atmosphere, 500 psia, 500°F			ERDA Atmosphere 1000 psia, 1000°F			ERDA Atm. 1000 psia, 447°F, 30 Days (saturated)§
				10 Days	20 Days	30 Days	10 Days	20 Days	30 Days	
Weight Change, %*	---	-2.1	-3.5	-1.0	-1.5	-1.1	-2.9	-3.1	-3.2	-1.9
Dimensional Change,%**	---	-0.3	Nil	+0.3	+0.1	+0.2	+0.1	Nil	+0.1	-0.1
Density (gm/cc)	1.58	1.55	1.54	1.55	1.51	1.52	1.53	1.53	1.53	1.54
App. Porosity, %	39	41	42	45	44	44	50	51	52	52
MOR (PSI)***	970±120 (430)	790±80	940±40 (450)	890±190	670±65	710±60	1160±40	1090±70	1090±90	960±270
XRD Analyses#										
Kyanite	M			M		M	M	M	M	M
Mullite	ud			ud		ud	ud	ud	ud	ud
α-Quartz	M			M		M	M	M	M	M
β-Cristoballite	ud			ud		ud	ud	ud	ud	ud
Alumina	M			M		M	M	M	M	M
Boehmite	ud			tr		tr	ud	ud	ud	ud
Calcite	ud			M		m	m	ud	m	ud
CA	m			ud		ud	ud	ud	ud	m
Bayerite	ud			ud		ud	ud	ud	ud	m
DTA-TGA Analyses										
%Weight Loss				3.9	3.2	4.1			1.4	5.3
%Boehmite				13.0	10.4	13.3			-	9.1
%Calcite				4.3	3.8	4.4			2.2	2.8
%CaO(Dry Weight Basis)				2.5	2.2	2.6			1.3	1.7

TABLE XII. Continued

PROPERTY	47.5 Steam - 52.5 CO (vol. %) Atmos. 465 psia, 10 Days			ERDA Atmos. with H_2S 1000 psia, 1000°F			ERDA Atm. with H_2S, 1000 psia, 447°F, 30 Days (Saturated)
	390°F (saturated)	500°F	1000°F	10 Days	20 Days	30 Days	
Weight Change, %*	-2.3	-1.3	-4.7	-2.9	-2.7	-2.9	+1.4
Dimensional Change,%**	+0.3	+0.5	-0.2	-0.1	Nil	Nil	+0.6
Density (gm/cc)	1.52	1.55	1.54	1.54	1.54	1.54	1.59
App. Porosity, %	48	45	47	51	51	51	45
MOR (PSI)***	870±55	850±70	1090±210	865±90	895±65	900±65	560±70
XRD Analyses# Kyanite	m	m		M	M	M	M
α-Quartz	M	M		M	M	M	M
Alumina	m	m		M	M	M	M
Boehmite	tr	tr		ud	ud	ud	tr
Calcite	ud	tr		m	m	m	tr
CA	ud	ud		m	m	m	m
Bayerite	ud	ud		ud	ud	ud	ud
DTA-TGA Analyses							
%Weight Loss	4.2	3.5	1.4	1.0	1.3	1.3	7.3
%Boehmite	14.1	12.2	Nil	Nil	Nil	Nil	6.4
%Calcite	1.0	3.8	2.3	1.7	2.2	1.9	3.3
%CaO(Dry basis)	0.6	2.2	1.3	1.0	1.3	1.1	2.0

Table XII Continued

PROPERTY	CO/H_2O=0.1 + 1 Vol.% H_2S 1000 psia, 20 days			CO/H_2O=1.0 + 1 Vol.% H_2S 1000 psia, 20 days		
	1000°F Unsaturated	532°F Saturated	532°F § In Water	1000°F Unsaturated	466°F Saturated	466°F§ In Water
Weight Change, %*	-3.2	-0.6	+3.1	-2.7	+0.5	+5.5
Dimensional Change, %**	-0.1	+0.6	+1.1	-0.1	+0.2	+0.8
Density (gm/cc)	1.52	1.51	1.51	1.55	1.57	1.68
App. Porosity, %	52	52	52	49	51	35
MOR (PSI)***	990±80	490±70	250	1010±40	1230±160	1190±90
XRD Analyses#						
Kyanite	m	m		m	m	m
α-Quartz	M	M		M	M	M
Alumina	m	m		m	m	m
Boehmite	ud	ud		ud	tr	tr
Calcite	tr	ud		tr	tr	tr
CA	ud	ud		ud	ud	ud
Bayerite	ud	ud		ud	ud	ud
DTA-TGA Analyses						
% Weight Loss	1.2	4.4	4.5			
% Boehmite	Nil	8.3	8.7			
% Calcite	1.8	1.6	3.5			
% CaO (Dry Wt. Basis)	1.0	0.9	2.1			

Table XII Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-2.6	-0.1	-1.1	-1.4	+1.2	+19.6
Dimensional Change, %**	Nil	+0.3	+0.5	+0.5	+0.3	
Density (gm/cc)	1.52	1.53	1.51	1.51	1.54	1.78
App. Porosity, %	47	51	52	52	50	37
MOR (PSI)***	800±40	1100±170	1440±210	1050±110	480±160	1340±480
XRD Analyses#						
DTA-TGA Analyses						
% Weight Loss						
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE XIII. Properties of LITECAST 60-25 After Exposure

Property	Dried 230°F 24 hr.	Fired 500°F 18 hr.	Fired 1000°F 18 hr.	CO/H_2O = 0.1 + 1 Vol% H_2S 1000 psia, 20 days			CO/H_2O = 1.0 + 1 Vol% H_2S 1000 psia, 20 days		
				1000°F Unsaturated	532°F Saturated	532°F § (In Water)	1000°F Unsaturated	466°F Saturated	466°F § (In Water)
Weight Change, %*	-	-5.4	-6.4	-6.7	-1.6	+5.5	-6.2	+0.4	+7.3
Dimensional Change,%**	-	Nil	Nil	-0.1	+0.4	+0.7	+0.3	+0.2	+0.2
Density (gm/cc)	1.25	1.16	1.13	1.17	1.19	1.31	1.18	1.24	1.33
App. Porosity, %	48	53	54	61	56	51	58	57	45
MOR (PSI)***	440±90	195±35	210±50	470±80	520±170	520±2	340±90	1000±260	880±30
XRD Analyses #									
Mullite				M				ud	ud
Alumina				ud				ud	m
α-Quartz				m				M	M
Boehmite				ud				tr	m
Calcite				ud				ud	ud
Kyanite				m				m	m
$C_{12}A_7$				ud				m	tr
C_2AS				m				ud	ud
DTA-TGA Analyses									
%Weight Loss				2.2	11.0				
%Boehmite				Nil	21.8				
%Calcite				3.4	4.1				
%CaO(Dry Wt. Basis)				1.9	2.6				

Table XIII Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-6.2	+1.4	-4.6		-2.1	
Dimensional Change, %**	-0.2	+0.1	+0.2	NOT	+0.5	NOT
Density (gm/cc)	1.16	1.22	1.14	TESTED	1.19	TESTED
App. Porosity, %	55	56	60		57	
MOR (PSI)***	370±50	785±85	1010±55		510±50	
XRD Analyses#						
DTA-TGA Analyses						
% Weight Loss						
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE XIIV. Properties of VSL-50 After Expcsure

Property	Dried 230°F 24 hr.	Fired 500°F 18 hr.	Fired 1000°F 18 hr.	CO/H_2O = 0.1 + 1 Vol% H_2S 1000 psia, 20 days			CO/H_2O = 1.0 + 1 Vol% H_2S 1000 psia, 20 days		
				1000°F Unsaturated	532°F Saturated	532°F § (In Water)	1000°F Unsaturated	466°F Saturated	466°F § (In Water)
Weight Change, %*	-	-4.5	-5.6	-7.0	-7.7	-5.2	-6.1	-6.2	-4.6
Dimensional Change,%**	-	Nil	-0.4	-0.6	+0.8	+9.8	-0.3	+0.5	+0.6
Density (gm/cc)	0.93 /	0.90	0.90	0.91	0.86	0.93	0.89	0.84	0.90
App. Porosity, %	56	62	63	68	68	64	67	70	67
MOR (PSI)***	145±15	120±10	100±20	50±10	120±25	170±5	110±10	300±10	420±20
XRD Analyses #									
Alumina				m				M	m
Boehmite				ud				tr	ud
α-Quartz				M				M	M
CA_2				ud				m	m
C_2AS				m				ud	ud
DTA-TGA Analyses									
%Weight Loss				1.8	4.0				
%Boehmite				Nil	10.8				
%Calcite				2.3	0.9				
%CaO(Dry Wt. Basis)				1.3	0.5				

Table XIV Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-6.5	-6.6	-4.6			
Dimensional Change, %**	-0.8	Nil	+1.3			
Density (gm/cc)	0.90	0.89	0.87	NOT TESTED		
App. Porosity, %	65	67	69			
MOR (PSI)***	110±10	280±50	390±40			
XRD Analyses#						
DTA-TGA Analyses						
% Weight Loss						
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.

TABLE XV. Properties of GREENPAK 90-P After Exposure

PROPERTY	Dried 230°F, 24 hr.	Fired 500°F, 18 hr.	Fired 1000°F, 18 hr.	ERDA Atmosphere, 500 psia, 500°F			ERDA Atmosphere 1000 psia, 1000°F			ERDA Atm. 1000 psia, 447°F, 30 Days (saturated)§
				10 Days	20 Days	30 Days	10 Days	20 Days	30 Days	
Weight Change, %*			---	+0.1	+0.1	Nil	-0.1	-0.2	-0.1	+0.2
Dimensional Change,%**			---	-0.3	-0.1	Nil	Nil	Nil	Nil	+0.2
Density (gm/cc)			2.95	2.91	2.97	2.97	2.90	2.94	2.95	2.96
App. Porosity, %			17	19	18	18	18	18	18	21
MOR (PSI)***			3910±320	3320±270	3960±450	4040±380	3340±420	3190±390	3610±570	1620±320
XRD Analyses#										
Alumina			M	M	M	M	M	M	M	M
$AlPO_4$ (Berlinite)			tr	m	m	m	M	m	M	m
$AlPO_4$(Orthorhombic)			tr	ud	ud	ud	ud	tr	ud	ud
X			ud	ud	ud	ud	ud	ud	ud	m
DTA-TGA Analyses										
%Weight Loss										

TABLE XV. Continued

PROPERTY	47.5 Steam - 52.5 CO (vol. %) Atmos. 465 psia, 10 Days			ERDA Atmos. with H_2S 1000 psia, 1000°F			ERDA Atm. with H_2S, 1000 psia, 447°F, 30 Days (Saturated)
	390°F (saturated)	500°F	1000°F	10 Days	20 Days	30 Days	
Weight Change, %*	-1.0	+0.1	-0.3	-0.3	-0.3	-0.3	+2.0
Dimensional Change,%**	-0.1	Nil	-0.1	-0.1	+0.2	+0.2	+0.3
Density (gm/cc)	2.87	2.87	2.9	2.87	2.88	2.87	2.90
App. Porosity, %	21	26	19	20	20	20	21
MOR (PSI)***	1290±650	2640±220	2960±210	2350±245	2175±305	2240±420	1100±120
XRD Analyses#							
DTA-TGA Analyses %Weight Loss				0.02		Nil	0.6

Table XV Continued

PROPERTY	CO/H_2O=0.1 + 1 Vol.% H_2S 1000 psia, 20 days			CO/H_2O=1.0 + 1 Vol.% H_2S 1000 psia, 20 days		
	1000°F Unsaturated	532°F Saturated	532°F § In Water	1000°F Unsaturated	466°F Saturated	466°F§ In Water
Weight Change, %*	-0.2	-0.7	+0.6	-0.2	-0.4	+3.2
Dimensional Change, %**	-0.1	Nil	+0.3	Nil	+0.3	+0.3
Density (gm/cc)	2.88	2.84	2.84	2.91	2.87	2.97
App. Porosity, %	20	23	22	19	21	19
MOR (PSI)***	2460±360	920±220	1080±190	2910±190	1920±720	1910±70
XRD Analyses#						
Alumina	M	M			M	M
$AlPO_4$(Berlinite)	m	m			m	m
$AlPO_4$(Orthorhombic)	ud	ud			ud	ud
α-$CaSiO_3$(Pseudowollastonite)	ud	ud			ud	tr
DTA-TGA Analyses						
% Weight Loss	Nil	0.2	0.4		0.6	0.8
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

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Table XV Continued

PROPERTY	CO/H_2O=3.0 + 1 Vol.% H_2S 1000 psia, 20 days			Long Term Exposure ERDA + 1 Vol.% H_2S 1000 psia, 60 days		
	1000°F Unsaturated	400°F Saturated	400°F § In Water	700°F Unsaturated	447°F Saturated	447°F § In Water
Weight Change, %*	-0.2	-0.4	+2.0		+1.3	
Dimensional Change, %**	-0.1	+0.2	+0.3	NOT	+0.1	NOT
Density (gm/cc)	2.87	2.84	2.88	TESTED	2.89	TESTED
App. Porosity, %	20	22	22		21	
MOR (PSI)***	2430±390	1760±230	1550±290		1600±260	
XRD Analyses#						
Alumina						
$AlPO_4$(Berlinite)						
$AlPO_4$()rthorhombic)						
α-$CaSiO_3$(Pseudowollastonite)						
DTA-TGA Analyses						
% Weight Loss						
% Boehmite						
% Calcite						
% CaO (Dry Wt. Basis)						

*Average percent weight change with as-dried weight as initial weight, +, weight gain; -, weight loss.

**Average percent dimensional change with as-dried dimension as initial dimension, +, expansion; -, contraction.

***The ± limit corresponds to one standard deviation. Data in parentheses represents manufacturer's published values.

#M = major; m = minor; tr = trace; ud = undetected.

§Data based on two specimens.