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AGS DIVISION TECHNICAL NOTE

No. 46

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CONSTRUCTION AND TESTING OF THE HIGH GRADIENT ACCELERATING COLUMN TEST SECTION

1. Preliminary

A test section was constructed for purposes of determining if the materials and methods being used for building the AGS and Conversion columns are adequate to withstand the loads and temperature variation to which the columns will be subjected.

The test column, being one-fifth the length of the final columns, consisted of an aluminum base plate, ceramic-aluminum ring assemblies and an aluminum end plate (Fig. 1). Epoxy was used to bond the components together and indium was used to isolate the epoxy (which outgasses) from the vacuum side or inside of the column.

2. Construction of the Column

a. Epoxy

Tests were made (Ref. 1) to obtain a flexible epoxy, to minimize shear stresses incurred during temperature changes, due to the difference in thermal expansion rates of the ceramics and adjoining aluminum rings. The desired epoxy also had to be strong enough to carry the column loading in tension and shear. The epoxy decided upon was "Grodan" with a ratio of 50% hardener to 50% resin. Since flexibility is proportional to the thickness of the epoxy, the epoxy gap between the ceramic and aluminum arrived at is .010 inches.

b. Machining of Ceramics and Aluminum Rings

The ceramics (Coors AD-85) had been lapped, using aluminum oxide, to a .001-in. flatness and opposite sides parallel to .001-in. The ceramics were then precision sandblasted in the epoxy areas. The surface finish after sand-blasting became 200 to 300 micro-inch R.M.S. The aluminum rings were machined to a .001-in. flatness and .001-in. parallelism, then sanded in areas to be epoxied.

c. Fabrication Single Ceramic-Aluminum Sections

Ceramic-Aluminum Jig Setup

A ceramic was centered on a jig plate and an aluminum disk placed in the jig over the ceramic. The jig was then adjusted so that a .010 ± .001-in. gap existed between the aluminum rings and the ceramic ring (Fig. 2).

d. Cleaning Ceramic and Aluminum Ring

The ceramic and aluminum ring was removed from the jig and placed in an ultrasonic cleaner containing Viathane for 20 minutes. Both rings were scrubbed with Alconox and warm water, rinsed with warm tap water (about 150°F), distilled water and alcohol. The ceramic was placed in a vacuum box for 3 hours to remove moisture. The aluminum ring was allowed to air dry. The aluminum then etched in the epoxy area (sanded area). The etching solution consisted of:

sulphuric acid	40 grams
sodium dichromate	8 "
silica	8 "
distilled water	100 "

The etch was left for 20 minutes on the aluminum ring then rinsed with distilled water and alcohol and wiped with clean gauze to remove sludge formed during etching. The sludge consisted of precipitated copper.

e. Epoxying - Ceramic-Aluminum Rings

The ceramic, after being removed from the vacuum box, was placed on an epoxy spreading table. The epoxy after being mixed (50%-50% ratio), was outgassed in a bell jar for several minutes and spread on the ceramic with a small glue brush. A spreading tool was set with a gap of .009-in. (Fig. 3) between tool and ceramic and then used to spread the epoxy. This gap was increased to .014-in. when building the final column; since it was noted that when the tool was spreading the epoxy, the epoxy thickness appeared less than the gap distance. This occurrence was attributed to drag due to the viscosity of the epoxy. The ceramic was then placed in the pre-set location on the jig table.

Epoxy had been spread on the aluminum ring in the same manner. The aluminum ring was then placed in the preset location on the jig table and the aluminum and ceramic sandwiched together to form the epoxied joint. Epoxy squeezed out from between the ceramic and aluminum to form a bead, giving added strength to the joint. Two sections had been made in this manner for the test column. The section was allowed to set overnight before removal from the jig plate.

3. Stacking of the Column

The baseplate consisted of an L-shaped aluminum ring 1/4-in. thick in the area the ceramic was epoxied (Fig. 1). The thin area (1/4-in) yields when stresses build during temperature change, i.e., when the aluminum ring and ceramic expand at different rates.

The baseplate was centered on an indium press (Fig. 4). An aluminum-ceramic section placed on the baseplate, aligned, checked for parallelism and "jigged" to obtain a .010-in. gap for epoxy. The ceramic side then re-scrubbed using the procedure in paragraph 2D and the section placed in the vacuum box for three hours.

The baseplate was cleaned and etched using procedure of paragraph 2D. Epoxy then spread on the baseplate and on the ceramic. Indium wire .020-in. thick was placed along the inner edge of the epoxy on the baseplate. The ceramic-aluminum section was then placed over the baseplate and pressure applied to compress the indium and force out the excess epoxy. Three equally spaced 4-ft straight edges were used to insure alignment of the column. The epoxy joint was allowed to set overnight under pressure.

The next aluminum-ceramic section was scrubbed on the ceramic side and etched on the aluminum side. Epoxy was then spread on the aluminum of the section previously installed on the baseplate and on the ceramic side of the next section being stacked. An inner ring was set in place (see Fig. 4) and a strip of indium inserted between the inner and outer aluminum rings. The epoxied ceramic was installed and pressure applied. The inner ring is thicker(stepped) than the outer aluminum ring so that a .010-in. epoxy gap was automatically obtained without using any jigs or shims. The pressures applied in each case were approximately 1200 psi using a 2-in. diameter hydraulic piston (3800 lbs). The pressure required to compress the indium was calculated to be 775 psi. The remaining pressure was required to overcome buoyancy of the epoxy. For building the final column the structural strength of the press was increased and pressures up to 1600 psi (5000 lbs) were applied.

The third, and last section, consisted of a 3/4-in. thick plate epoxied to a ceramic and again a .020-in. diameter indium wire was installed. The thicker plate was used as a gage for testing the flexibility strength ratio of the epoxy. This section was stacked similar to the previous section.

4. Testing

The test column cured for two weeks and then was set up on a test stand (Fig. 5). The column was enclosed with insulation (Marinite). Three 1000W heaters were installed in the enclosure. Two temperature bulbs were also installed, one on the top and one on the bottom of the enclosure. Each bulb was attached to an external temperature gage. Two thermocouples were installed, one on the ceramic and one on the aluminum baseplate. Strain gages also were installed, along the thin section of the baseplate to determine stress set up during loading and temperature changes.

A brace attached to the free end of the column held a 4-in. diameter hydraulic ram.

Loads were applied to the column via the hydraulic ram and the temperature varied to simulate air temperature changes which occur around the final column installation.

Test Results

To simulate loads on actual column the following minimum conditions were desired:

Moment-cantilevered with skirts	73,500 in-lbs
Shear- " " "	3,500 lbs
Moment- double supported with skirts	18,375 in-lbs
Shear- " " " "	2,187 lbs
Moment-cantilevered without skirts	53,000 in-lbs
Shear- " " "	2,535 lbs
Moment-double supported without skirts	13,300 in-lbs
Shear- " " " "	1,570 lbs

Period of Testing - 2 weeks varying loads and temperatures

Test	Max. Load lbs.	Max.Equiv(lbs) Moment -due to loading	Max.Equiv.(psi) Shear -due to loading	(1) Max. Stress (psi)	(2) Max. Deflect. (in.)	(3)Change Δ Air Temp. ^{o}F	Time Temp Change(hrs
1	1937	35,500	19.8	4,580	.002	33	2
2	2905	53,600	29.6	7,730	.005	42	1
3	3905	72,200	40.0	10,310	.009	45	1/2
4	5160	95,500	52.1	13,750	.016	45	1/2
5	6060	Held for 2 weeks with no noticable changes in deflection (creep).					

NOTES

(1) Information obtained from strain gage located at area of most critical loading on thin section of baseplate. These stresses developed during temperature variation. The stresses due to loading only were minor.

(2) These deflections are with respect to the baseplate and are due largely to strain on the thin area of the baseplate and partially to strain on the epoxy and intermediate aluminum rings.

(3) The temperature change of the ceramic and aluminum lagged behind the air temperature by between 3 and 4 hours on all tests. For example; on tests 3 and 4 the air temperature was held at a maximum after 1/2 hour. It then required between 3 to 4 hours to raise the column to the air temperature. Also the aluminum lagged behind the ceramic temperature by approximately 2 - 3°F.

As a final, crucial test, the test column was placed outdoors subjecting it to a temperature change of 75°F (from 70° to -5°F). The top thick plate broke the ceramic. The baseplate at the thin section developed leaks but did not develop any major fractures. The two intermediate aluminum rings showed no signs of failure.

Safety Factors - Based on maximum applied load. The column was not loaded to breaking point.

	With Skirts
Safety Factor - Shear	2.4 both ends supported
Safety Factor - "	1.5 cantilevered
Safety Factor - Moment	5.2 both ends supported
Safety Factor - "	1.3 cantilevered
	Without Skirts
*Safety Factor - Shear	3.3 both ends supported
Safety Factor - "	2.0 cantilevered
*Safety Factor - Moment	7.1 both ends supported
Safety Factor - "	1.8 cantilevered

*Expected condition for mounting is supported at both ends and without skirts.

References

1. AGS Division Technical Note 43 - S. Senator, 1/8/68
2. J. Grisoli, I. Polk, W. Schneider - Private communication
3. Memo- R. Amari, T. Sluyters 2/8/67
4. 550kV Accelerating Tube Report, CERN MPS/Int. Lin 65-3

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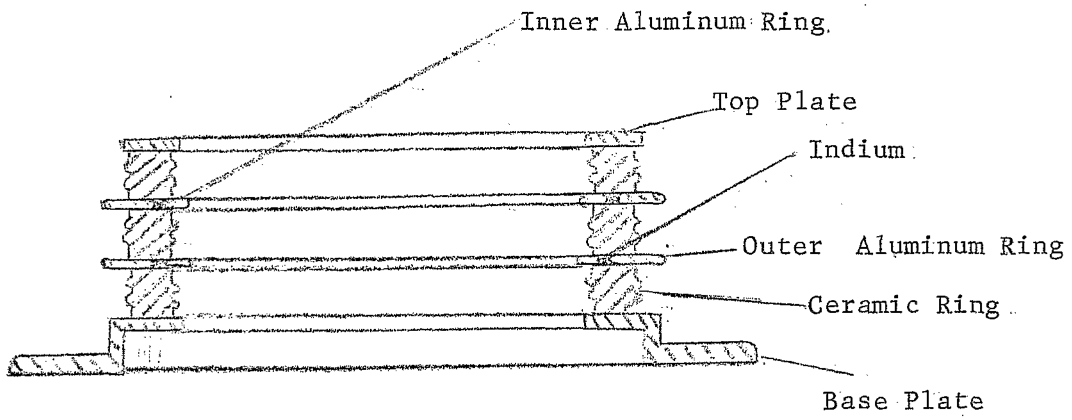

FIG. 1 - Test Column

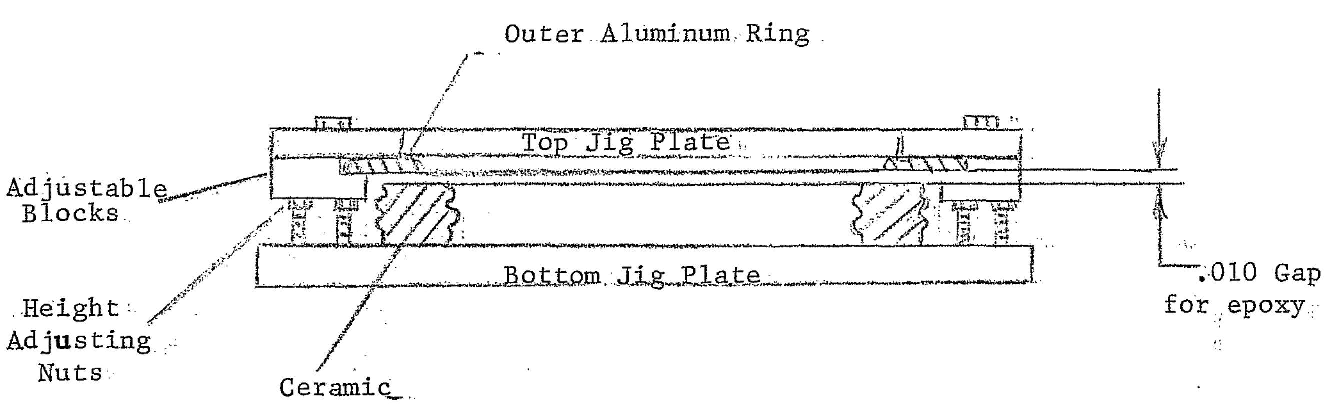

FIG. 2 - Epoxy Gap Jig

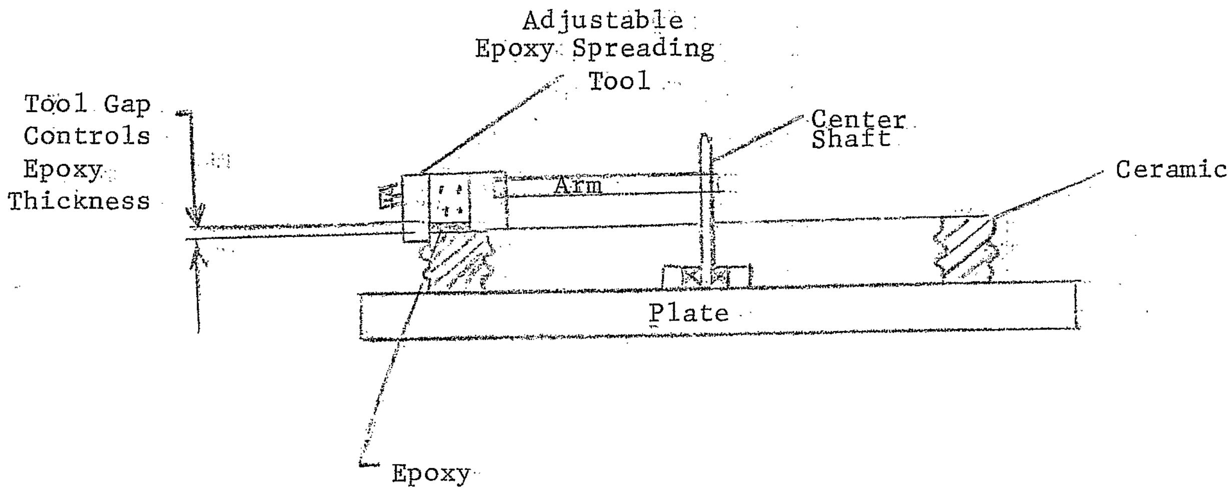

FIG. 3 - Epoxy Spreading Setup

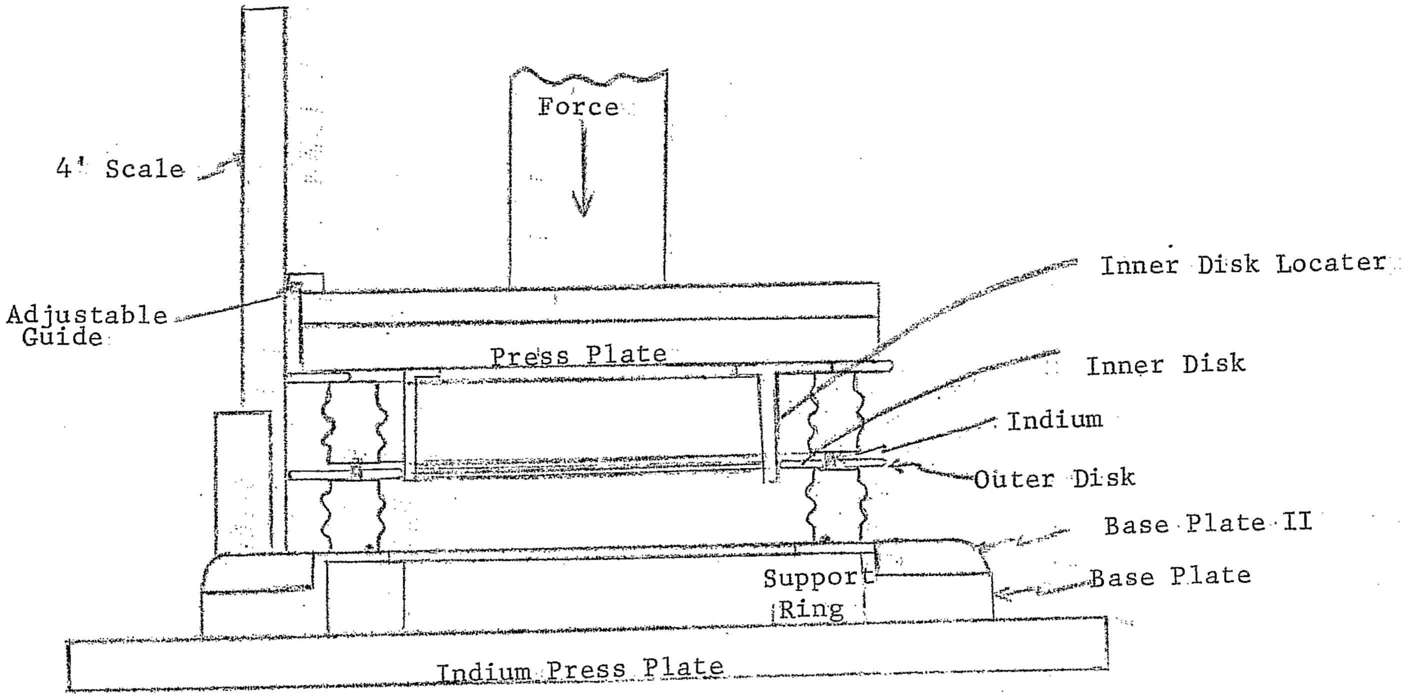

FIG. 4 - Indium Press and Assembly of Second Ceramic-Aluminum Section

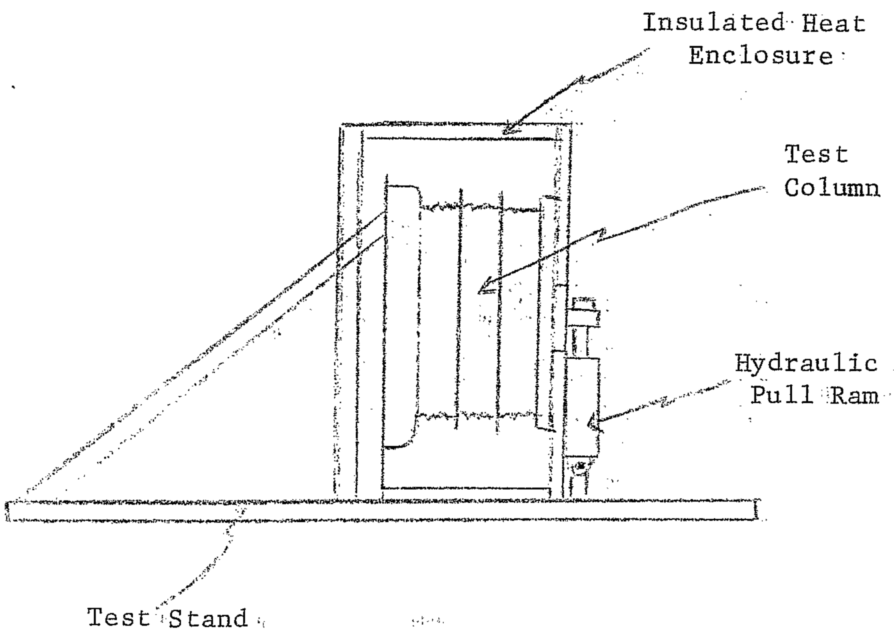

FIG. 5 - TEST SET-UP