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IMPROVEMENT I N THE BOND STRENGTH OF METAL TO CERAMIC EPOXY JOINTS

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1. Introduction

1.1 To date four, large diameter (30") linac preinjector high gradient accelerating columns have been constructed at Brookhaven. One assembly was subsequently stripped and its components used for other work. The second assembly was used as the preinjector for the 50-MeV linac and, with additions, will be used in the 200-MeV linac Pit I. The third assembly was manufactured in 1969 and is now operating in the 200-MeV linac Pit II. A fourth assembly was manufactured in 1971 and was supplied to Berkeley for use with the old BNL 50-MeV linac as the injector for the Bevatron.

1.2 These accelerating column structures consist of alternate metal (Titanium) and ceramic rings bonded together with epoxy resin. The construction and testing of the previously manufactured columns has been adequately covered by others.[1,2,3] Since the construction of the assembly made in 1971, "Hughson Chemical Company" of Erie, Pa. has marketed a range of adhesion promoters. According to their literature, these appeared to be suitable for use in the bonding of metal to ceramic joints of the type used in the construction of accelerating columns.

1.3 To make the column assembly taken from the old 50-MeV linac suitable for use in Pit I of the 200-MeV linac, an additional three ceramic ring section must be manufactured. It was felt that the use of the adhesion promoters mentioned above would improve the quality of the bonded joints used. Tests were therefore made to check the improvement of the bond strength with the use of the promoters.

2. Epoxy Resin Bonded Joints

2.1 In epoxy joint design the configuration of the joint surfaces is as important as the bonding strength of the epoxy. For this reason, plus the need to use cheap available materials the test joint configuration was made as simple as possible.

2.2 The joints were made between an aluminum and a ceramic surface and were one square inch in area with 0.94 square inches recessed to a depth of .010" to allow a specific epoxy film thickness. The aluminum surface was prepared on a 1" X 1" X 2" long aluminum block. The ceramic surface was prepared on a alumina ring 6-3/4" i.d. 8-3/4" o.d. X 1" thick. To make maximum use of the materials available 4 blocks were bonded to each side of each ceramic ring thus allowing 8 test joints for each ring. A typical test joint is shown in Fig. 1.

2.3 After discussions with "Hughson Chemical Company" it was decided that adhesion promoter type AP-134 was likely to be the most suitable and a sample was obtained for testing.

2.4 All surfaces were sandblasted, cleaned and treated using the same processes and equipment used for the treatment of the column metal and ceramic rings. Special fixtures were made to apply the epoxy films. The epoxy resin used was "Grodan" Vary Flex #1 type HV mixed in the ratio of 50/50 resin to hardener. The epoxy resin was again always treated in the same way that it would be treated for application to the column construction.

2.5 Two rings, 16 joints, were assembled using the above cleaning techniques, all 8 joints on each ring being bonded at the same time. Each set of 8 joints was cured overnight on the press table, a pressure of 1000 lbs. was applied to ensure a film thickness of .010" in the joint zone.

2.6 Two rings, 16 joints, were assembled using the techniques stated in paragraph 2.5, except that a film of AP-134 adhesion promoter was used during construction. The AP-134 was applied to the surfaces of the ceramic and aluminum before the applications of the epoxy resin, and was allowed to air dry for some 15 to 20 minutes prior to the application of the resin.

3. Testing of Joints

3.1 All joints were allowed to cure for a minimum of 6 days before testing; most joints had been made for at least 3 weeks before testing.

3.2 Joint testing was carried out on the "Baldwin Tate Emery" tensile testing machine in the Materials Science Laboratory, Bldg. 480. Load/extension curves were plotted on the "Satec" extensometer associated with this machine. One ring of each type of treatment (i.e. with or without AP-134) was selected and subjected to tensile tests only. The remaining 2 rings were subjected to a double shear test only. The tensile tests were set up as in Fig. 2, thus testing 2 joints in series, the weaker joint failed during this test. The remaining joint was set up as shown in Fig. 3 and tested to failure. The double shear test was set up as in Fig. 4 and the remaining 2 rings were tested until one or both joints failed at each joint position. A preload of 100 lbs. was applied to all joints before recording any extension.

4. Table of Results

4.1 Tensile testing AP-134 not used. Tensile testing using AP-134.

Ring #	Joint #	Extension to failure	Load lbs. at failure	Ring #	Joint #	Extension to failure	Load lbs. at failure
1	11/6	.013	1820	3	10/16	.020	3200
1	2/14	/	25	3	1/17	.022	3820
1	3/15	.011	1030	3	8/19	.020	3550
1	5/12	.012	1520	3	7/30	.019	3100
1	6	.013	1580	3	1	.029	3250
1	2	.010	920	3	10	.025	3000
1	12	.014	1385	3	30	.021	3000
1	15	.007	930	3	19	.029	3440

4.2 Shear testing AP-134 not used. Shear testing using AP-134.

Ring #	Joint #	Extension to failure	Load lbs. at failure	Ring #	Joint #	Extension to failure	Load lbs. at failure
2	23/27	.017	3000	4	29/9	.016	4880
2	28/33	.011	3065	4	21/22	.009	4060
2	20/32	.007	2200	4	26/4	.012	2630
2	24/25	.004	945	4	13/8	.006	1330

4.3 Typical load/extension curves for the tensile tests are shown in Fig. 5.

5. Conclusions

5.1 Comparison of the results for the testing of joints shows an increase in tensile strength of approximately 2.0 to 2.5 when using AP-134. Shear strength is improved by approximately 1.35. Neglecting the data for ring #1 joint 2/14, it is clear that the spread of tensile test values is considerably less when using the AP-134. The large spread of values for shear failure is probable due to small misalignment of the test blocks, thus producing stresses other than pure shear. In all cases except ring #1 joint 2/14 the first failure on a joint pair resulted in some damage to the remaining good joint. This damage produced a 5% to 15% reduction in the joint strength.

5.2 The preparation of the metal and ceramic surfaces for bonding involves a number of cleaning treatments carried out in sequence. The success of each step can only be checked by a subjective observation. The results indicate that variations do occur in these cleaning processes and are detrimental to the success of a bonded joint. The use of AP-134 tends to reduce the influence of variations in the cleaning processes and produce a more uniform strength joint.

5.3 Adhesion promoters are normally supplied in one gallon units and only small quantities are used at any one time. It was found that AP-134 quickly deteriorates when exposed to normal room air and can then reduce the joint strength acting only as a contaminant. For this reason, AP-134 should always be decanted from its container into smaller units just prior to use. A nitrogen blanket should be maintained above the remaining liquid in the container at all times.

References

1. S. Senator, BNL Accel. Dept. AGS Div. Tech. Note #43, (1968).
2. R. Amari, BNL Accel. Dept. AGS Div. Tech. Note #46, (1968).
3. R. Amari, BNL Accel. Dept. AGS Div. Tech. Note # , (1970).

RMcKW/lsk

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FIG 1 TYPICAL JOINT ASSEMBLY

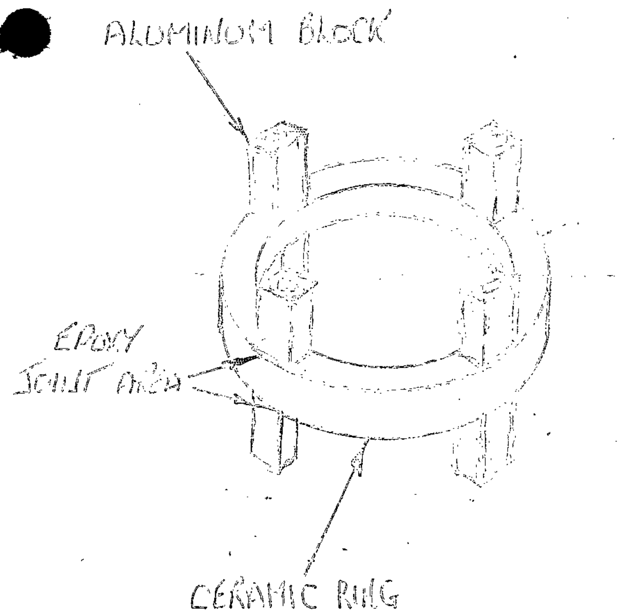


FIG 2.
DOUBLE JOINT
TENSILE TEST ASSY.

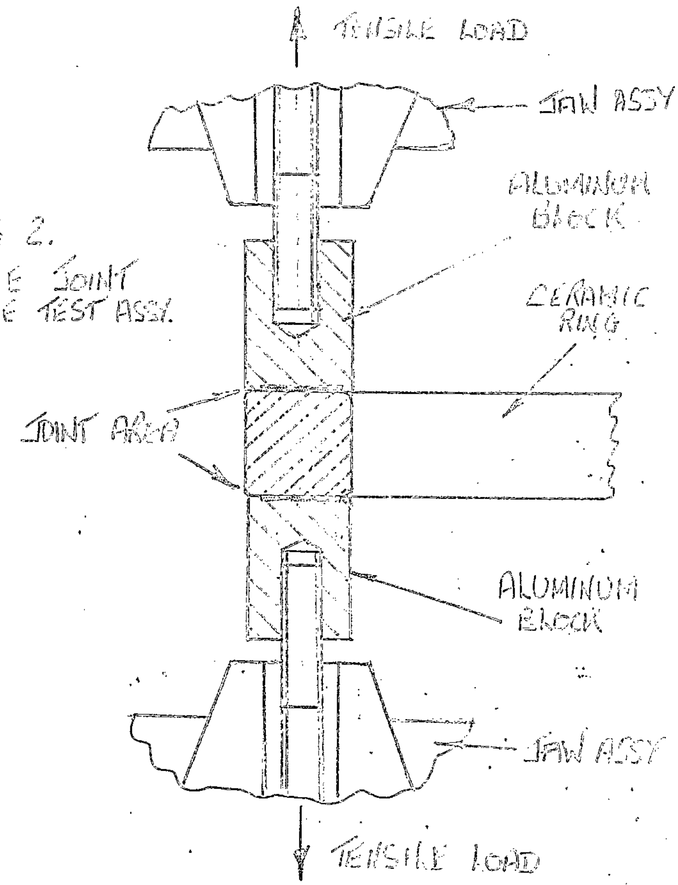


FIG 3
SINGLE JOINT
TENSILE TEST ASSY

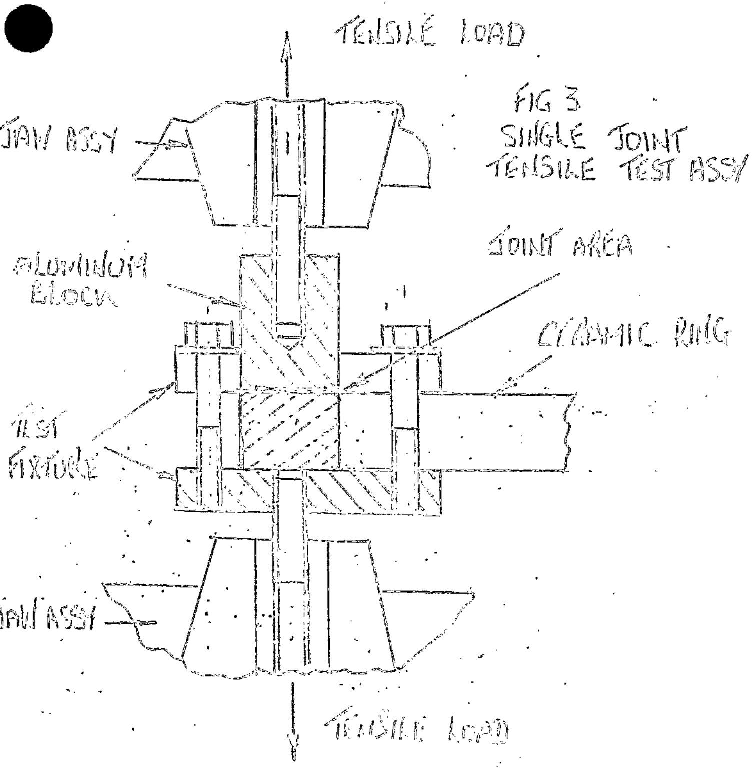
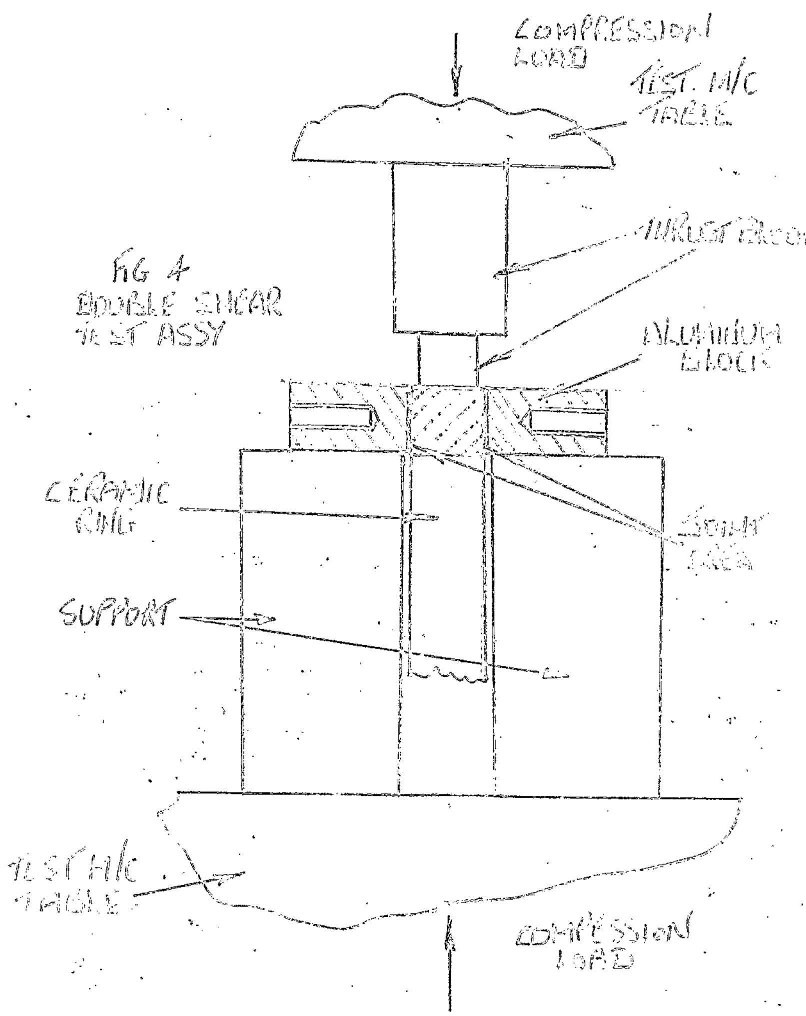


FIG 4
DOUBLE SHEAR
TEST ASSY



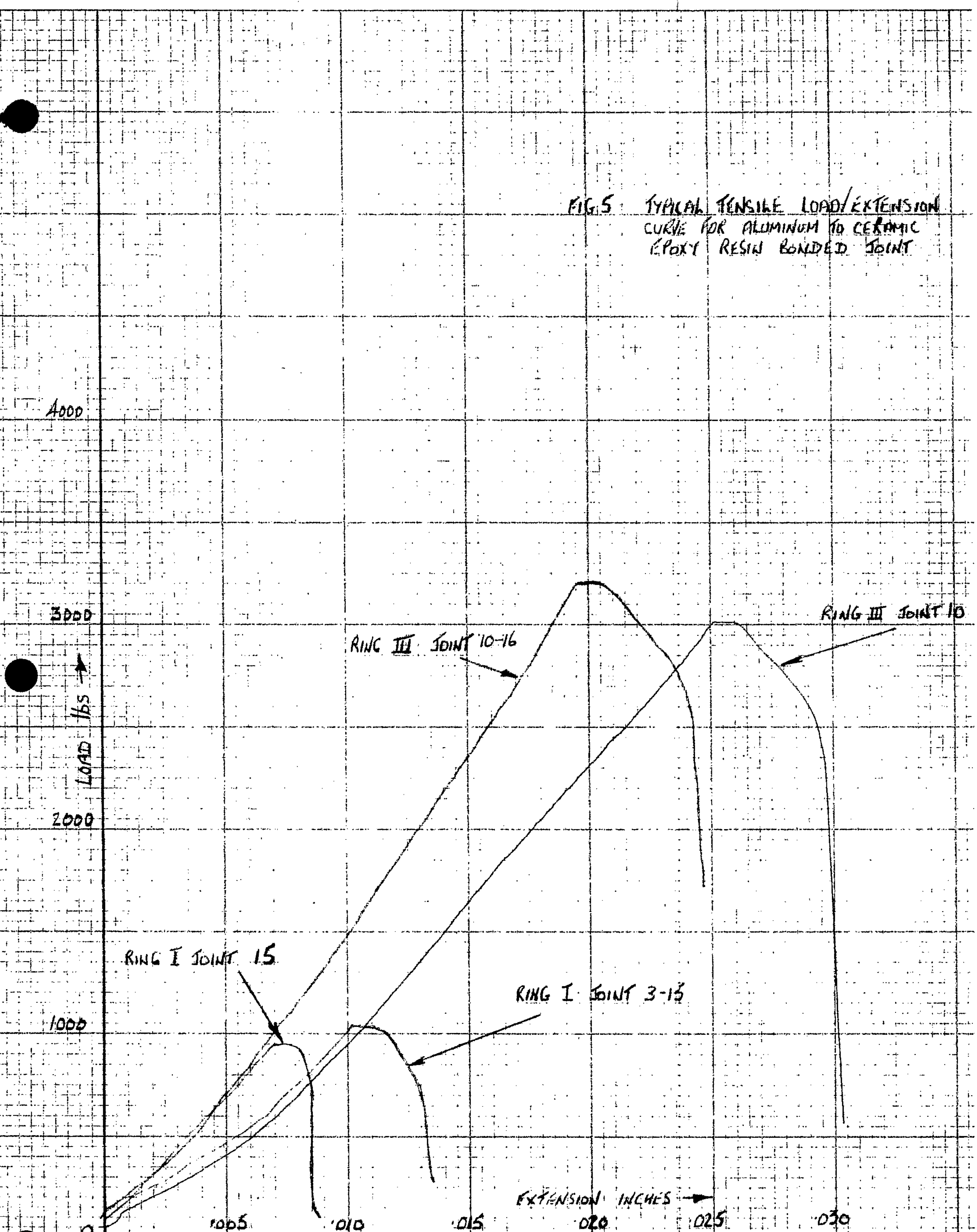


FIG. 5 TYPICAL TENSILE LOAD/EXTENSION CURVE FOR ALUMINUM TO CERAMIC EPOXY RESIN BONDED JOINT
4000
3000
2000
1000
0
LOAD lbs
RING III JOINT 10-16
RING III JOINT 10
RING I JOINT 15
RING I JOINT 3-15
EXTENSION INCHES
.005
.010
.015
.020
.025
.030