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National Research Corporation

N.R.C. Project No. 42-1-121

INVESTIGATION OF ADHESION

AND COHESION OF METALS

IN ULTRAHIGH VACUUM

First Quarterly Progress Report
September 15, 1961

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Contract No. NAsr-48
Contract Period - June 15, 1961 to June 30, 1962

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Submitted to:

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9/20/61

ABSTRACT

Apparatus for the measurement of cohesion has been modified and calibrated in preparation for initial tests on O.F.H.C. copper by the fracture-rejoin method proposed.

INTRODUCTION

This is the first quarterly report on this project and covers the period 15 June to 15 September 1961. The preparatory work to be described is based on Proposal No. Q42-1019 of March 2, 1961 with Scope amended by the revised Work Statement in Proposal No. Q42-1065A of May 26, 1961.

The original apparatus and tabular data on preliminary attempts to join specimens of copper were presented in the proposal. It was designed to make and break or break and make hot cylindrical specimens end to end. Force is applied by heating or cooling the legs of the yoke; heat is provided by electron bombardment; and force measured by electrical transducers.

PROGRESS

Apparatus designed for the measurement of cohesion has been modified and calibrated.

The transducers used for measuring the force at which specimens are pushed together and the force required to pull them apart consist of thin copper-beryllium alloy bushings with resistance type strain gauges glued on with epoxy. The modification consisted of putting four gauges on one bushing (full bridge) and none on the other and of preloading the bushings with 2500 lbs. compressive force. The calibration consisted of measuring bridge recorder deflection while loading the assembly with a standard tensile testing machine. Sensitivity and reproducibility are very good.

Molybdenum aligning webs were installed to maintain accurate alignment of the specimen after fracture or prior to joining.

The specimen design was changed to permit break-make-break-make type operation rather than make-break-make-break. That is, the specimen is originally a single piece rather than a pair, but sharply notched to minimize distortion prior to fracture. One such specimen of O.F.H.C. copper is now in place.

The apparatus was set up, baked out, and pumped down but had to be re-opened twice to repair electrical shorts in the high voltage circuit used to heating of the specimen by electron bombardment. The filament cathodes consist of thoriated tungsten wires passing through holes in the specimen. The shorts were due to use of a ceramic insulated wire ("Ceramatemp") which proved inadequate at the higher voltages.

All of the auxiliary tubes, valves and heaters required for controlling the force by differential expansion and contraction of the long stainless steel tubes comprising the yoke are in place and have been tested.

The new specimen design is given in Figure 1. Thermocouples are spot welded to it, thoriated tungsten wires pass through the holes and alignment after fracture is maintained by thin close fitting molybdenum webs clamped to the side legs.

The calibration curves for the force transducers are given in Figures 2 and 3. A force of $\pm$ 5 lbs. is easily readable. Figure 2 shows the curve without preloading and Figure 3 shows the preloaded curve to be used. Figure 4 is a sketch of the assembly.

PROCEDURES

The following tentative procedure has been laid out for the first test:

1. Have heaters ready in side legs. (Never let the legs or specimen change temperature without reading force and compensating, if necessary).
2. Have air and water ready for middle leg but no water in it.

3. With filaments cold, gradually raise high voltage to 1500 volts to check insulation. Be sure filament is negative with respect to ground.

4. With 1500 volts on the cathodes, raise current in filaments slowly enough to keep pressure below 10^{-6} mm.

5. When m.a. meter starts to move, raise current in top filament until 10 m. a. is obtained, keeping voltage at 1500.

6. Then raise the current in the bottom filament until 20 m. a. is obtained. Occasionally check that the m. a. is the same for each filament by cooling one until it no longer effects the total m. a. and seeing that the drop is 50%.

7. Raise the total m. a. as necessary to reach 500°C without exceeding 10^{-6} mm pressure, while heating side legs as necessary to keep the force at zero.

8. After obtaining the best possible vacuum with the specimen at 500°C (may take a day or two) cool it to 400°C, keeping force at zero and the voltage at 1500.

9. Run air through the middle leg until it is below 100°C, then water if necessary, watching the force constantly and watching through the window for fracture. If no fracture occurs, heat the side legs until it does.

10. Note the exact time of fracture and immediately blow the water out of middle leg, put a heater in it and turn it on full, then pull the heaters out of the side legs and put air through them until they reach 100°C (then water if necessary) but do not let the force exceed that which was required for fracture. When this force is reached, immediately cool the side legs until the force is exactly one-half of the fracture force. Try to hold this condition for two hours, taking frequent readings of all variables. (Note the exact time of first compression).

11. After two hours repeat the procedure, starting with item (9), to measure the force of cohesion, if any. Note the exact time of fracture and rejoin specimens immediately by procedure (10) and adjust compressive force to same value as before, but...

12. If cohesive force was high, drop the specimen temperature 50°C. If it was low (or zero) raise specimen temperature 50°C as quickly as possible after noting the cohesive force.

13. Hold this condition for two hours, then repeat, starting with item (9).

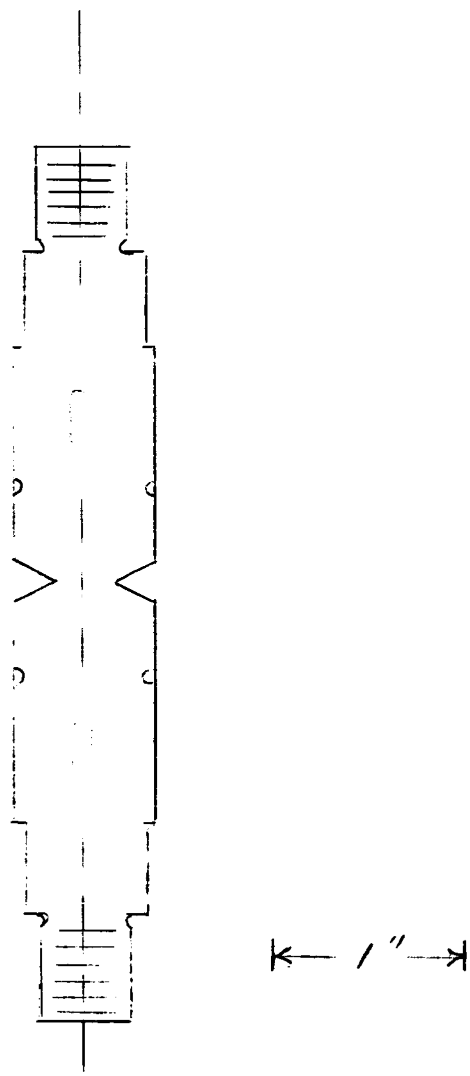

Figure 1. COHESION TEST SPECIMEN OF THE "BREAK-MAKE" TYPE

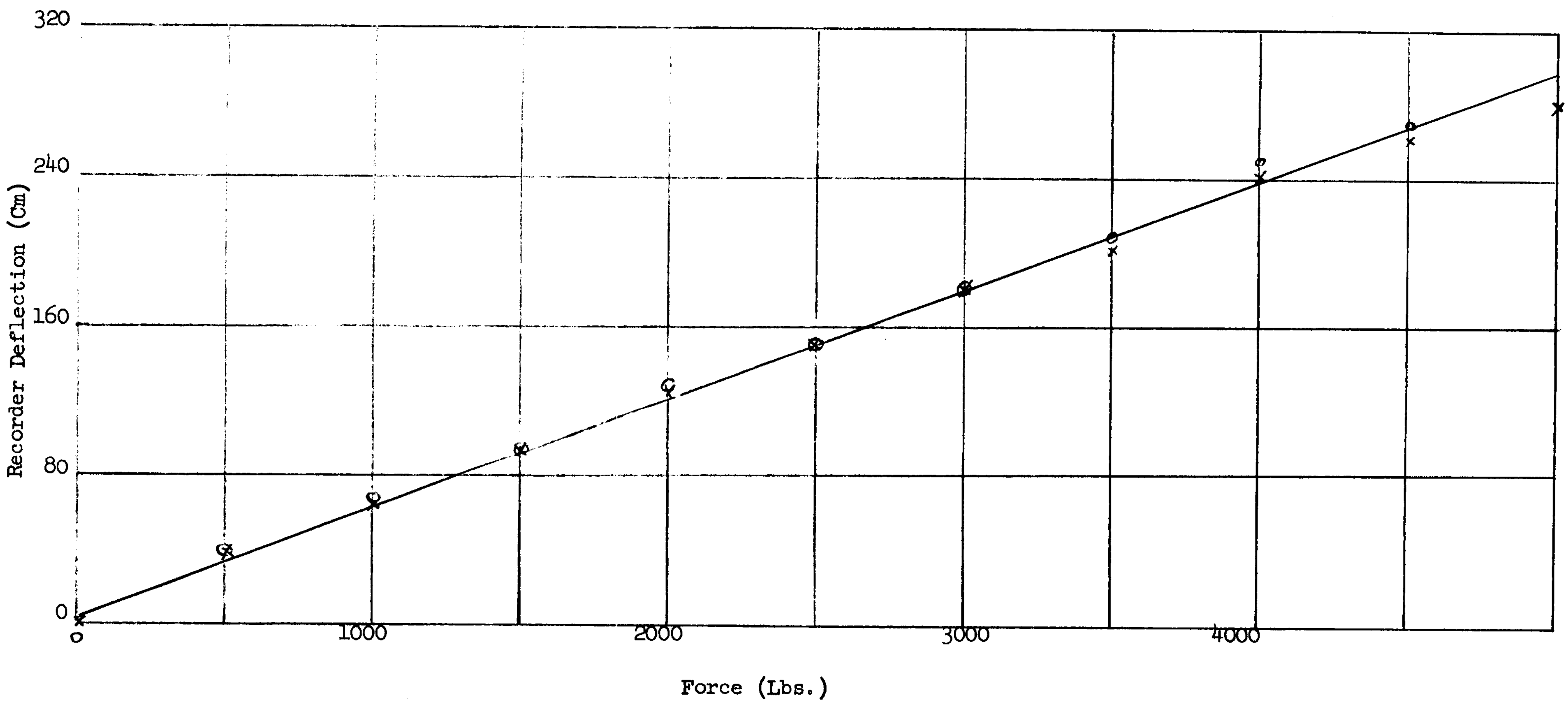

Figure 2. CALIBRATION CURVE FOR THE FORCE MEASURING TRANSDUCER WITHOUT PRELOADING

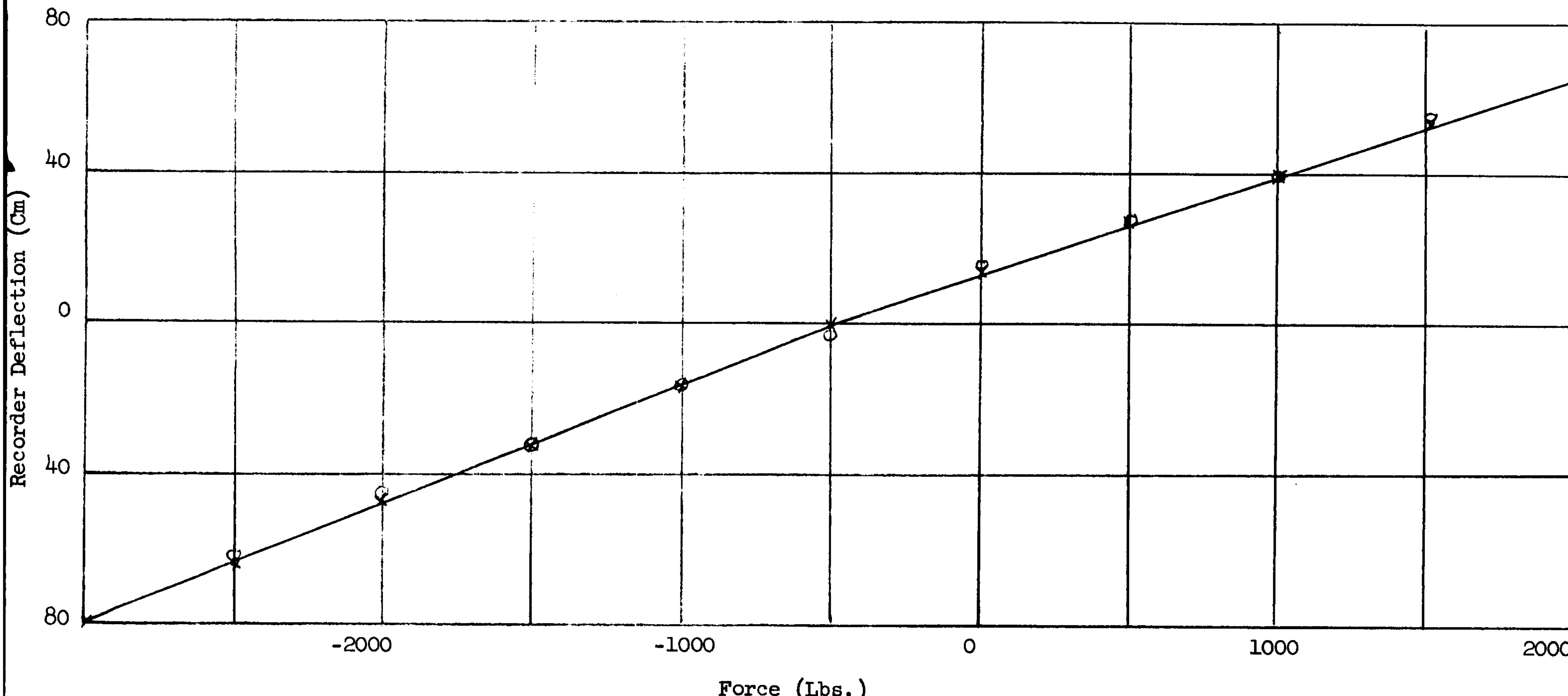

Figure 3. CALIBRATION CURVE FOR THE FORCE TRANSDUCER PRELOADED TO 2500 LBS.

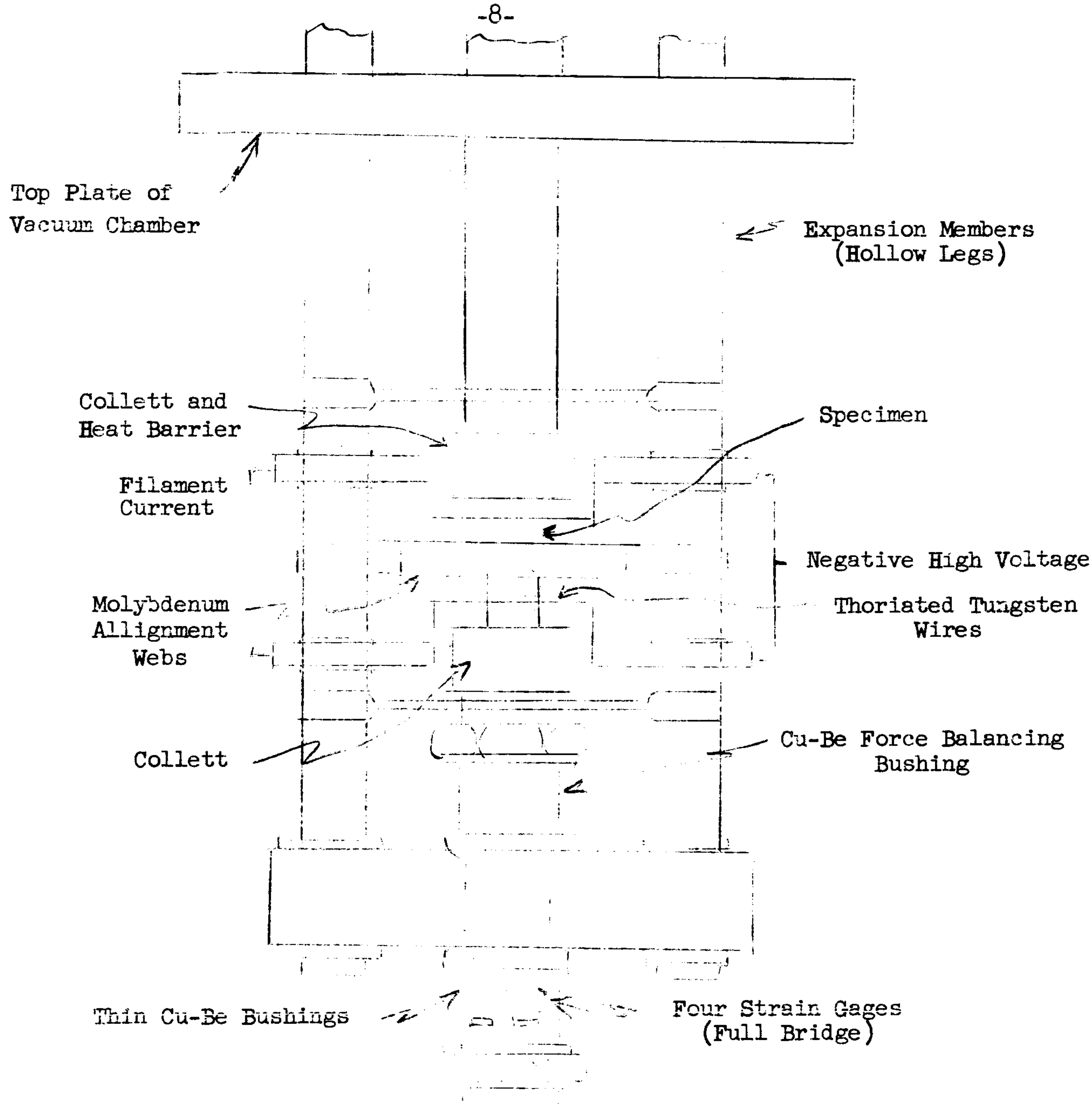

Figure 4. SCHEMATIC DRAWING OF COHESION TEST ASSEMBLY