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RADIATION LABORATORY

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TESTS ON A HIGH CURRENT R.F. JOINT IN VACUUM

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July 25, 1951

Berkeley, California

TESTS ON A HIGH CURRENT R.F. JOINT IN VACUUM

I Introduction

An R.F. joint tester was designed to determine the relative heating and tendency toward arcing at high RF current density (100 amps/linear inch) of a 12" diameter circular copper butt joint in vacuum with several types of inserts and at various amounts of axial loading, ranging from a very small contact pressure to one of 1400 pounds per linear inch of joint.

To obtain the necessary high RF current a coaxial line oscillator, operating at 11 megacycles and supplying 50 KW of power was used. So that excessively high voltages could be eliminated, capacitive loading of the line at the 10° ($\lambda/36$) point was used. A brief description of the oscillator and associated equipment appears in the appendix.(1)

II Procedure

The joint under study was made in the inner conductor of the coax line, with five viewing ports in the outer conductor. The volume surrounding the joint was evacuated by an oil diffusion pump to a pressure of about 10^{-5} mm. Hg. The axial load (contact pressure) was applied to the joint by eight 1/2" - 20 bolts through a heavy pressure plate, the load being measured by torque wrench.(2) Uneven loading was accomplished (for certain of the tests described(3)) by clamping the plate on only one side and jacking up on the other side with a hydraulic jack.

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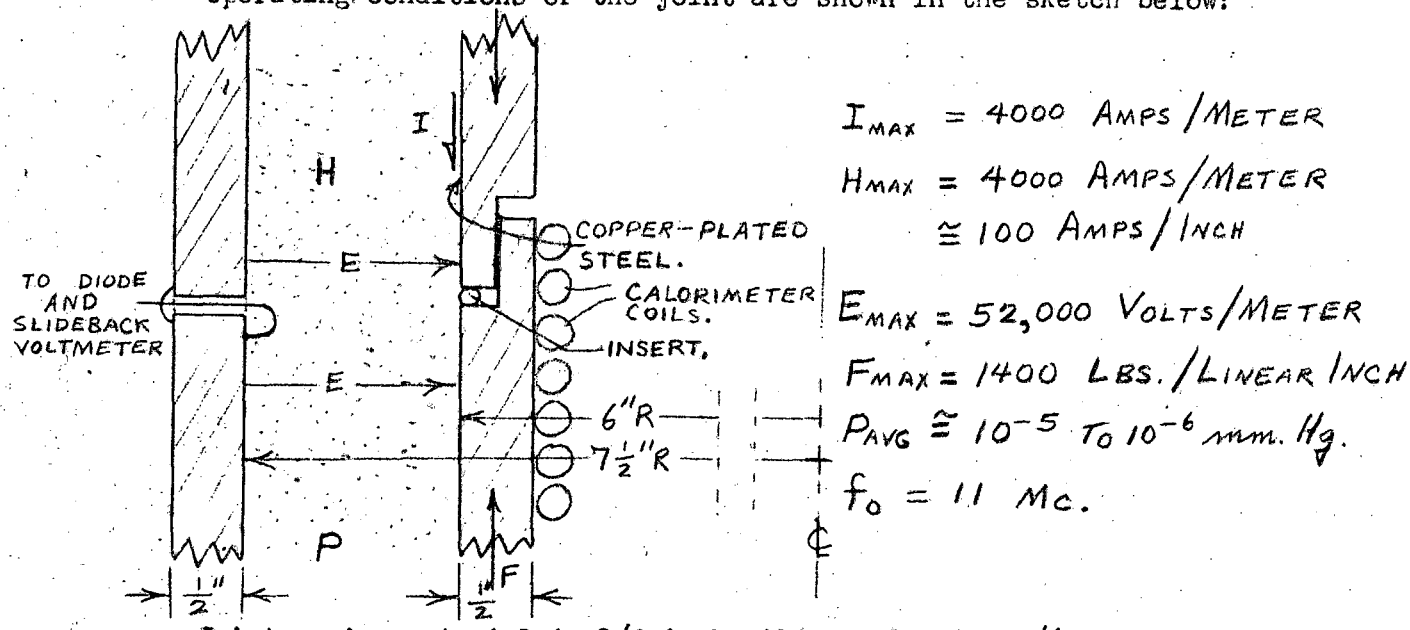
(1) Page 7 below

(2) Appendix, page 8

(3) See pages 3, 4 and 8

Operating conditions of the joint are shown in the sketch below:



Joint region material is 1/2 inch mild steel, with 1/64 inch copper plating. Surface cleaned by emery paper.

The current density was measured by inserting a calibrated loop through the vacuum wall of the outer conductor directly opposite the joint (as shown above) and calibrating the associated metering circuits to read current density on the inner conductor.(4) To check the loop measurements a peak-reading RF voltmeter was employed across the upper end of the line (high voltage end) and independent calculations of current density made.(5)

The joint heating was measured by calorimetric methods. Cooling coils were soldered to the back surfaces of all cavity walls to dissipate about 50 KW of I^2R heat. The coils behind the joint region were isolated and thermometers inserted into the water line upstream and downstream. The flow rate was metered by calibrated flask and stopwatch. The results were expressed in watts.(6)

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(4) Appendix, page 8

(5) Appendix, page 8

(6) Appendix, page 9

Visual observations of the cavity and joint area were made through the viewing ports.

III Tests Made

1. "Shakerproof washer" insert(7)

   (a) Runs of joint heating as a function of RF current density at constant contact pressure, plotted on graph 1.

   (b) Runs of joint heating as a function of contact pressure at constant current density, plotted on graph 2.

   (c) Long time run at constant current and contact pressure, to observe any tendency of the joint to fatigue or change resistance. Plotted on graph 3.

   (d) Visual observation for joint heating and arcing as contact pressure and current were varied, was made. Uneven contact pressure(8) also was applied.

2. B and S #12 Copper Wire Insert (bent into a loop)

   (a) Runs of heating as a function of RF current, as above.

   (b) Runs of heating as a function of contact pressure, as above.

   (c) Visual observations, as above.

3. Simple Butt Joint (no insert)

   (a) Runs of heating as a function of RF current, as above.

   (b) Runs of heating as a function of contact pressure, as above.

   (c) Visual observations, as above.

   (d) Complete separation of the horizontal contact surfaces, to determine

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(7) UCRL Sketch 200-2691 (R. Olson)

(8) Page 1 above and page 4 below

if contact between the vertical centering sleeves (see sketch, page 2 above) bypasses the current around the insert.

4. A new type insert, the tests of which may be completed by the time of writing of this report.

IV Conclusions

1. Run Series No. 1 ("shakeproof washer")

   (a) Relative heating level (at 90 amps/in) 1350 watts. (NOTE: Calorimeter has been recalibrated since the preliminary runs of April 6, 1951)

   (b) Heating is essentially independent of contact pressure.

   (c) No fatiguing of insert or joint was apparent during more than twenty hours of continuous operation. (Except for short intervals off to repair equipment.)

   (d) No joint arcs appeared under normal conditions. Severe arcing, which finally melted the insert, occurred when extremely uneven clamping pressure was applied. "Extremely uneven" means clamping one side of the joint and jacking up on the other until the surfaces have a crack (1/64") between them.

2. Run Series No. 2 (#12 copper wire insert)

   (a) Relative heating level (at 90 amps/in) 620 watts.

   (b) Heating dependent on clamping pressure up to about 100 lb/in and then independent up to limit of clamping bolts. (1400 lb/in.)

   (c) No arcs observed except with considerably uneven clamping pressures. With extremely uneven clamping pressures moderately large joint arcs occurred and the insert became cherry red hot, expanding clear out of the joint crack. (linear heat expansion of wire.)

3. Run Series No. 3 (simple butt joint: no insert)

   (a) Relative heating level (90 amps/in) 680 watts.

   (b) Heating slightly dependent on clamping pressure up to about 40 lb/in and then independent on up.

   (c) Joint arcs present regardless of clamping pressure at currents above about 75 amps/in. The arcs were small white sparks across joint crack and were very intermittent. No red heat could be seen even with extremely uneven clamping pressure, but severe arcing occurred, throwing out drops of molten copper.

   (d) When the joint was jacked apart about 1/64 inch no oscillations could be established, indicating any incidental contact through the centering sleeve was of a very high resistance, so that appreciable current could not flow through this alternate path.

4. Tests of a proposed new type of joint to combine the good qualities of joints 1 and 2 have not been completed, but results may be available in the near future.

5. Incidental to the joint tests, much data concerning reliability of some components in high power, high ambient temperature applications was compiled.

Vacuum capacitors VC-100A (Amperex) gave much trouble with small internal arcs plating copper on the glass. These were run with watercooled sockets and 1/2 HP of blower air, with about 95 amps of current.

Eimac RF finger contact strips as sockets for VC-100A's were wholly inadequate at high currents and had to be replaced by more rigid clamp type sockets.

The machine has given a great deal of difficulty with component failures, due to the large voltages and currents produced. Approximately 90% of the time has been spent maintaining the joint tester.

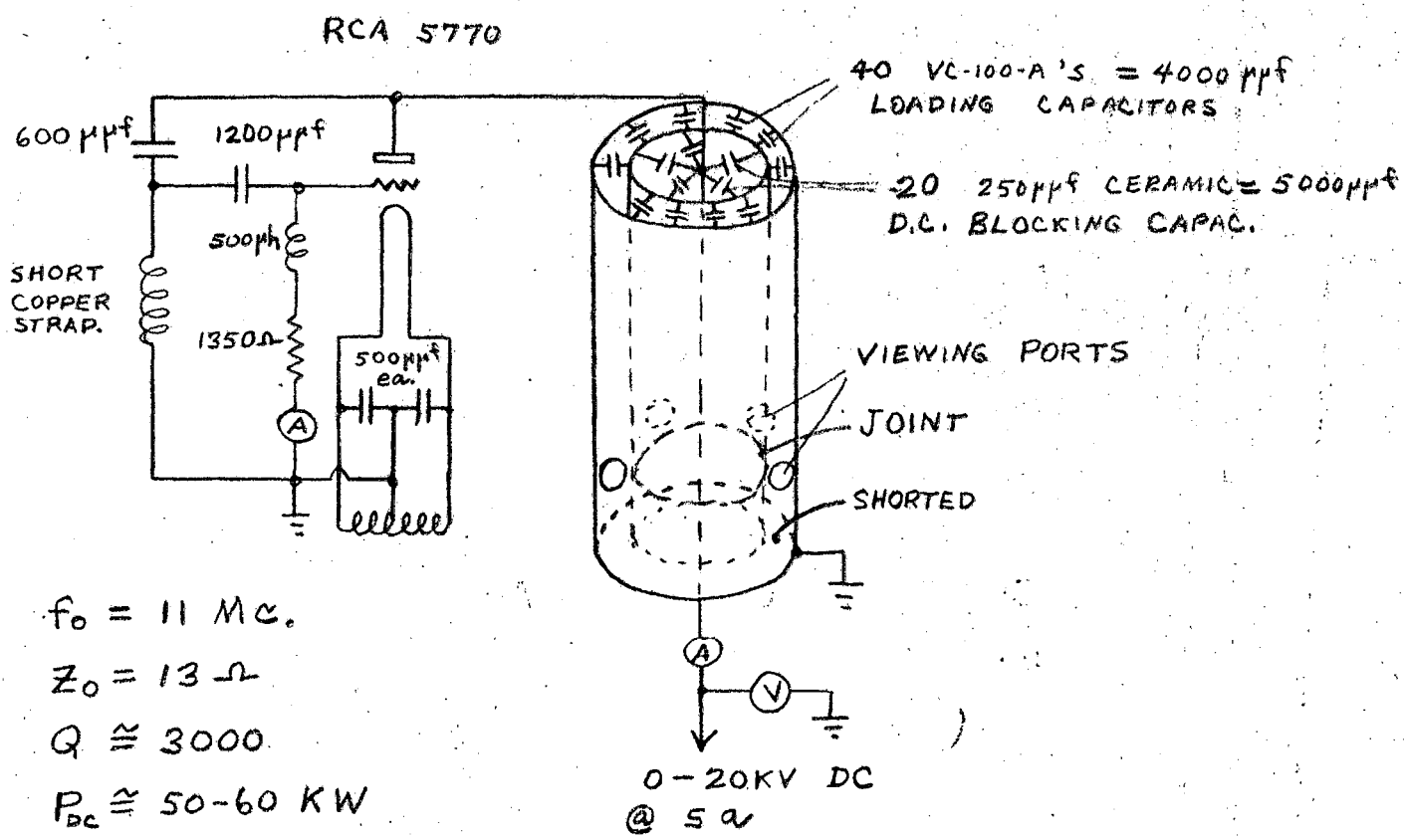
V Graphs

Performance curves have been explained in the text above.

VI Appendix

A. Footnotes

(1) Brief description of oscillator



$f_o = 11$ Mc.

$Z_o = 13\ \Omega$

$Q \cong 3000$

$P_{DC} \cong 50\text{-}60$ KW

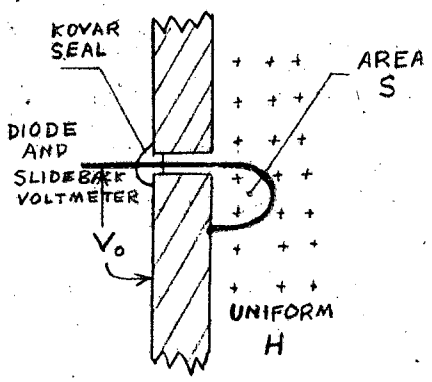
(2) Clamping pressure, determined by torque wrench:

F (lb/in) = 29 T (lb-ft.)

<u>Bolts, Nuts and Screws</u>, Lampson and Sessions Co. 1944, p. 152.

(3) See page 3 and 4 above.

(4) <u>RF loop calibration</u>



$$V_o = \oint E \cdot dl = \int_S \nabla \times E \cdot dS = \int_S -\frac{\partial B}{\partial t} \cdot dS = -j\omega\mu H S$$

I_J = JOINT CURRENT DENS. = H = AMPS/METER

$$= \frac{V_o}{-j\,\omega\mu_0 S} = \frac{V_o}{-j(2\pi)(11\times10^6)(4\pi\times10^{-7})(87\times10^{-6})}$$

$$\boxed{I_J = j\ 132\ V_o}$$ FOR THIS EQUIPMENT

I_J READ DIRECTLY ON A CALIBRATED PANEL METER.

(5) <u>Peak-reading RF voltmeter calibration</u>

V = VOLTAGE ON A SHORT-CIRCUIT LINE = $Z_0 I \sin \beta l$

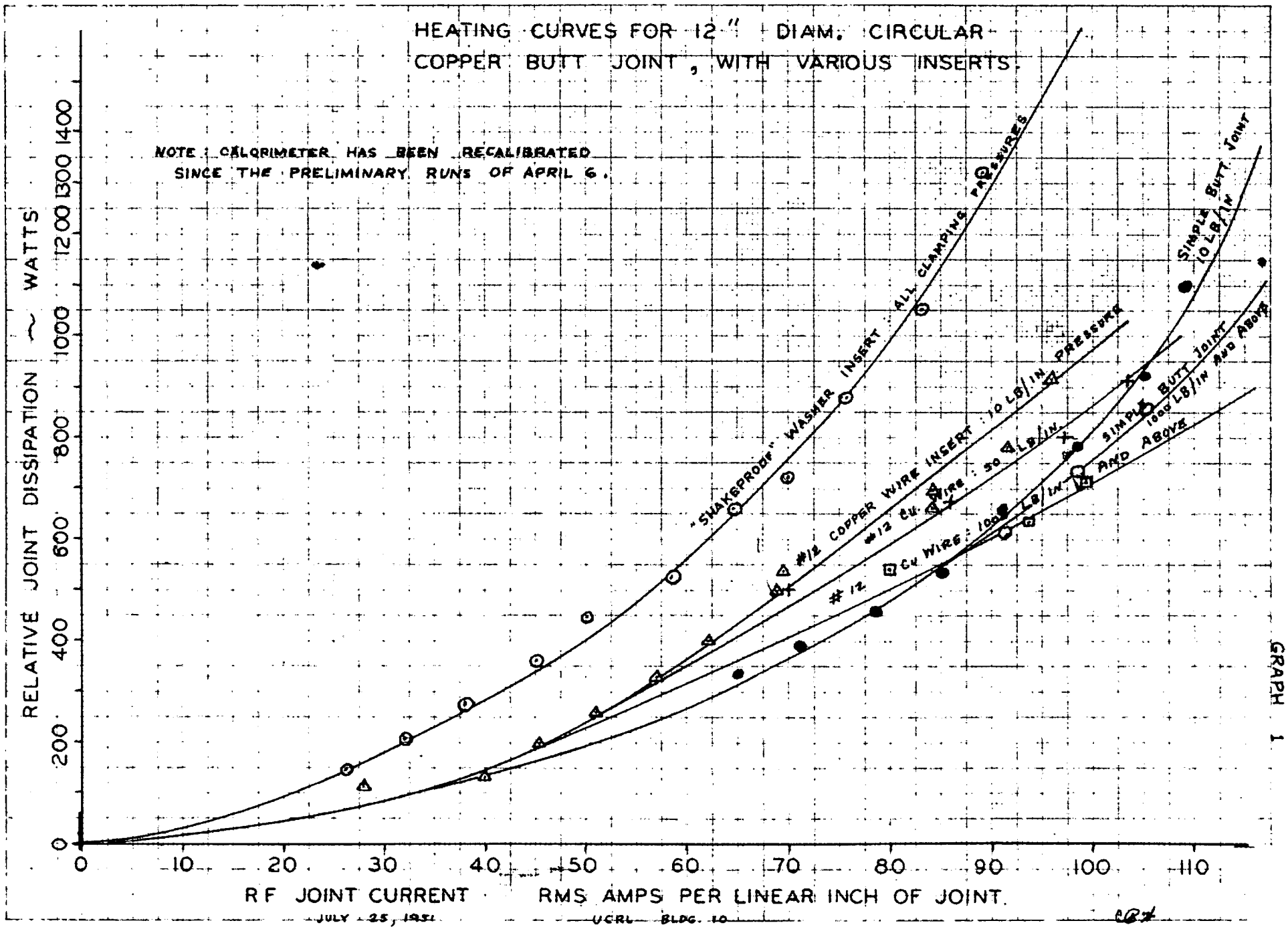
$$I = I_J = \frac{V}{Z_0 \sin \beta l} = \frac{V}{(13.5\,\Omega)(\sin[13.2][.84])} = \boxed{.385\ V}$$

I_J READ DIRECTLY ON A SECOND CALIBRATED PANEL METER.

The two methods of measurement compared within about 10% at all times.

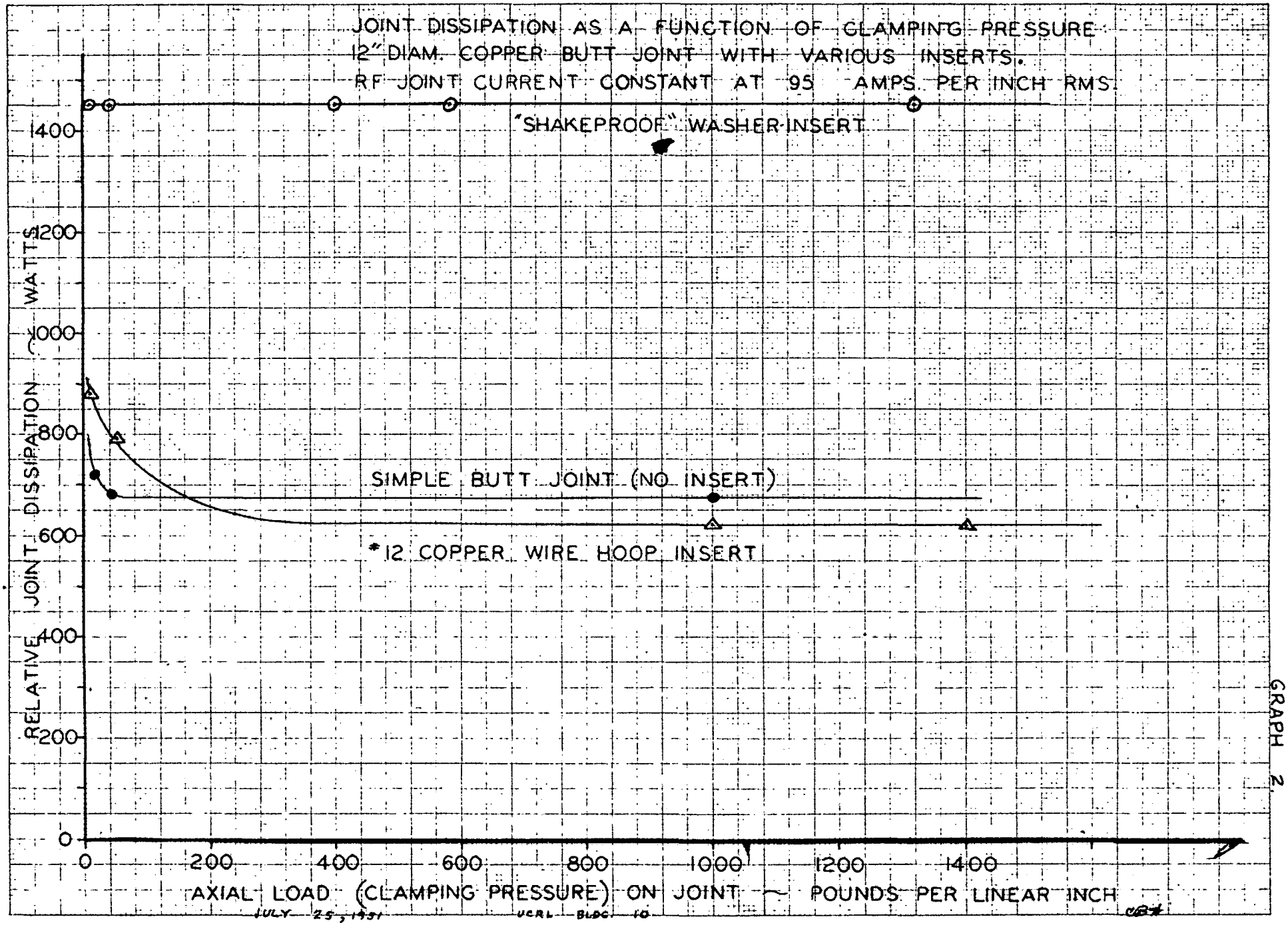
(6) Calorimetric Calibration

(a) $P\ (\text{watts}) = 263\ (\Delta T)\ (W)$ (Handbook of Chemistry and Physics)
$\qquad\qquad\qquad


HEATING CURVES FOR 12" DIAM. CIRCULAR COPPER BUTT JOINT, WITH VARIOUS INSERTS.
NOTE: CALORIMETER HAS BEEN RECALIBRATED SINCE THE PRELIMINARY RUNS OF APRIL 6.
"SHAKEPROOF" WASHER INSERT ALL CLAMPING PRESSURES
#12 COPPER WIRE INSERT 10 LB/IN PRESSURE
#12 CU. WIRE: 50 LB/IN.
#12 CU WIRE: 100 LB/IN AND ABOVE
SIMPLE BUTT JOINT 10 LB/IN
SIMPLE BUTT JOINT 100 LB/IN AND ABOVE
RELATIVE JOINT DISSIPATION ~ WATTS
0
200
400
600
800
1000
1200
1300
1400
0
10
20
30
40
50
60
70
80
90
100
110
RF JOINT CURRENT RMS AMPS PER LINEAR INCH OF JOINT.
JULY 25, 1951
UCRL BLDG. 10

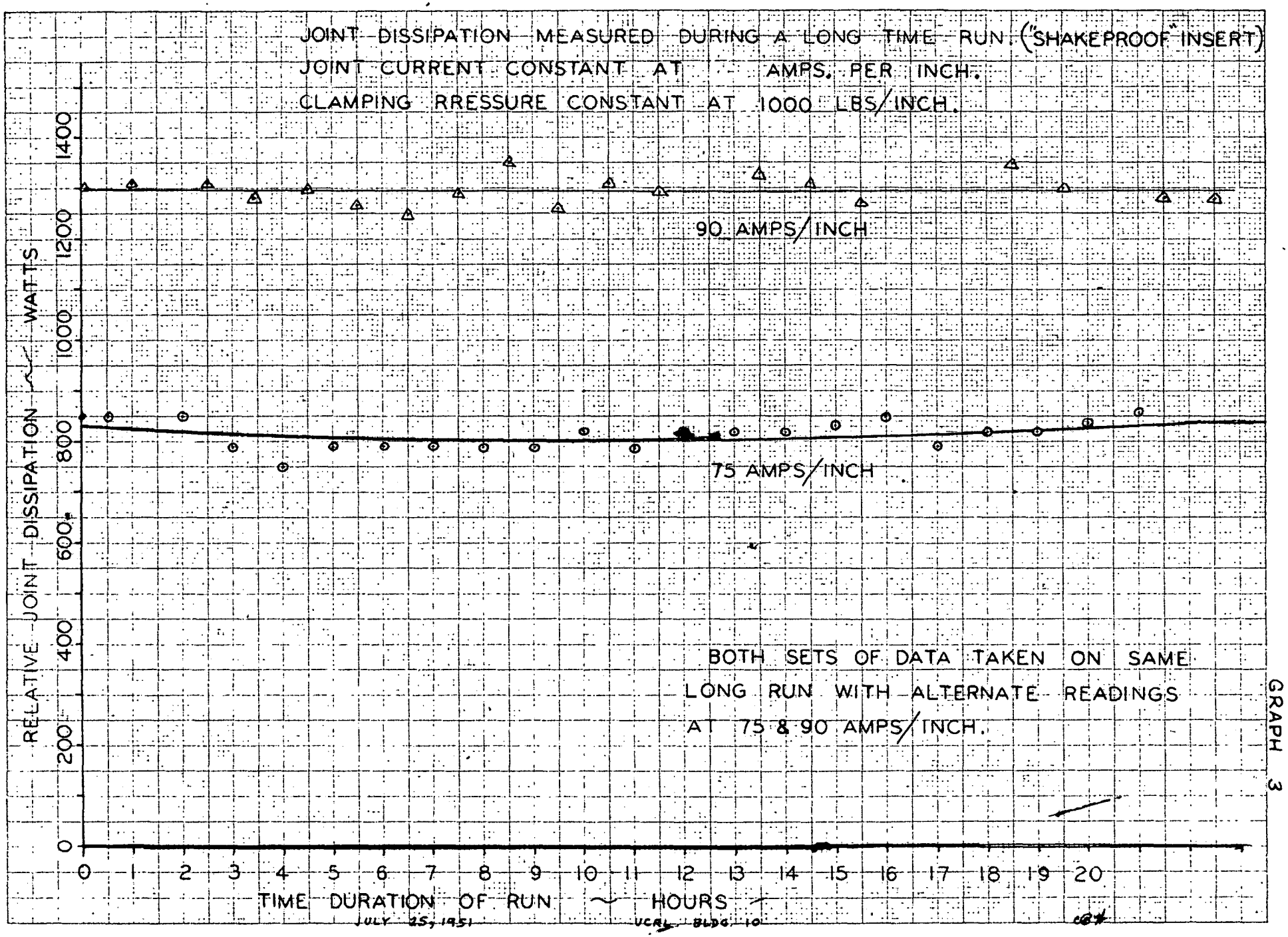
GRAPH 1

KEUFFEL & ESSER CO.



GRAPH 2

359-146 KEUFFEL & ESSER CO.
Millimeters, 5 mm lines accented, on fine heavy.
MADE IN U.S.A.



GRAPH 3

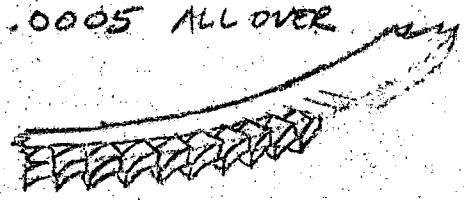
UCRL 1429

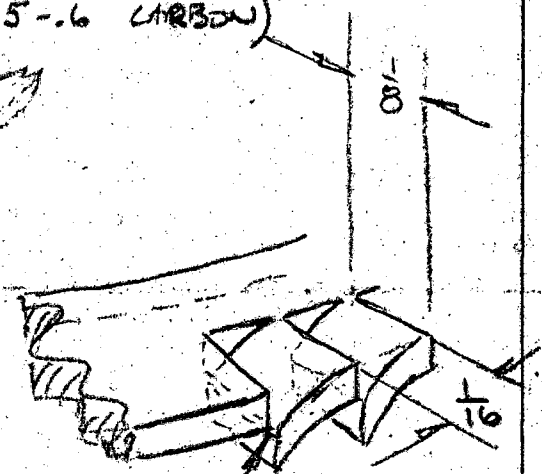
SUBJECT	SKETCH	JOB ORDER INFORMATION	
JOINT TESTER	RADIATION LABORATORY UNIVERSITY OF CALIFORNIA - BERKELEY	JOB NO. 200-10	TAG NO.
DRAWN BY R OLSON #254		SERIAL NO.	NO. REQD. 4
DATE 10-24-50 / BUILDING NO. 51 / ROOM NO.	APPROVED BY / DATE	DATE ISSUED	DATE REQD. 3 NOV 50
		DELIVER TO OLD CANTEEN-GOW BLDG 10	

CONTACT RING MAKE 4 SHEET, 20 GA (.0359), COLD ROLLED STEEL

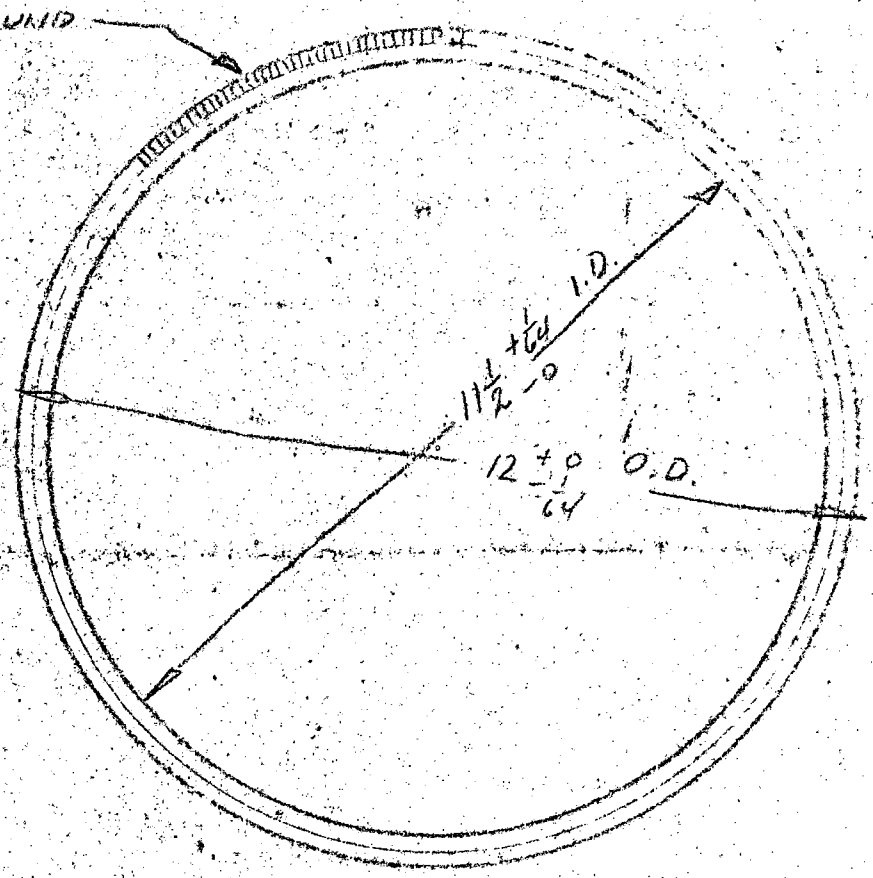
PACK HARDEN TO ROCKWELL C 30-40 (.5-.6 CARBON)

SILVER PLATE .0003-.0005 ALL OVER





PUNCHED SERRATIONS ALL AROUND



NO SCALE

HOLD FLAT TO WITHIN 1/8

SKETCH NUMBER 200-2691