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PROCESS DEVELOPMENT

FABRICATION OF B_4C POWDER CONTROL RODS FOR ALTERNATE DRESDEN DESIGN

August 6, 1958

J. W. Weyers

FUELS AND MATERIALS DEVELOPMENT SUB-SECTION
ENGINEERING SECTION

GENERAL ELECTRIC

ATOMIC POWER EQUIPMENT DEPARTMENT

SAN JOSE, CALIFORNIA

ENGINEERING REPORT

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FABRICATION OF B_4C POWDER CONTROL RODS

FOR

ALTERNATE DRESDEN DESIGN

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I. Summary

An alternate control rod design and prototype fabrication effort was requested as a backup for the Dresden Boron Stainless reference design. This backup was considered necessary since the material suppliers were having difficulty fabricating boron stainless plate, and the irradiation stability of control rods fabricated from boron stainless left something to be desired.

B_4C control rods were fabricated in two configurations; one type (flat blades) for VBWR, and the second type (cruciform) for the Dresden prototype.

The program consisted of design, preliminary fabrication of blackness test samples, fabrication of full size components, and inspection and/or testing.

II. Design Basis

The design criteria was established as follows:

A. Must have a minimum control rod life of five years.
B. Must have structural stability during repeated scram at 1000 psi, 600°F boiling water.
C. Must be fabricable within Dresden core tolerance requirements, and must be dimensionally stable.
D. Must cost less than Boron Stainless rod.
E. Must suffer no irradiation damage.
F. Must be blacker than 2% Boron Stainless.

III. Preliminary Fabrication and Blackness Tests

The analysis of the design parameters indicated that boron carbide powder encapsuled in stainless steel tubes with a structural cover holding the tubes into orientation might be the best approach. A blackness test sample was fabricated as shown in Figure I (Critical Assembly Control Rod Blackness Test #1).

Fabrication studies consisted of determining the correct mesh size powder to use to obtain the maximum fill density. Both -325 mesh and 14F mesh were tried with the coarser 14F mixture giving the higher fill density as shown below:

Powder Size	Wt. per 11-3/4" tube	Wt/cc	% T. Density
14F mesh	10.1 grams	1.64 grams	66
-325 mesh	8.0 grams	1.30 grams	53

Tubes were filled with powder vibrated with a small electric vibrator marking to ı, and tube ends were plugged with corks. Periodic checks indicated that no settling or stratification occurred once the tube was filled in this manner, when the 14F mesh powder was used. The finer -325 mesh powder did not flow freely and sometimes "hung up" in the fill funnel.

Blackness testing was done in the VAL critical assembly facility. The slab (Figure I) was compared with the same size slab of cadmium, 2% Boron stainless, and the slab shown in Figure II. The slab shown in Figure II was fabricated and tested to determine the effect of closing the "window" between the poison areas with 2% boron stainless strips.

Blackness test results were as follows:

Geometry and Material	Relative Blackness
A. Cadmium slab	1
B. 2% Boron Stainless slab	1.13
C. B_4C per Figure I	1.11
D. B_4C per Figure I corrected for 1/4" undersize in length and 1/4" undersize in width	1.17
E. B_4C per Figure II	1.17351

IV. VBWR Control Rods

Replacement control rods were needed for VBWR because the boron carbide pressed blocks used for startup showed evidence of excessive breakdown under water flow and irradiation. A program was established to design and fabricate the replacement rods using the B_4C powder-tube configuration.

A. Design - The detail design is shown on the attached Drawing No. 612D321 - VBWR B_4C Powder Control Rod. The design had to be detailed such that the rod would have the same outside structural shape as the original control rods, attach to existing control rod drives, have approximately 42" of poison height, and not weigh in excess of 100 lbs.

The blackness tests (see paragraph III above) indicated that B_4C powder in stainless tubes had sufficient poison, and the concept was incorporated in the detail design.

Pressure Calculation - Using 1800 psi yield strength at 600°F for 304 S.S. welded and drawn tubing, .020 wall thickness, .250 O.D., an internal pressure of 3000 psi can be contained. Internal gas buildup due to fission of boron was calculated at 800 psi, maximum for a 5-year life.

A heliarc (T.I.G.) plug weld was used to seal the tube ends, and a test pressure (at room temperature) of 3000 psi was used as a weld proof test on each tube.

Coolant - Steam or water drain holes in the outside skin were added to maintain safe operating temperatures of the tubes, and to serve as pressure equalizers on both sides of the skin.

B. Fabrication - Standard sheet metal fabrication techniques were used on the structural components. Loading tubes with powder was performed as in paragraph III above, using a funnel and vibrator to obtain the fill density of 1.6 gm per cc minimum. Welds on tube ends were tested at 3000 psi hydrostatic, and were mass spectrometer leak tested. Only seven leaks were found, and these were, where the B_4C powder was too close to the end plug, thus contaminating the molten weld pool.

C. Costs and Schedules - Six rods were designed and built on D.O.S. 120-064 in the two-week period between March 7 and March 21, 1958, at a cost of $5,700.

V. Dresden Alternate Design

Using the design parameters as outlined in paragraph II, above, and the design and fabrication experience gained from producing the blackness test samples and VBWR prototypes, the design evolved as depicted on the enclosed Drawing No. 141F569 - Alternate Dresden Control Rods. Alternate 3 was chosen for fabrication since no special bending or welding fixtures would be required. It should be noted that alternate #1 could also be easily fabricated should physics analysis show that a poison center or core is required.

VI. Fabrication

As stated in paragraph V, above, no special bending or welding fixtures were required, and standard sheet metal fabrication techniques were used. Because of the tube length, (9 ft long), a special mass spectrometer test fixture had to be built.

A. Fabrication Experience on Original Design - Alternate 3 was selected on Drawing No. 141F569 to be built on D.O.S. 120-067. Detail cross section is shown in Figure III. Excessive warpage and distortion occurred during fusion welding the sheath to the center bar. The assembly was redesigned as shown in Figure IV.

B. Fabrication Experience on Redesign - The center bar was lengthened, on each web, so that a resistance weld joint could be used to eliminate the distortion during fusion welding as described in paragraph VI-A above.

C. Inspection Results - Inspection results are shown in Table I, attached.

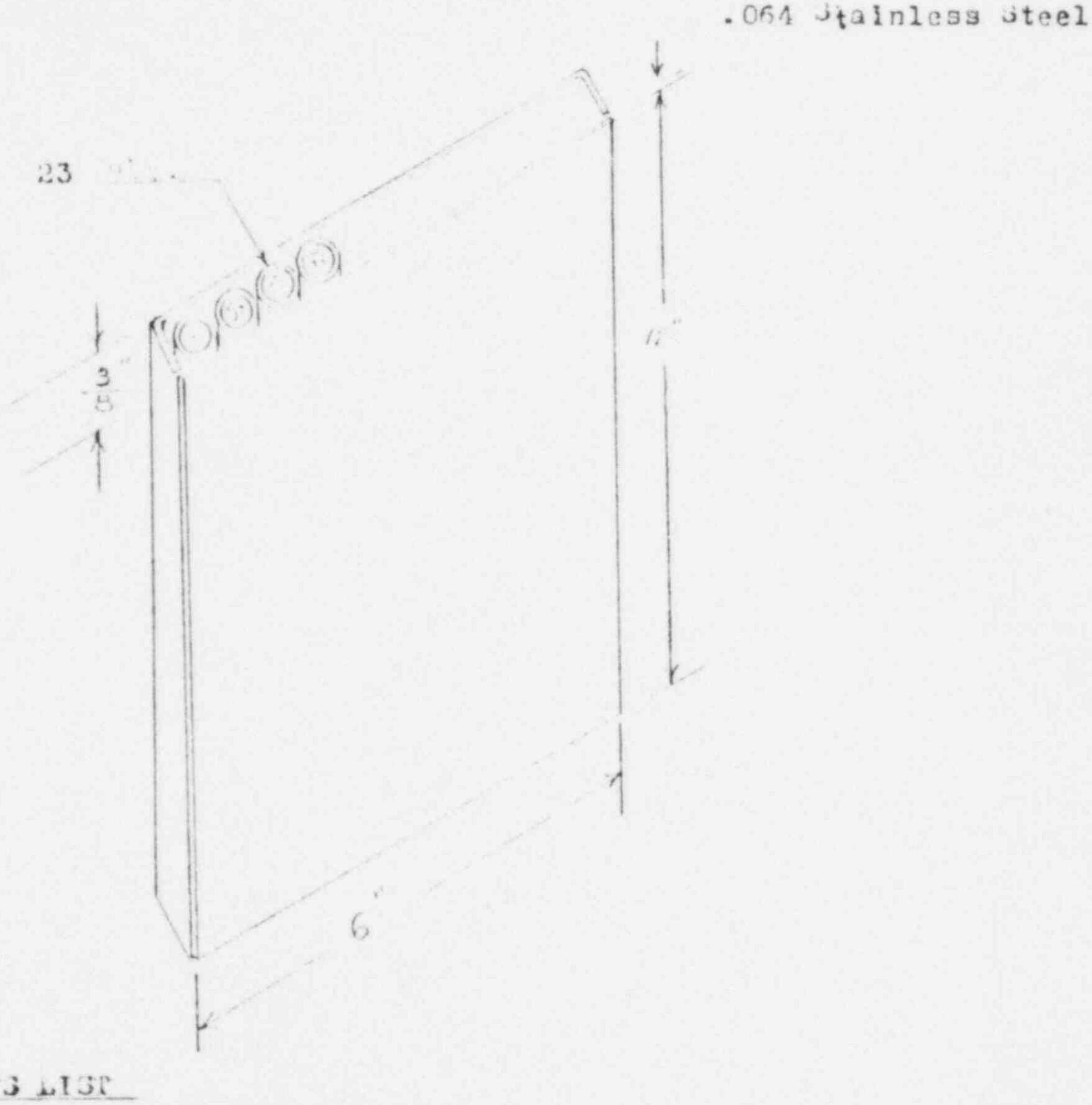
D. Costs - The cost limitation on the D.O.S. was $3,500 of which approximately $2,500 was used.

VII. Irradiation Test Results

Four VBWR rods were inserted at VAL on May 1, 1958, and have been used as shut-down control, only. During operation, these rods are above the core in the steam zone. Several 12-inch tubes filled with B_4C powder are now awaiting a license permit before being inserted into the core for irradiation testing to accurately measure internal gas buildup.

FIGURE 1

CRITICAL ASSEMBLY CONTROL ROD BLACKNESS TEST - PIECE # 1



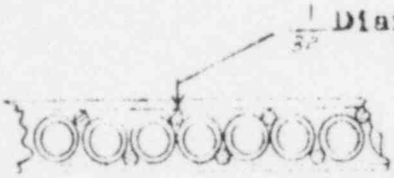
PARTS LIST

23 pieces ¼" O.D. x .020" wall x 12" long 304 S.S. tubes
1 piece .060" thick 304 S.S. skin and cover
46 corks 3/16" Diam., 1/8" long
232 grams B_4C powder 14F mesh

FIGURE II

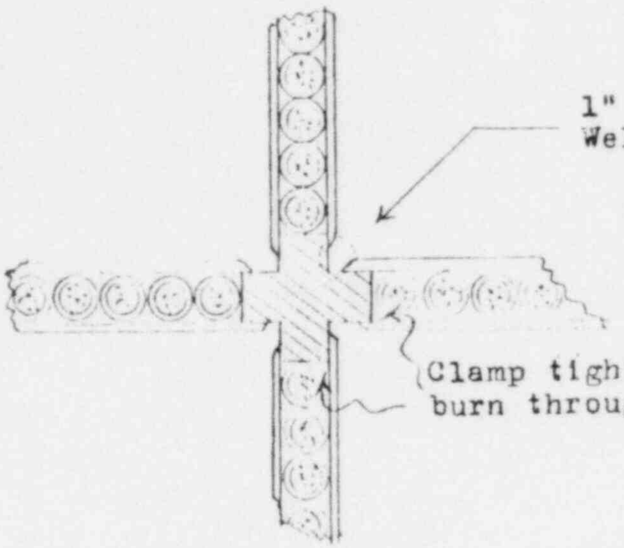
CRITICAL ASSEMBLY CONTROL ROD BLACKNESS TEST - PIECE # 2

Test was run to determine the effect of closing the poison gap between the B_4C powder in the tube type configuration shown in Figure I,

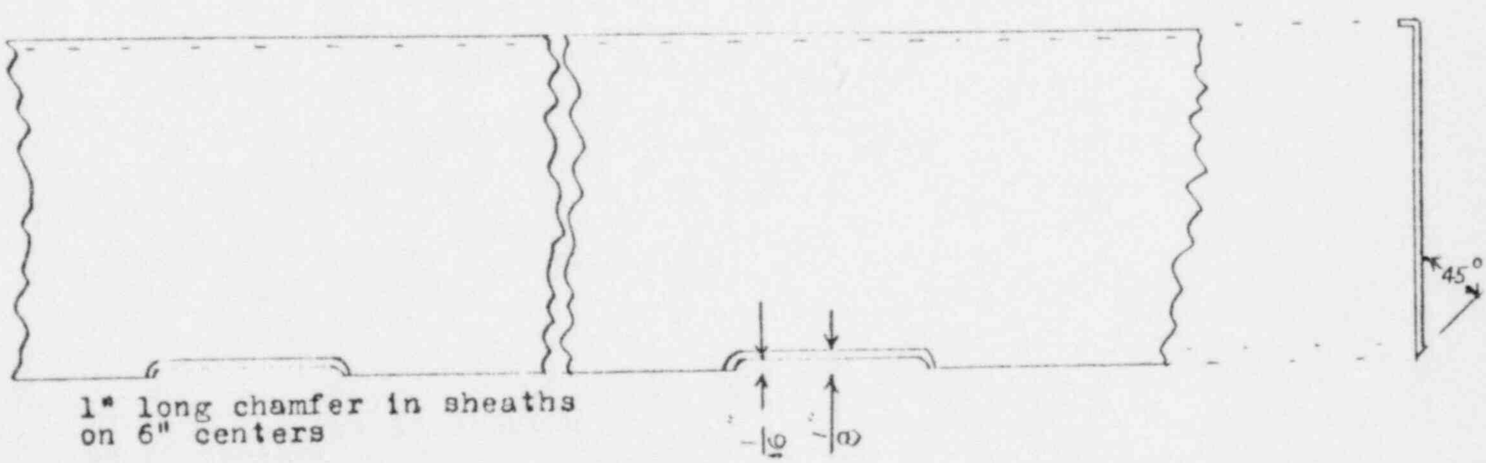


22 wire rods were added to the test piece (see Figure I)
Total weight of rods - 120 grams.

FIGURE III ORIGINAL DRESDEN PROTOTYPE DESIGN - DWG. 141F569a



CROSS SECTION OF CONTROL ROD AT WELD AREA



Line up grooves space in all 8 pieces before grinding bevel or chamfer.

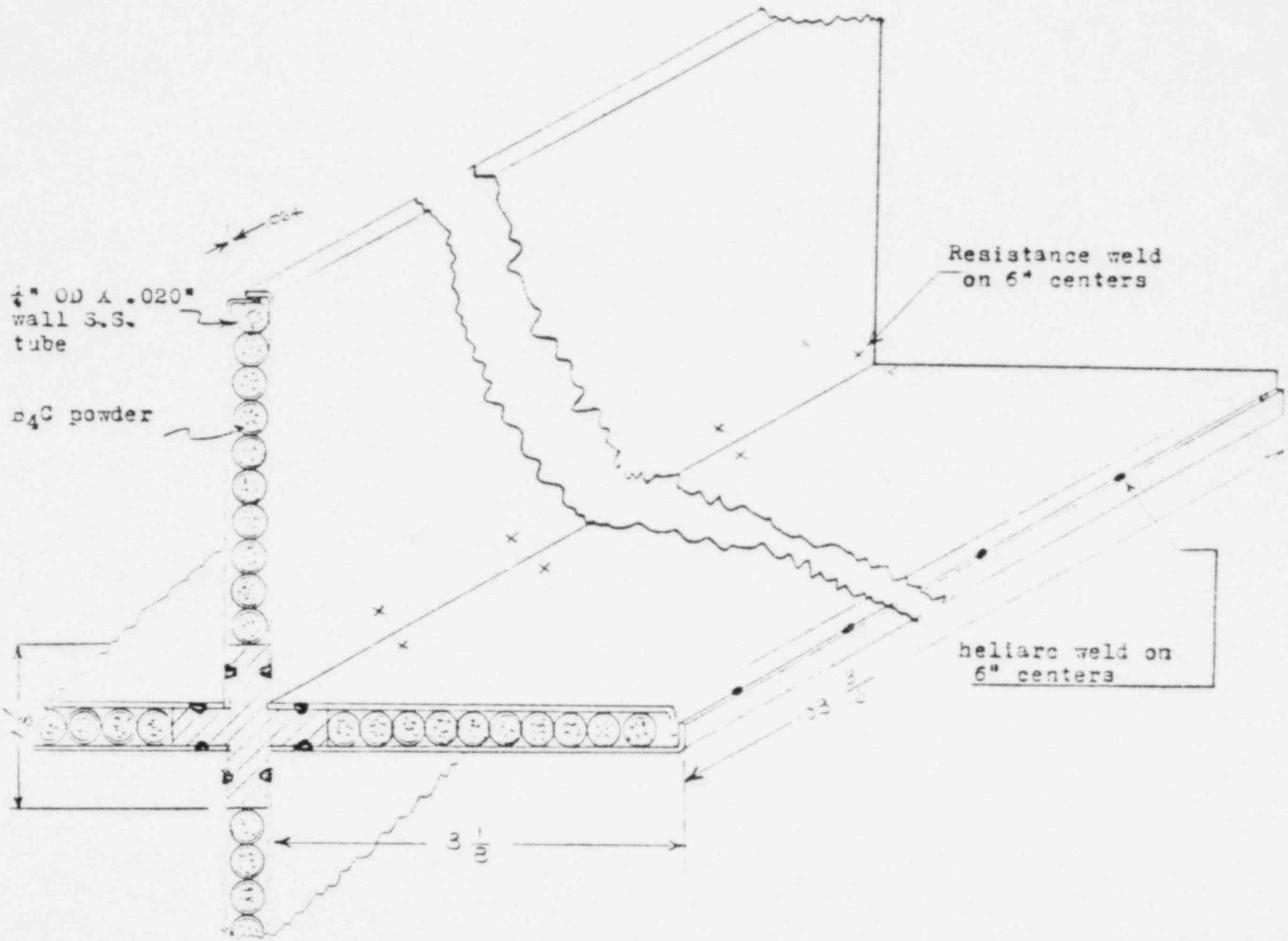
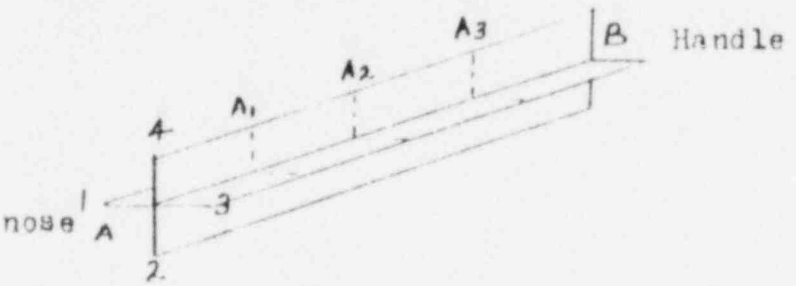


FIGURE IIII BORON CARBIDE DRESDEN PROTOTYPE CONTROL ROD

TABLE V

BORON CARBIDE RESISTANCE WELDED CONTROL ROD

Measured on surface plate in building 301, accuracy of measurement due to surface irregularity, etc, is ± .010".



Tolerances on Dwg.

Bow - .062"
Angularity ± ¼ degree or ± .014"at extreme ends of blade
Twist - .062"

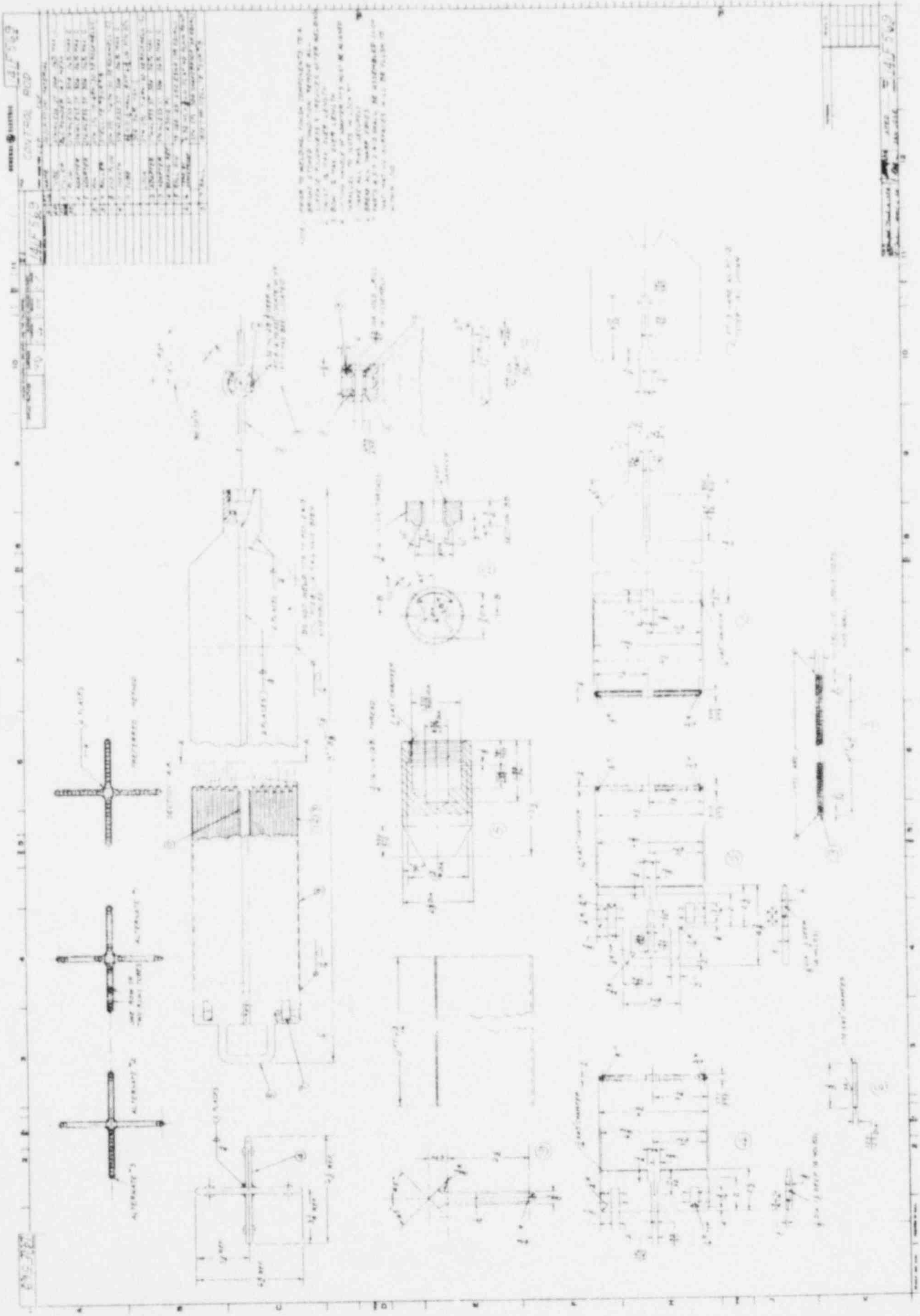
Deviation from flat	Blade # 1	2	3	4
A	0	0	-.039	.021
A_1	.015	.046	-.022	0
A_2	.015	-.004	0	0
A_3	-.011	-.010	-.027	-.065
B	0	0	-.066	-.069

Angularity	Blades Measured 1-4	2-3	1-2	3-4
A	-.009	-.008	0	.004
A_1	.017	.018	.022	.012
A_2	-.030	.008	.018	.010
A_3	.010	.010	.015	.019
B	0	.002	0	.002

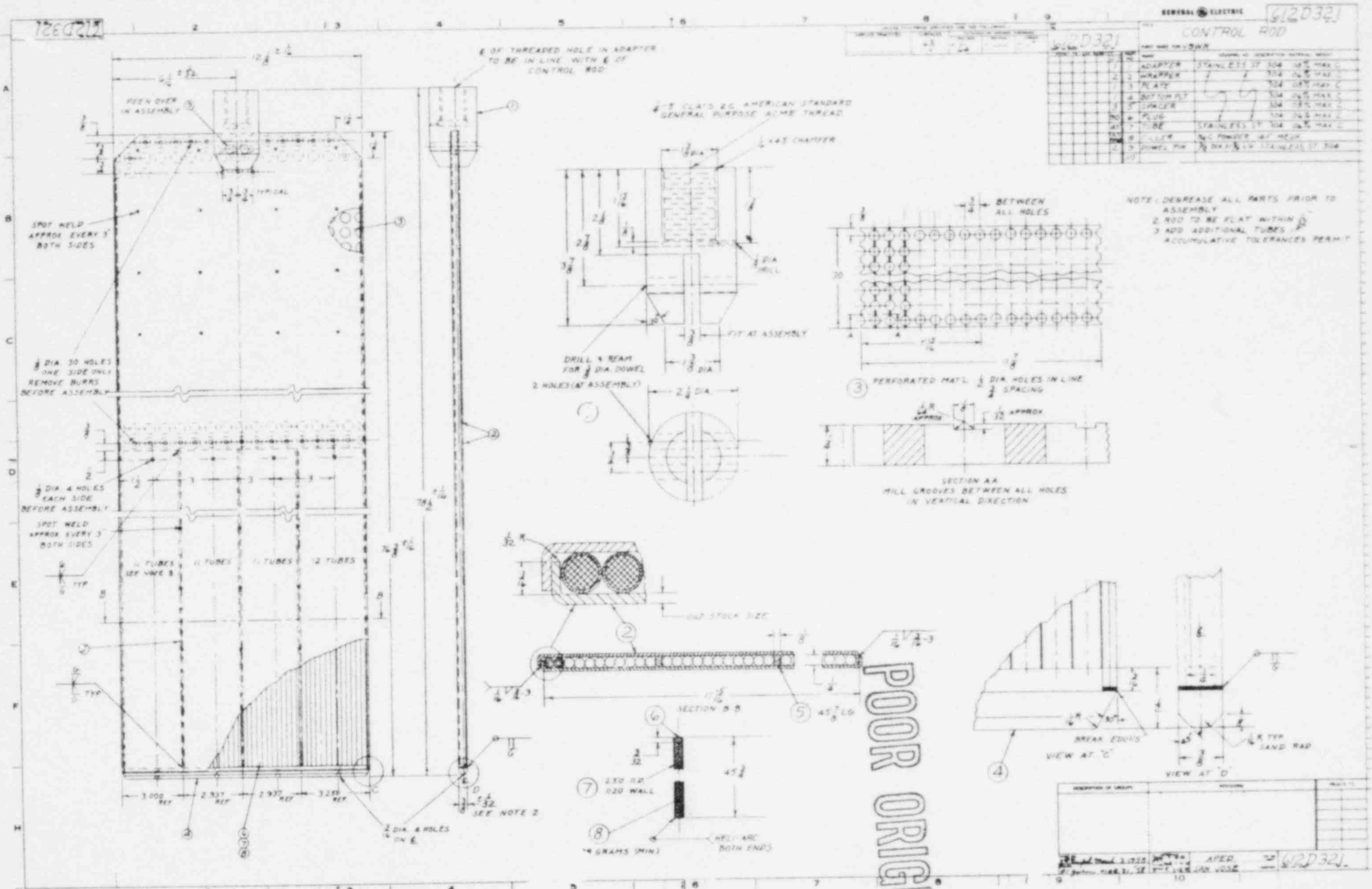
Angularity in thousands of an inch measured at extreme ends of blade.

Twist

Twist measured - .051"



POOR ORIGINAL


GENERAL ELECTRIC
612D321
CONTROL ROD
ADAPTER
WRAPPER
PLATE
BOTTOM PLT
SPACER
PLUG
TUBE
FILLER
DOWEL PIN
STAINLESS ST 304
B4C POWDER 100 MESH
NOTE: DEGREASE ALL PARTS PRIOR TO ASSEMBLY
2. ROD TO BE FLAT WITHIN
3. ADD ADDITIONAL TUBES IF ACCUMULATIVE TOLERANCES PERMIT
℄ OF THREADED HOLE IN ADAPTER TO BE IN LINE WITH ℄ OF CONTROL ROD
PEEN OVER IN ASSEMBLY
TYPICAL
SPOT WELD APPROX EVERY 3" BOTH SIDES
DIA. 30 HOLES ONE SIDE ONLY REMOVE BURRS BEFORE ASSEMBLY
DIA. 4 HOLES EACH SIDE BEFORE ASSEMBLY
11 TUBES SEE NOTE 3
11 TUBES
11 TUBES
12 TUBES
TYP
3.000 REF
2.937 REF
2.937 REF
3.259 REF
DIA. 4 HOLES ON ℄
SEE NOTE 2
GENERAL PURPOSE ACME THREAD
45 CHAMFER
DRILL
FIT AT ASSEMBLY
DRILL & REAM FOR DIA. DOWEL
2 HOLES (AT ASSEMBLY)
BETWEEN ALL HOLES
PERFORATED MAT'L DIA. HOLES IN LINE SPACING
APPROX
SECTION A-A
MILL GROOVES BETWEEN ALL HOLES IN VERTICAL DIRECTION
OLD STOCK SIZE
SECTION B-B
.250 O.D. .020 WALL
GRAMS (MIN)
HELI-ARC BOTH ENDS
BREAK EDGES
VIEW AT "C"
R TYP SAND RAD
VIEW AT "D"
APED
SAN JOSE
612D321