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TATB FORMULATION STUDY

Jim A. Crutchmer

DEVELOPMENT DIVISION

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FINAL REPORT

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ABSTRACT

The physical characteristics of several TATB formulations were investigated for use in booster pellets. These formulations included fine particle size TATB, without binder and with 1% Kel-F binder and 2% Kel-F binder. Corresponding tests were performed on RX-03-BB (7.5% Kel-F) for comparison.

Test samples from each formulation were prepared for thermal cycling, moisture resistance, compression, indirect tensile and density gradient.

INTRODUCTION

Two-inch diameter pellets were fabricated from five each lots of TATB material. These formulations were F1 and F2 material, which are dry-aminated fine particle size TATB, two formulations of F2 material with 1% and 2% Kel-F binder, respectively, and RX-03-BB. F1 material refers to Lot No. 6169-135-01 with particle size analysis of 69.38% < 20 μm and 95.99% < 44 μm while F2 refers to Lot No. 6232-135-01 with 79.88% < 20 μm and 97.86% < 44 μm. Pellets were pressed to 1.70 and approximately 1.80 Mg/m^3 densities using a mechanical punch and die set. The high density pellets were all pressed to the same load and densities varied from 1.80 to 1.84 Mg/m^3 depending on the amount of binder in the TATB. Some of the pellets from each lot were machined into hemispheres for thermal cycling. The remaining pellets were machined into compression and indirect tensile specimens. These parts were also used to determine density gradients. One compression sample from each group was used to check moisture resistance. Test specimens were also machined from available isostatic pressings of F1 and F2 materials.

EXPERIMENTAL TESTS AND RESULTS

Thermal Cycling Tests

Four hemispherical parts from each lot of material were thermally conditioned from -54 C to +74 C per 24 hours for a total of 30 cycles. The four parts consisted of two low density and two high density hemispheres from each group except for the F1 isostatic pressing; only high density parts were available from this group. Thermal cycling results are summarized in Table I and Figs. 1 through 7. The F1 and F2 parts gave a higher growth rate than those samples containing Kel-F. In all cases the growth rates of the low density specimens was somewhat greater than the high density parts, this being more pronounced for those parts containing Kel-F. Those F1 and F2 parts pressed mechanically showed a significant difference in growth rate at the pole and at the equator. This may be due to the density gradient through the pellets, although the measured gradient did not appear to be significant (density gradient will be discussed later). The high density parts containing Kel-F appeared to reach near maximum growth after 30 cycles while all of the other parts continued to grow at a fairly constant rate.

Moisture Resistance

One compression sample at each density was selected from each group of parts to measure moisture resistance. These samples were subjected to relative humidity atmospheres of 10%, 50% and 75% for 72 hours each. As an extreme condition, the samples were also totally submerged in water for one hour. It was found that placing the samples in a dessicator over night was sufficient to dry the parts to their original weight. This indicates the moisture gain was surface moisture.

Results of the moisture resistance tests are summarized in Table II. The samples did not adsorb moisture in the 10% and 50% RH atmospheres. In the 75% RH atmosphere, all samples adsorbed moisture ranging from 0.1 to 0.2 mg/g. None of the materials showed any advantage over the others, but the low density parts were more moisture resistant. However, when totally submerged, the high density parts were significantly more moisture resistant than those of low density as was expected. Also, those samples containing Kel-F show a definite advantage over the pure materials under this extreme condition.

Physical Properties

The small scale compression specimens were tested at 21 C at a constant crosshead velocity of 0.021 mm/sec. Results are shown in Figs. 8 through 14 and Tables III through IX. Indirect tensile specimens were also tested at 21 C but at a constant crosshead velocity of 0.002 mm/sec. Results are summarized in Table X.

Results of the high density specimens of RX-03-BB are used as a baseline for discussion since there is a considerable amount of data available for this material. However, the results reported for RX-03-BB are considerably lower than those obtained for the normal density ($\sim 1.90\ Mg/m^3$), isostatically pressed material due to the density difference.

The compression test data, shown in Table III through IX, are summarized in Table XI to aid in interpretation. As seen in the table, the ultimate stress for each of the low density parts was approximately 50% lower than that of the high density parts. The difference in rupture strain, between the low and high density parts, appears to be a function of the amount of binder in the material. This difference was 12 to 15% for the pure materials (F1 and F2) and varied down to 24% for RX-03-BB. For high density parts only, the ultimate stresses for the pure materials were from 38 to 45% lower than for RX-03-BB. The difference in rupture strain between the pure materials and RX-03-BB indicate there may be a significant difference between isostatically and mechanically pressed parts. This difference was 24 to 28% for the mechanically pressed parts compared to 42 to 47% for those pressed isostatically.

Results of the indirect tensile tests, as shown in Table X, indicate no significant difference between isostatically and mechanically pressed parts for F1 and F2 materials. However, the ultimate stress for the high density parts from these materials was approximately 60% lower than for RX-03-BB. The ultimate stress of the low density parts was approximately 60% lower than that of the high density parts of the same material.

The densities of the indirect tensile specimens were used to determine the density gradient of the individual 50.8 mm diameter x 31.8 mm height TATB pellets. The density gradients are shown in Table X. The location of the specimens taken from the individual pellets are shown in Fig. 15. As seen in Table X, the largest spread in density occurred in the low density F2/1% Kel-F pellet. The density gradient for this pellet was only 0.007 Mg/m^3 which is rather insignificant.

COMMENTS AND CONCLUSIONS

Two areas of some significance which should be considered are handleability and machinability of the F1 and F2 materials relative to those formulations containing Kel-F. The pure materials, with very small particle size, tend to adhere to all surfaces contacted. This presents a problem in transferring the powder from the weighing container to the die cavity (for mechanically pressed parts). In some cases as much as 0.4 g of powder adhered to the weighing container during the transfer operation. This much weight loss though small relative to the approximately 100 g pellet, causes difficulty in controlling densities accurately.

Pellets made from pure TATB were also rather difficult to machine, particularly at the low density. Isostatically pressed parts appeared to be more difficult to machine than mechanically pressed parts. The material chipped easily, particularly around the edges.

The moisture resistance tests indicate there may be a problem in machining these materials wet, even RX-03-BB at low densities.

FIGURES

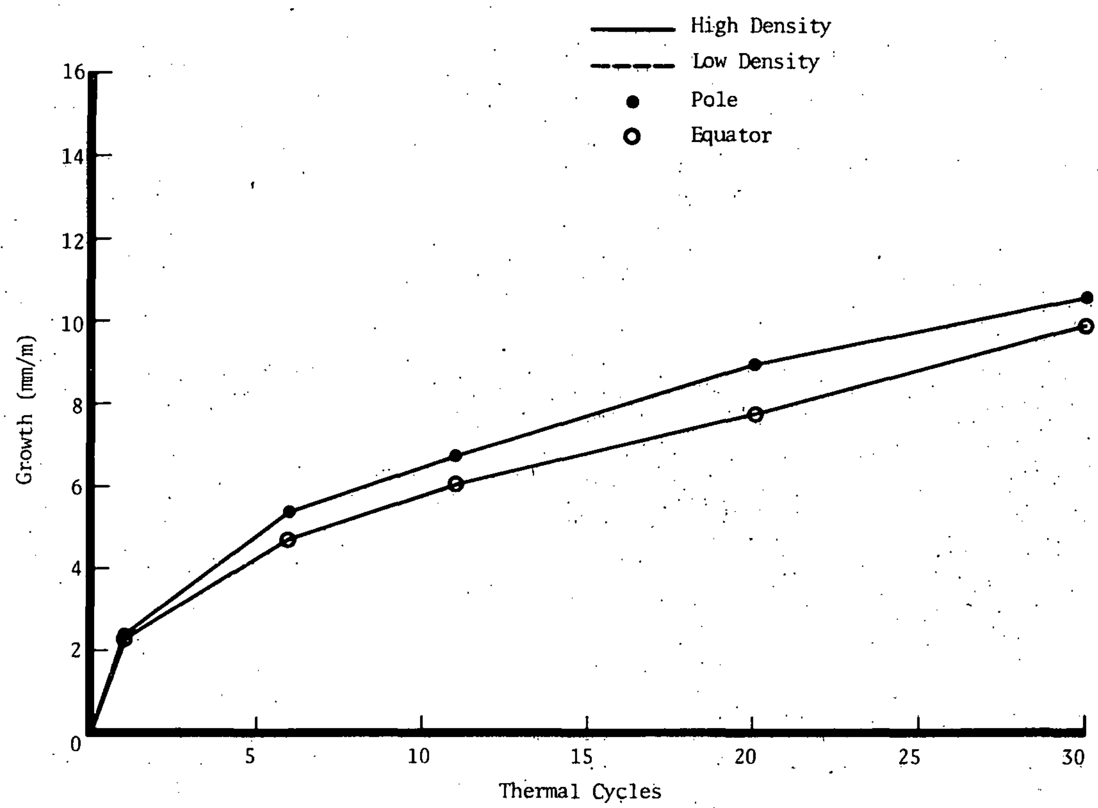

Figure 1. TATB Dimensional Stability Test (F1 Material - Isostatic Pressings)

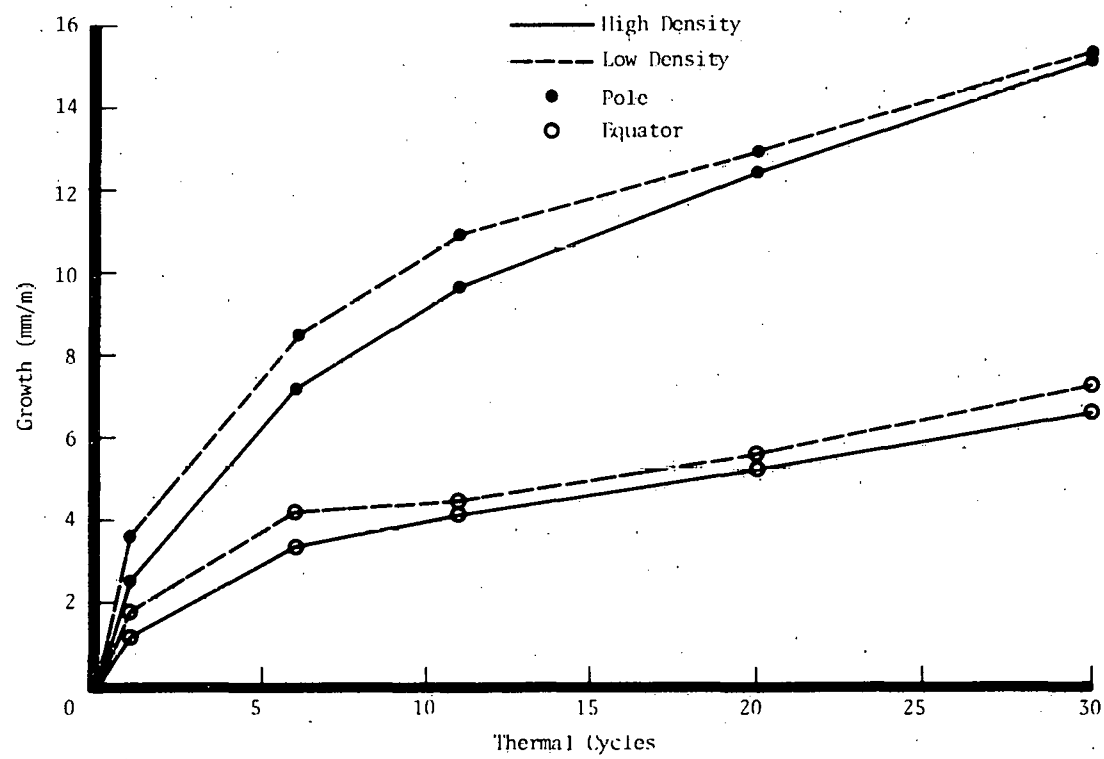

Figure 2. TATB Dimensional Stability Test (F1 Material - Mechanical Pressings)

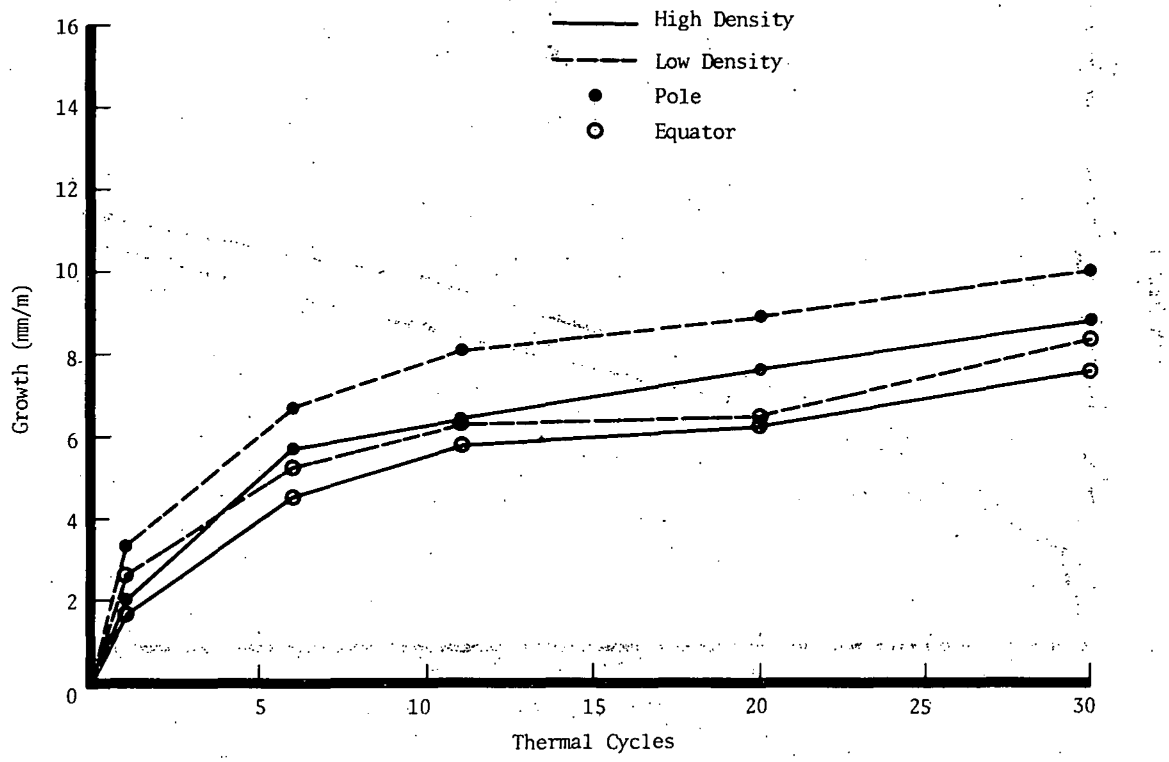

Figure 3. TATB Dimensional Stability Test (F2 Material - Isostatic Pressings)

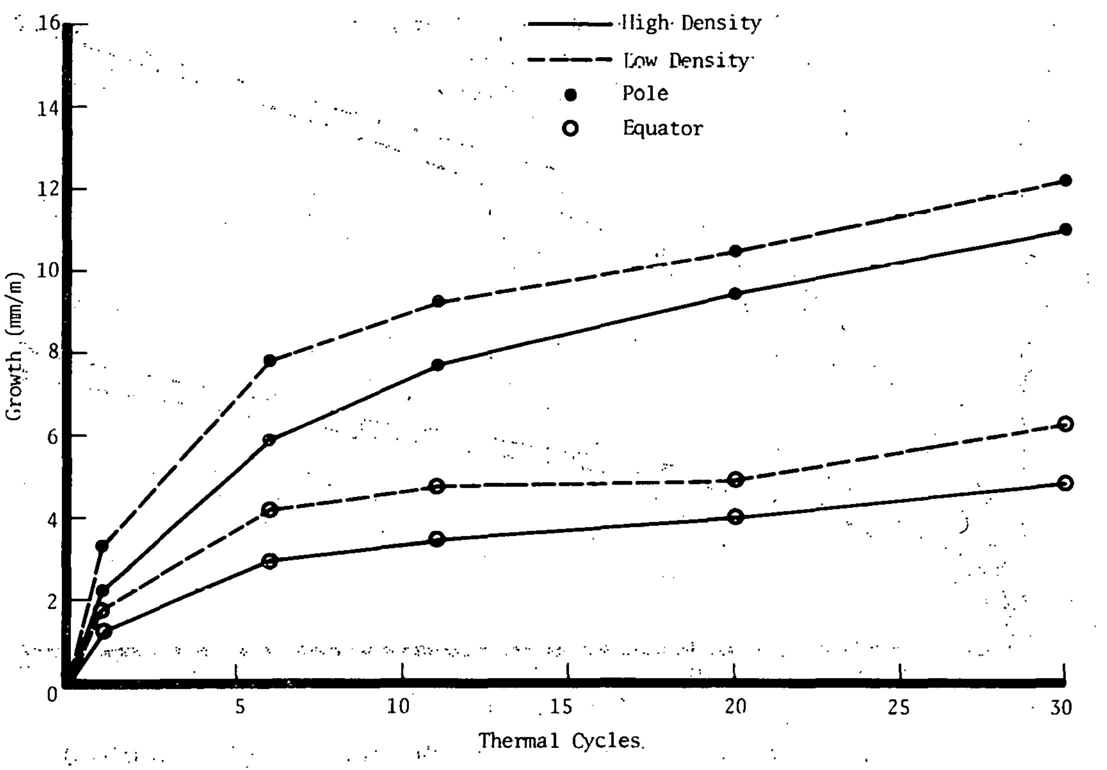

Figure 4. TATB Dimensional Stability Test (F2 Material - Mechanical Pressings)

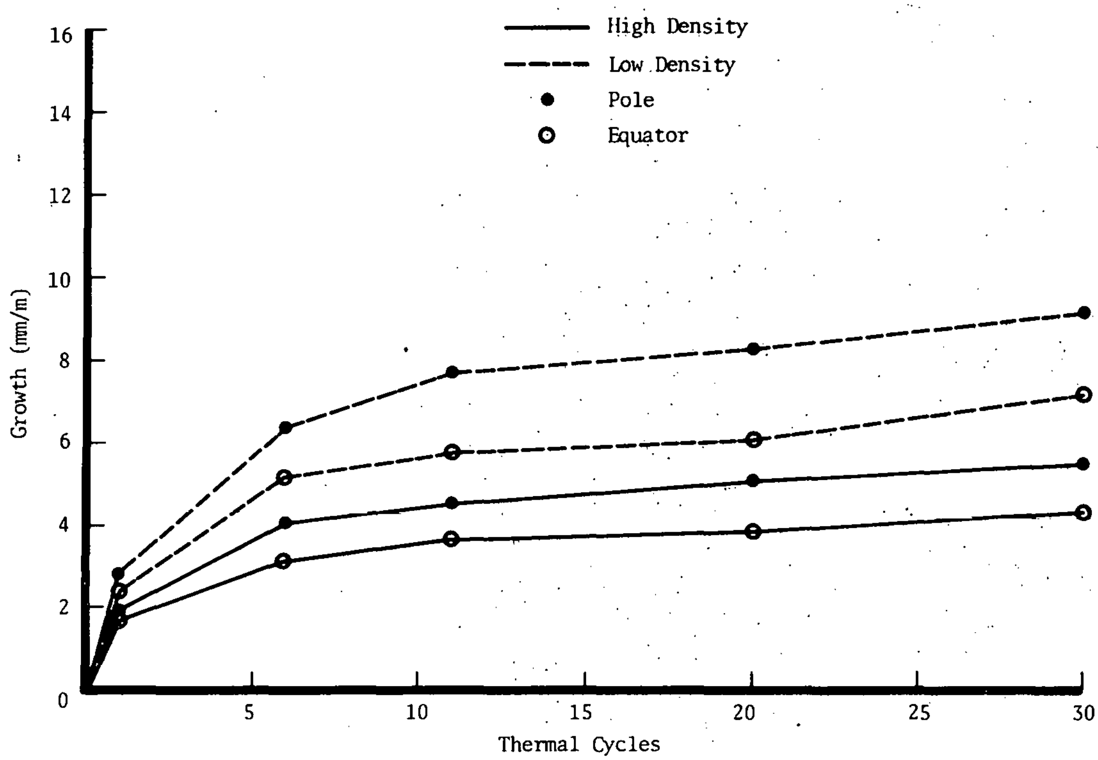

Figure 5. TATB Dimensional Stability Test (1% Kel-F Binder)

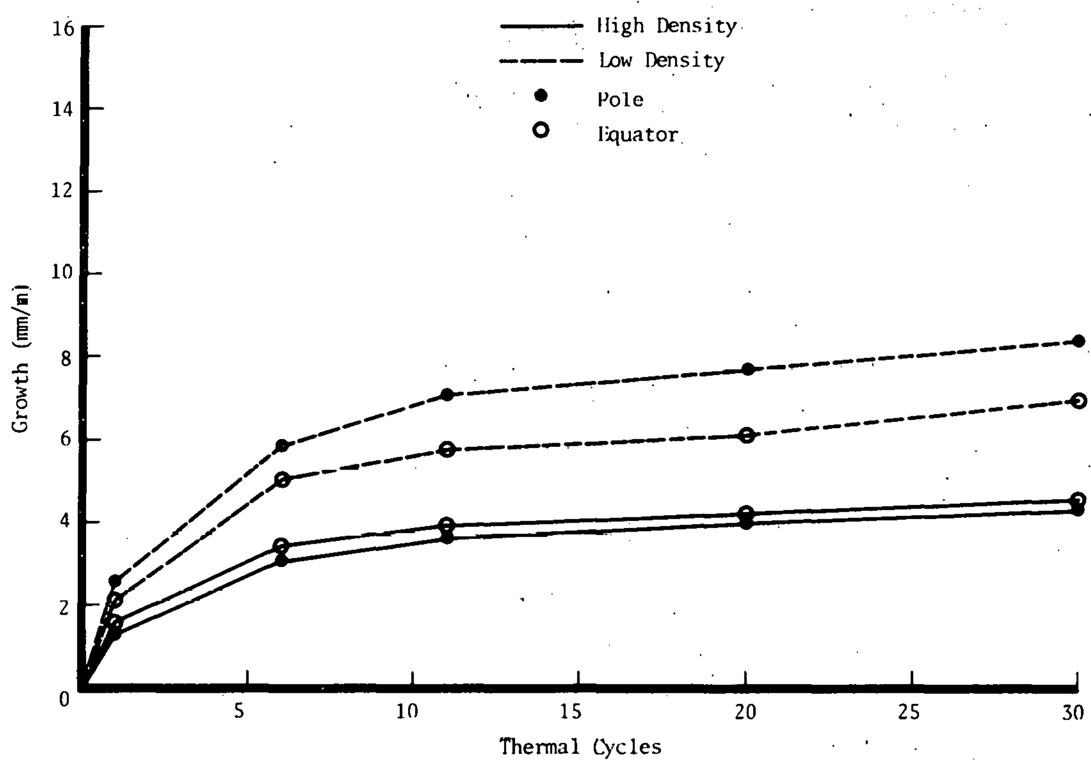

Figure 6. TATB Dimensional Stability Test (2% Kel-F Binder)

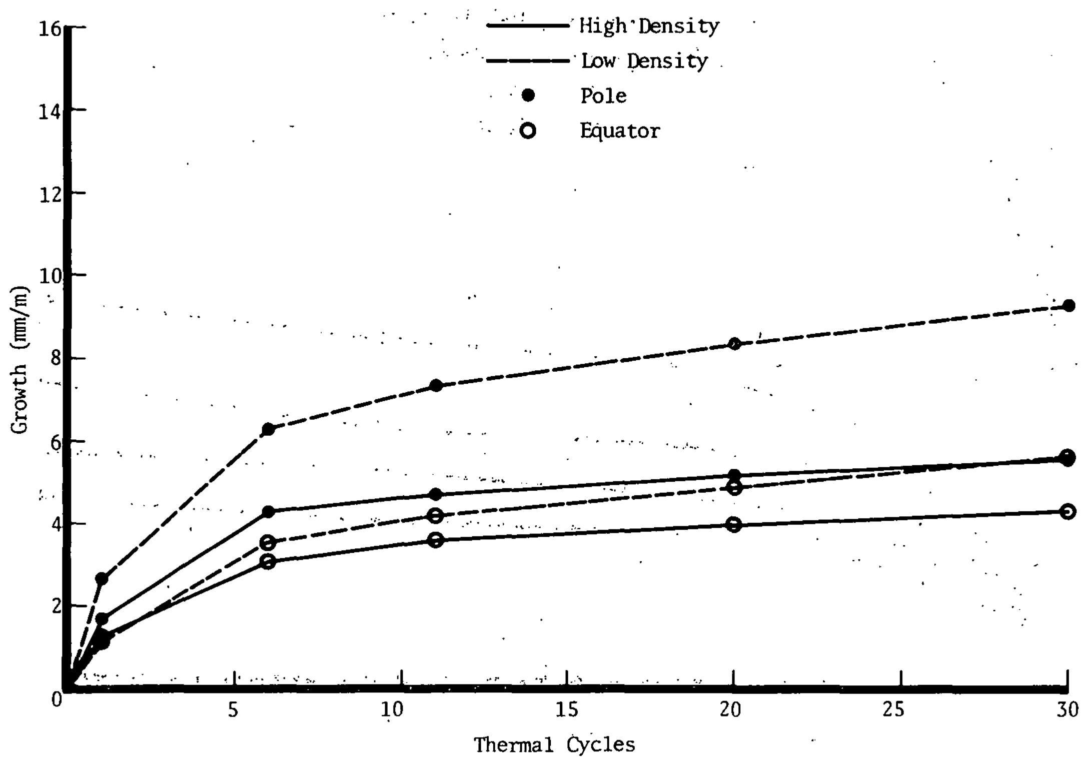

Figure 7. TATB Dimensional Stability Test (RX-03-BB).

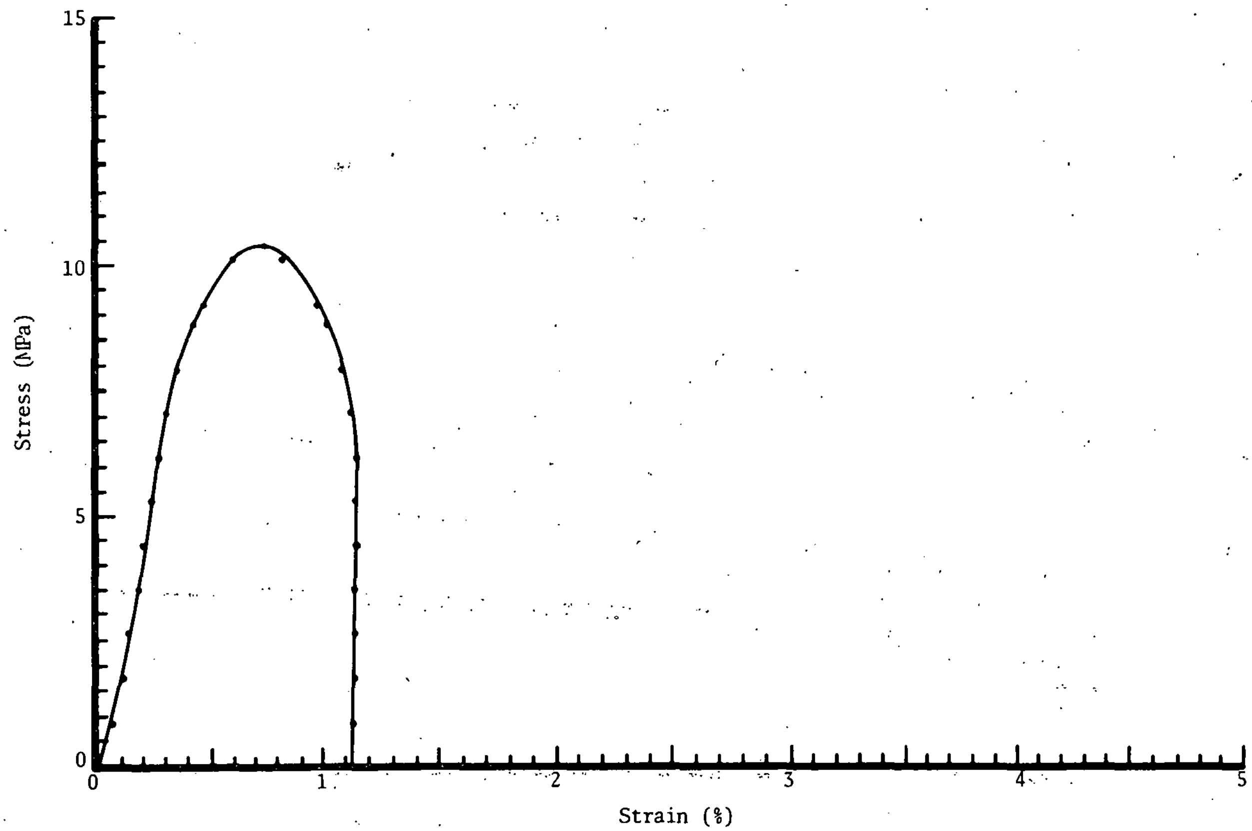

Fig. 8. F1 TATB (Isostatic -1.803 Mg/m^3) Compression Test at 21 C at a Constant Crosshead Speed of 0.021 mm/s

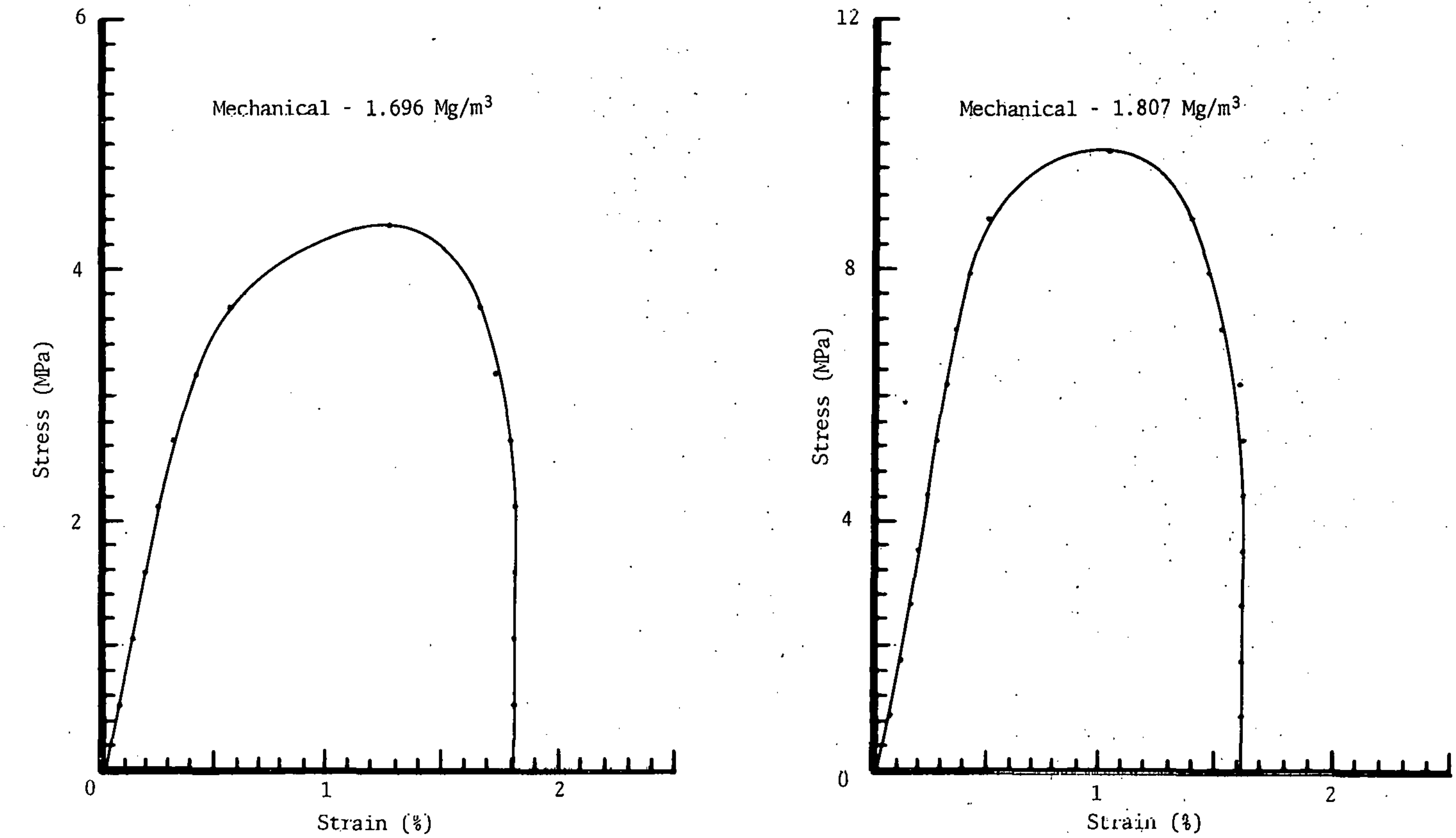

Fig. 9. F1 TATB Compression Test at 21 C at a Constant Crosshead Speed of 0.021 mm/s

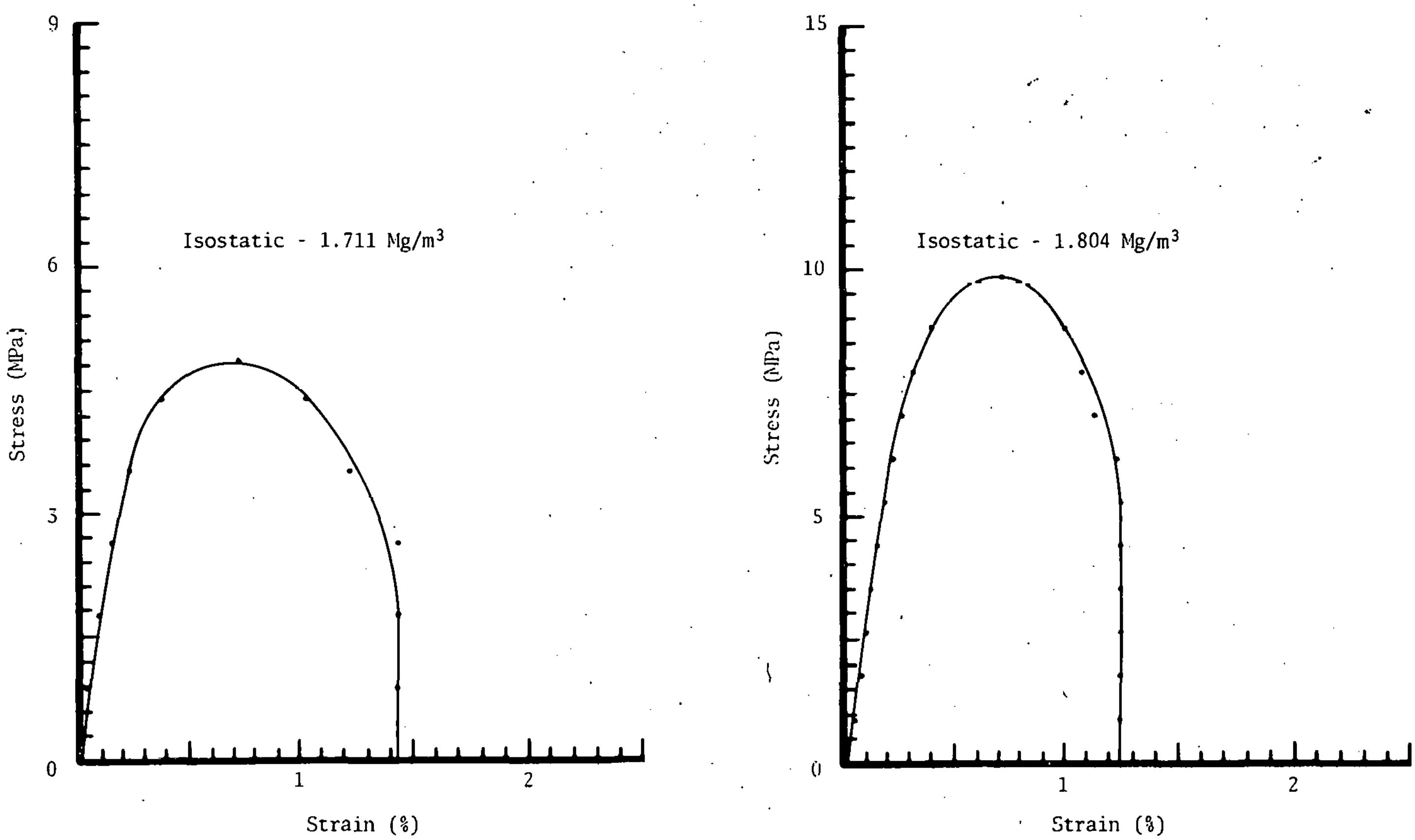

Fig. 10. F2 TATB Compression Test at 21 C at a Constant Crosshead Speed of 0.021 mm/s

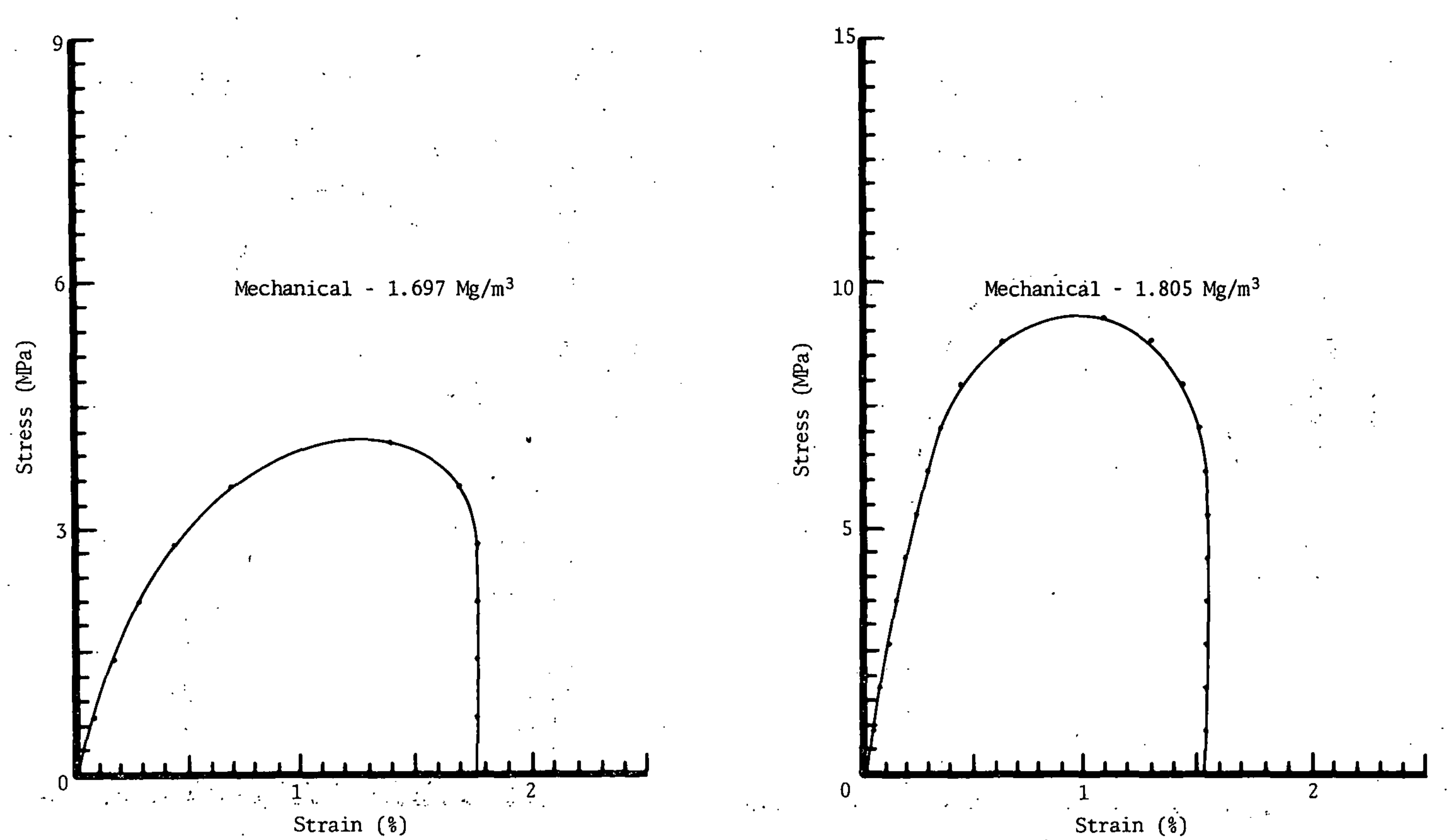

Fig. 11. F2 TATB Compression Test at 21 C at a Constant Crosshead Speed of 0.021 mm/s

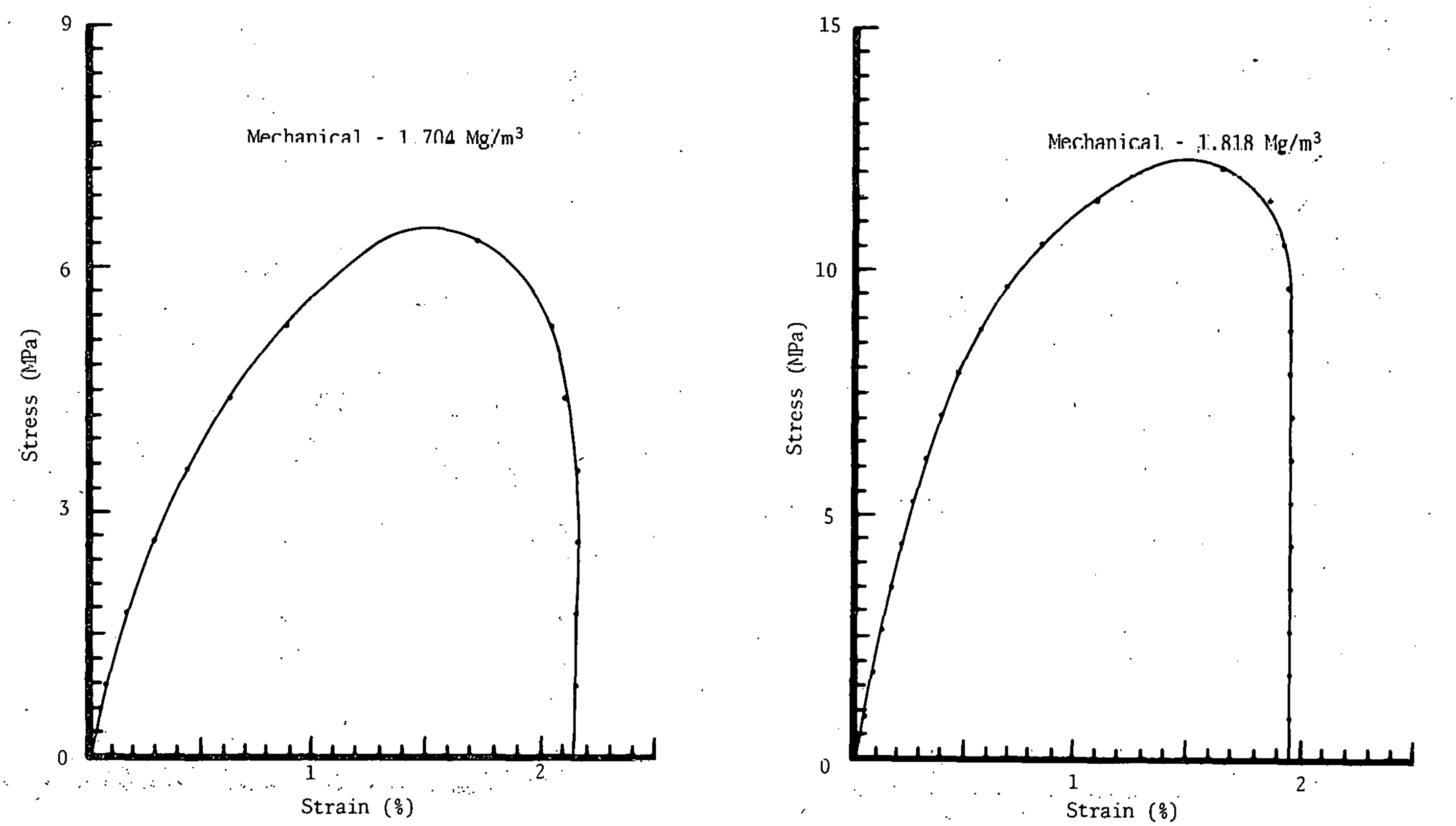

Fig. 12. F2/1% Kel-F TATB Compression Test at 21 C at a Constant Crosshead Speed of 0.021 mm/s

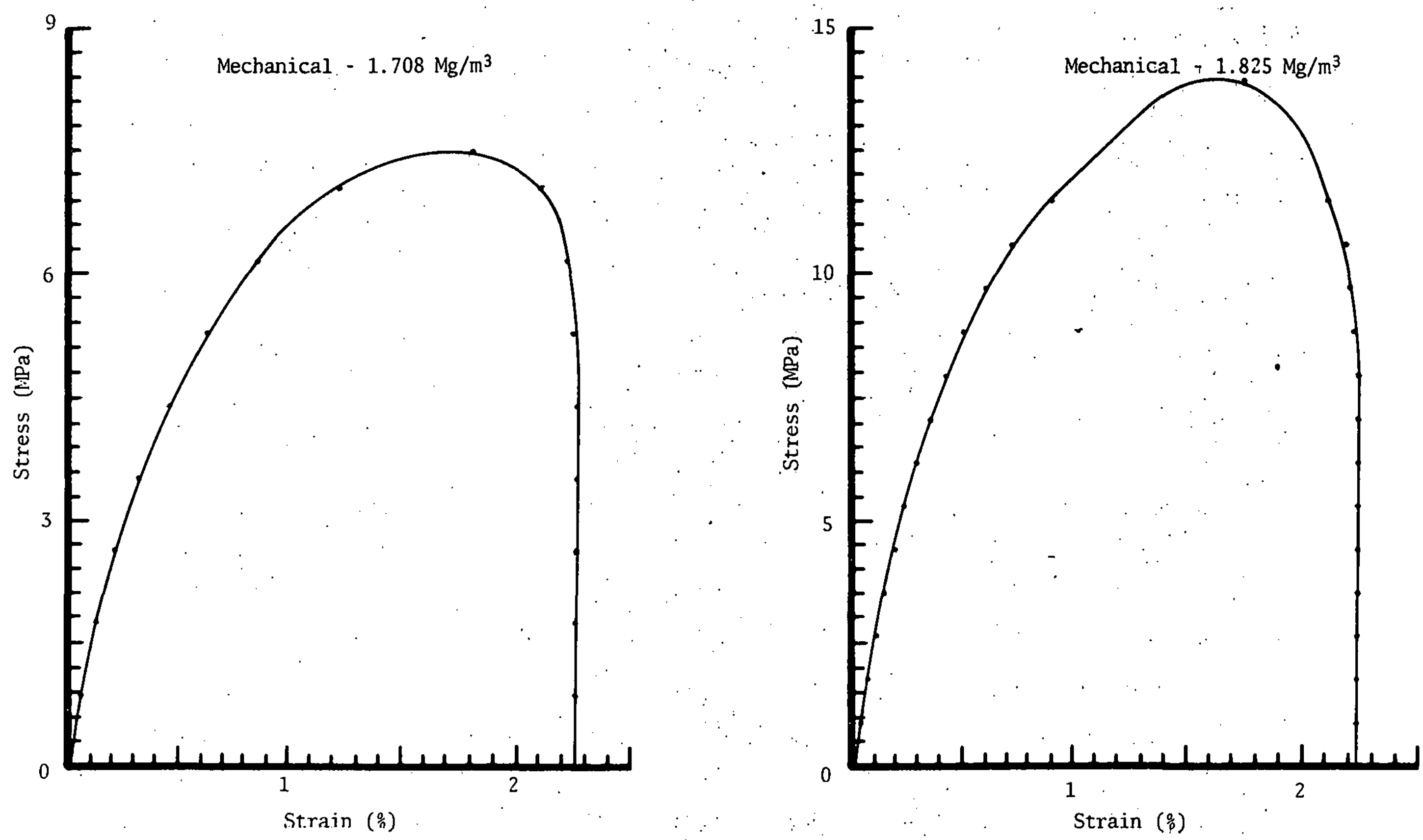

Fig. 13. F2/2% Kel-F TATB Compression Test at 21 C at a Constant Crosshead Speed of 0.021 mm/s

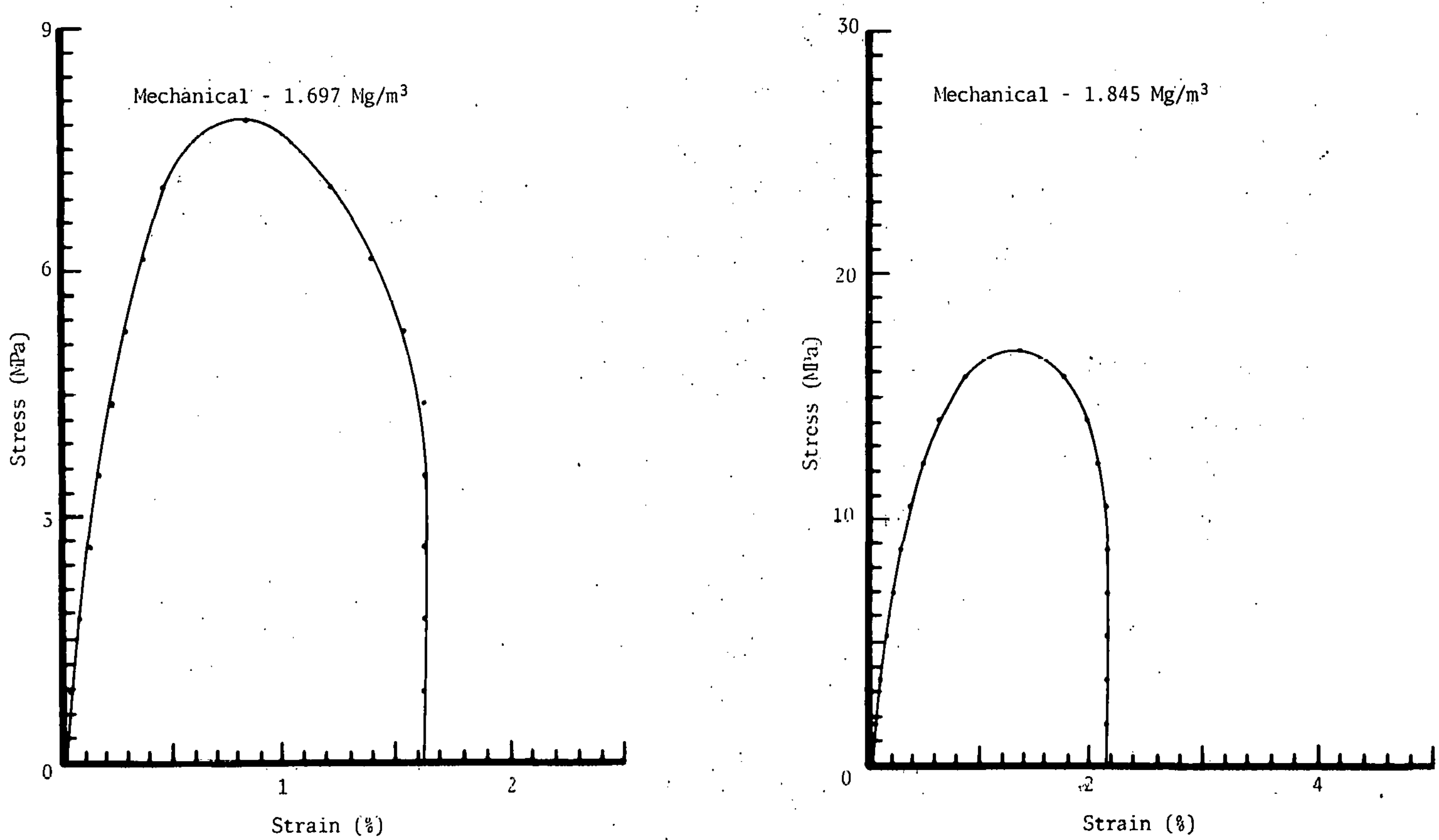

Fig. 14. RX-03-BB Compression Test at 21 C at a Constant Crosshead Speed of 0.021 mm/s

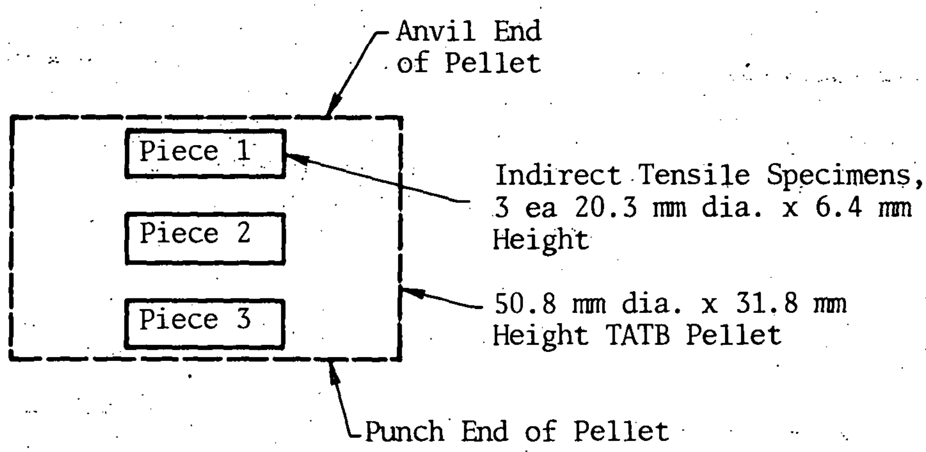

Fig. 15. Schematic of TATB Pellet Showing Location of Parts Used to Determine Density Gradient

T A B L E S

Table I. Thermal Cycling Results of Hemispherical TATB Parts

Material	Density (g/cc)	Growth (mm/m) Thermal Cycles 1 Pole	1 Equator	6 Pole	6 Equator	11 Pole	11 Equator	20 Pole	20 Equator	30 Pole	30 Equator
F1 - Isostatic	1.799	2.38	2.31	5.40	4.72	6.75	6.05	8.98	7.76	10.56	9.90
F1 - Mechanical	1.701	3.60	1.78	8.45	4.20	10.90	4.45	12.96	5.59	15.35	7.25
	1.804	2.55	1.14	7.20	3.33	9.65	4.11	12.46	5.23	15.16	6.61
F2 - Isostatic	1.710	3.30	2.61	6.70	5.22	8.10	6.28	8.90	6.44	10.00	8.33
	1.804	2.00	1.67	5.70	4.50	6.40	5.78	7.60	6.22	8.80	7.55
F2 - Mechanical	1.699	3.30	1.73	7.80	4.17	9.25	4.72	10.50	4.89	12.20	6.28
	1.807	2.20	1.22	5.90	2.92	7.70	3.45	9.45	4.00	11.00	4.83
1% Kel-F	1.702	2.85	2.39	6.40	5.20	7.70	5.78	8.30	6.09	9.15	7.14
	1.817	1.90	1.64	4.07	3.11	4.55	3.67	5.10	3.86	5.50	4.28
2% Kel-F	1.701	2.60	2.11	5.90	5.03	7.10	5.78	7.75	6.14	8.45	6.97
	1.828	1.30	1.58	3.10	3.45	3.65	3.92	4.00	4.23	4.35	4.56
RX-03-BB	1.699	2.65	1.14	6.30	3.51	7.35	4.17	8.35	4.87	9.25	5.56
	1.847	1.70	1.23	4.30	3.06	4.70	3.59	5.15	3.95	5.50	4.28

Table II. Moisture Pickup of TATB Parts Subjected to Different Relative Humidity Atmospheres

Material	ρ (g/cc)	Dry Wt. (g)	10% R.H. Δ Wt. (g)	10% R.H. Δ Wt. (mg/g)	50% R.H. Δ Wt. (g)	50% R.H. Δ Wt. (mg/g)	75% R.H. Δ Wt. (g)	75% R.H. Δ Wt. (mg/g)	Submerged Δ Wt. (g)	Submerged Δ Wt. (mg/g)
F1 - Mechanical	1.6790	4.0690	NO CHANGE		NO CHANGE		0.0004	0.10	0.1387	34.09
	1.8051	4.3747					0.0008	0.18	0.0722	16.50
F2 - Isostatic	1.7093	4.1293					0.0003	0.07	0.1476	35.74
	1.8038	4.3565					0.0005	0.11	0.0745	17.10
F2 - Mechanical	1.6973	4.0893					0.0005	0.12	0.1476	36.09
	1.8076	4.3656					0.0008	0.18	0.0818	18.74
1% Kel-F	1.6979	4.0909					0.0005	0.12	0.0619	15.13
	1.8161	4.3650					0.0006	0.14	0.0172	3.94
2% Kel-F	1.7016	4.1106					0.0004	0.10	0.0295	7.18
	1.8227	4.4066					0.0007	0.16	0.0096	2.18
RX-03-BB	1.6917	4.0835					0.0004	0.10	0.0126	3.09
	1.8422	4.4455					0.0005	0.11	0.0040	0.90

Table III. Compression Test at a Constant Crosshead Speed of 0.021 mm/s at 21 C for F1 TATB (Isostatic)

Density 1.803 Mg/m^3

Piece No.	Time (s)	Failure Stress (MPa)	Failure Strain (%)	Rupture Time (s)	Rupture Strain (%)	Work To Rupture (MJ/m^3)
1	12	11.24	0.796	16	1.213	0.08
3	11	11.10	0.722	16	1.188	0.07
4	9	9.34	0.534	12	0.840	0.05
5	10	9.90	0.844	14	1.241	0.07
Mean	11	10.40	0.724	15	1.122	0.07
Std. Dev.	1	0.93	0.136	2	0.189	0.01

Table IV. Compression Test at a Constant Crosshead Speed of 0.021 mm/s at 21 C for F1 TATB (Mechanical)

Piece No.	Time (s)	Failure Stress (MPa)	Failure Strain (%)	Rupture Time (s)	Rupture Strain (%)	Work To Rupture (MJ/m³)
Density 1.696 Mg/m³						
1	16	4.20	1.278	20	1.780	0.04
10	16	4.72	1.210	24	1.840	0.05
11	16	4.34	1.310	24	1.904	0.04
12	15	4.11	1.184	20	1.674	0.04
Mean	16	4.34	1.246	22	1.800	0.04
Std. Dev.	1	0.27	0.059	2	0.098	0.01
Density 1.807 Mg/m³						
1	16	9.68	1.102	22	1.786	0.10
3	13	9.94	0.916	19	1.560	0.08
4	14	9.96	1.010	20	1.484	0.08
Mean	14	9.86	1.009	20	1.610	0.09
Std. Dev.	2	0.16	0.093	2	0.157	0.01

Table V. Compression Test at a Constant Crosshead Speed of 0.021 mm/s at 21 C for F2 TATB (Isostatic)

Piece No.	Time (s)	Failure Stress (MPa)	Failure Strain (%)	Rupture Time (s)	Rupture Strain (%)	Work To Rupture (MJ/m³)
Density 1.711 Mg/m³						
2	10	4.60	0.678	17	1.240	0.03
3	10	5.09	0.680	20	1.580	0.04
4	12	4.79	0.782	21	1.608	0.04
5	10	4.92	0.708	16	1.240	0.03
Mean	10	4.85	0.712	18	1.417	0.04
Std. Dev.	1	0.21	0.049	2	0.205	0.01
Density 1.804 Mg/m³						
7	8	9.48	0.516	16	1.150	0.06
8	11	10.17	0.740	17	1.315	0.07
9	11	9.53	0.728	16	1.216	0.07
10	11	10.11	0.804	16	1.258	0.07
Mean	10	9.82	0.697	16	1.235	0.07
Std. Dev.	2	0.37	0.125	1	0.070	0.00

Table VI. Compression Test at a Constant Crosshead Speed of 0.021 mm/s at 21 C for F2 TATB (Mechanical)

Piece No.	Time (s)	Failure Stress (MPa)	Failure Strain (%)	Rupture Time (s)	Rupture Strain (%)	Work To Rupture (MJ/m^3)
			Density 1.697 Mg/m^3			
5	19	4.06	1.338	23	1.738	0.04
6	17	3.81	1.394	22	1.726	0.04
7	18	4.14	1.346	22	1.698	0.04
8	19	4.11	1.456	23	1.820	0.04
13	19	4.16	1.364	24	1.844	0.04
Mean	18	4.06	1.380	23	1.765	0.04
Std. Dev.	1	0.14	0.048	1	0.063	0.00
			Density 1.805 Mg/m^3			
4	14	9.36	1.016	21	1.544	0.08
9	15	9.18	1.060	20	1.526	0.08
10	16	9.46	1.158	22	1.600	0.09
11	14	8.78	0.962	20	1.448	0.06
12	15	9.41	1.106	21	1.548	0.08
Mean	15	9.24	1.060	21	1.533	0.08
Std. Dev.	1	0.28	0.076	1	0.055	0.01

Table VII. Compression Test at a Constant Crosshead Speed of 0.021 mm/s at 21 C for F2/1% Kel-F TATB (Mechanical)

Piece No.	Time (s)	Failure Stress (MPa)	Failure Strain (%)	Rupture Time (s)	Rupture Strain (%)	Work To Rupture (MJ/m^3)
			Density 1.704 Mg/m^3			
1	22	6.43	1.774	27	2.114	0.08
2	21	6.11	1.676	28	2.192	0.08
6	22	6.37	1.702	28	2.220	0.08
7	22	6.36	1.674	26	2.080	0.07
Mean	22	6.32	1.707	27	2.152	0.08
Std. Dev.	1	0.14	0.047	1	0.066	0.00
			Density 1.818 Mg/m^3			
3	22	12.08	1.672	26	1.984	0.14
4	22	12.34	1.622	27	2.024	0.14
9	22	11.99	1.616	25	1.858	0.13
10	22	11.89	1.552	27	1.998	0.14
12	22	12.08	1.666	25	1.862	0.13
Mean	22	12.08	1.626	26	1.945	0.14
Std. Dev.	0	0.17	0.048	1	0.079	0.01

Table VIII. Compression Test at a Constant Crosshead Speed of 0.021 mm/s at 21 C for F2/2% Kel-F TATB (Mechanical)

Piece No.	Time (s)	Failure Stress (MPa)	Failure Strain (%)	Rupture Time (s)	Rupture Strain (%)	Work To Rupture (MJ/m³)
		Density 1.708 Mg/m³				
1	23	7.52	1.794	28	2.246	0.10
2	23	7.62	1.724	27	2.160	0.10
5	24	7.38	1.836	29	2.306	0.10
7	23	7.34	1.816	29	2.348	0.10
Mean	23	7.46	1.793	28	2.265	0.10
Std. Dev.	0	0.13	0.049	1	0.082	0.00
		Density 1.825 Mg/m³				
4	23	13.31	1.685	27	2.085	0.17
10	23	13.96	1.775	29	2.265	0.18
11	24	14.10	1.754	30	2.340	0.19
12	24	14.06	1.728	30	2.268	0.18
Mean	24	13.86	1.736	29	2.240	0.18
Std. Dev.	1	0.37	0.039	2	0.109	0.01

Table IX. Compression Test at a Constant Crosshead Speed of 0.021 mm/s at 21 C for RX-03-BB (Mechanical)

Piece No.	Time (s)	Failure Stress (MPa)	Failure Strain (%)	Rupture Time (s)	Rupture Strain (%)	Work To Rupture (MJ/m³)
		Density 1.697 Mg/m³				
1	11	8.06	0.790	19	1.482	0.07
2	12	8.11	0.808	21	1.616	0.07
9	13	7.73	0.900	22	1.734	0.08
10	11	7.53	0.760	20	1.624	0.07
Mean	12	7.86	0.815	21	1.614	0.07
Std. Dev.	1	0.28	0.060	1	0.103	0.01
		Density 1.845 Mg/m³				
3	19	17.00	1.292	29	2.186	0.19
4	19	16.86	1.284	29	2.116	0.19
5	19	17.00	1.306	28	1.956	0.17
6	18	16.63	1.334	28	2.104	0.19
7	19	16.73	1.348	29	2.228	0.20
Mean	19	16.84	1.313	28	2.118	0.19
Std. Dev.	1	0.16	0.027	1	0.104	0.01

Table X. TATB Indirect Tensile Tests at 21 C at a Constant Crosshead Speed of 0.002 mm/s

Material	Piece No.	Low Density: Density (Mg/m³)	Low Density: Stress (MPa)	Low Density: Strain (%)	High Density: Density (Mg/m³)	High Density: Stress (MPa)	High Density: Strain (%)
F1 - Isostatic	1	LD			1.800	1.164	0.344
	2	LD			1.800	0.957	0.264
	3	LD			PL		
	$\bar{X}$				1.800	1.061	0.304
	σ				0.000	0.146	0.057
F1 - Mechanical	1	1.696	0.308	0.054	1.800	1.210	0.274
	2	1.697	0.440	0.094	1.802	1.259	0.293
	3	1.700	0.480	0.191	1.803	1.278	0.238
	$\bar{X}$	1.698	0.409	0.113	1.802	1.249	0.268
	σ	0.002	0.090	0.070	0.002	0.035	0.028
F2 - Isostatic	1	PL			1.804	1.358	0.333
	2	PL			1.804	1.052	0.359
	3	PL			1.804	1.110	0.281
	$\bar{X}$				1.804	1.173	0.324
	σ				0.000	0.163	0.040
F2 - Mechanical	1	1.700	0.488	0.122	1.805	1.276	0.262
	2	1.700	0.350	0.088	1.806	1.287	0.235
	3	1.703	0.605	0.068	1.807	1.221	0.272
	$\bar{X}$	1.701	0.481	0.093	1.806	1.261	0.256
	σ	0.002	0.128	0.027	0.001	0.035	0.019
F2/1% Kel-F	1	1.693	0.744	0.238	1.810	1.586	0.354
	2	1.695	0.673	0.193	1.810	1.606	0.341
	3	1.700	0.680	0.214	1.811	1.668	0.395
	$\bar{X}$	1.696	0.699	0.215	1.810	1.620	0.363
	σ	0.004	0.039	0.023	0.001	0.043	0.028
F2/2% Kel-F	1	1.693	0.902	0.226	1.822	2.253	0.630
	2	1.695	0.935	0.274	1.822	2.266	0.478
	3	1.699	0.946	0.234	1.824	2.222	0.436
	$\bar{X}$	1.696	0.928	0.245	1.823	2.247	0.515
	σ	0.003	0.023	0.026	0.001	0.023	0.102
RX-03-BB	1	1.693	0.996	0.211	1.841	3.184	0.706
	2	1.694	1.040	0.246	1.842	3.163	0.718
	3	1.697	1.040	0.242	1.842	3.036	0.670
	$\bar{X}$	1.695	1.025	0.233	1.842	3.128	0.698
	σ	0.002	0.025	0.019	0.001	0.080	0.025

LD = Low Density Isostatic Parts Not Available
PL = Piece Lost During Machining.

Table XI. Summary of TATB Compression Tests

Material		Low Density (Mg/m^3)	Failure Stress (MPa)	Failure Strain (%)	Rupture Strain (%)	Work To Rupture (MJ/m^3)	Δ^a(%) Ultimate Stress	Δ^a(%) Rupture Strain	High Density (Mg/m^3)	Failure Stress (MPa)	Failure Strain (%)	Rupture Strain (%)	Work To Rupture (MJ/m^3)	Δ^b(%) Ultimate Stress	Δ^b(%) Rupture Strain
F1 - Isostatic	$\bar{X}$	NA	NA	NA	NA	NA	NA	NA	1.803	10.40	0.724	1.122	0.07	-38.2	-47.0
	σ								0.012	0.93	0.136	0.189	0.01		
F1 - Mechanical	$\bar{X}$	1.696	4.34	1.246	1.800	0.04	-56.0	11.8	1.807	9.86	1.009	1.610	0.09	-41.4	-24.0
	σ	0.005	0.27	0.059	0.098	0.01			0.003	0.16	0.093	0.157	0.01		
F2 - Isostatic	$\bar{X}$	1.711	4.85	0.712	1.417	0.04	-50.6	14.7	1.804	9.82	0.697	1.235	0.07	-41.7	-41.7
	σ	0.001	0.21	0.049	0.205	0.01			0.001	0.37	0.125	0.070	0.00		
F2 - Mechanical	$\bar{X}$	1.697	4.06	1.380	1.765	0.04	-56.1	15.1	1.805	9.24	1.060	1.533	0.08	-45.1	-27.6
	σ	0.002	0.14	0.048	0.063	0.00			0.001	0.28	0.076	0.055	0.01		
F2/1% Kel-F	$\bar{X}$	1.704	6.32	1.707	2.152	0.08	-47.7	10.6	1.818	12.08	1.626	1.945	0.14	-28.3	-8.2
	σ	0.002	0.14	0.047	0.066	0.00			0.001	0.17	0.048	0.079	0.01		
F2/2% Kel-F	$\bar{X}$	1.708	7.46	1.793	2.265	0.10	-46.2	1.1	1.825	13.86	1.736	2.240	0.18	-17.7	5.8
	σ	0.003	0.13	0.049	0.082	0.00			0.004	0.37	0.039	0.109	0.01		
RX-03-BB	$\bar{X}$	1.697	7.86	0.815	1.514	0.07	-53.3	-23.8	1.845	16.84	1.313	2.118	0.19	-0-	-0-
	σ	0.009	0.28	0.060	0.103	0.01			0.001	0.16	0.027	0.104	0.01		

[a]*Differences in ultimate stress and rupture strain compared to high density parts of same material.*
[b]*Differences in ultimate stress and rupture strain compared to high density parts of RX-03-BB.*

NA = Not Available