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INVESTIGATION OF ULTRASONIC WELDING
OF REFRACTORY METALS AND ALLOYS

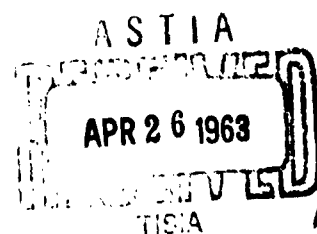
March 1963

Prepared under Navy Bureau of Naval Weapons

Contract No. NOw 63-0125-c

Bimonthly Progress Report No. 3

16 December 1962 through 15 February 1963



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ABSTRACT

Both power and clamping force associated with ultrasonic welding have been successfully programmed. By means of a servo-controlled hydraulic valve in the clamping force system, the previously reported inadequate force response times have been improved and are now adequate for carrying out the projected welding of refractory metals with this improved technique. Tentative specifications for refractory metals of reasonably satisfactory quality have been established.

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INVESTIGATION OF ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS

The ultrasonic welding cycle involves an induction period wherein the sonotrode tip slips during the establishment of coupling, and an interval wherein tip amplitude may decrease as the weld is generated. The slip interval produces heat that is probably unnecessary, and the interval of amplitude decline seems to be associated with high cyclic stresses in the weldment. The programming of power and clamping force will operate to reduce power, to improve control, and to extend the utility of the process. Thus, the work here discussed is concerned with power-force programming and with the specific objective of joining refractory metals.

The division of the work and development effort is presented in the program control chart included in Progress Report No. 2, Figure 3.

A summary of the work executed during this period follows:

Power-Force Programming Equipment

A. Power Programming

Circuitry has been designed and assembled to control the application of ultrasonic welding power on the basis of any program set out on the power control panel (Figures 1 and 3A).

Initial measurements of the power control signal programmed in progressive 10 percent increments of the pre-set maximum signal level show that the power control signal does not respond with uniform increments (Figures 3-A and 3 B-1). This is due to the electronic circuitry constants associated with the oscillator drive and its coupling circuits into the power amplifiers. Such deviation from linearity will be corrected.

B. Force Programming

It was previously shown (Figure 1-B, Progress Report No. 2) that various devices controlling the applied clamping force did not have sufficiently fast response to meet the requirements that have appeared necessary. A high-response servo valve and associated servo amplifier were adapted for use on the laboratory welder shown in Figure 1.

Figure 2 summarizes the results obtained progressively with the force system to date. Figure 2-A reproduces an actual strip-chart oscillogram of the clamping force when a single step signal is applied to the system incorporating the shear valve (as reported in Progress Report No. 2).

Figure 2-B shows the actual response when a step signal is applied to the system incorporating the new servo valve and amplifier. Figure 2-C reproduces several previous response plots (curves B, C, and D which were described in Figure 1-B, Progress Report No. 2) and the properly scaled response curve of "B". Thus, the servo valve and associated amplifier permit realization of the force response requirements initially deemed desirable.

Scouting investigations were carried out with the complete power-force program controlled welder in joining 0.040-inch thick and 0.050-inch thick 2024-T3 bare aluminum and using 0.015-inch Mo-0.5Ti. No quantitative weld data have yet been obtained, but it appears that the power-force program control system is functioning as intended.

Weldment Materials

The materials selected for this investigation include Inconel-X and AlSI 304 stainless steel for the preliminary evaluation of power-force programming, plus Mo-0.5Ti, one columbium-base alloy and tungsten for later work. Inconel-X has been secured in 0.025 and 0.031-inch thickness, and the AlSI 304 stainless steel in 0.030, 0.040, and 0.050 inch thickness. It has not yet been possible to secure any of the three refractories with the desired quality. Such metals acquired previously have exhibited serious surface and subsurface contamination, brittleness, and recrystallization.

Review of information, and discussion with manufacturers and users of refractory metals* produced sufficient information on Mo-0.5Ti and tungsten to establish procurement specifications for these two. However, the recrystallization encountered in D-31 columbium alloy, and the lack of rigorous information concerning it, indicated that this alloy can probably not be procured currently in the desired consistent quality. D-31 columbium alloy should probably be dropped from the investigation, and one of the columbium-base refractory alloys listed below substituted. Available technical information, consultation with material manufacturers, and careful consideration of the requirements for consistent high-quality metal, indicate that one of these should be satisfactory.

<u>Alloy</u>	<u>Manufacturer</u>
B-33	Westinghouse
B-66	
C-103	Wah Chang
FS-82	Fansteel

Procurement of Mo-0.5Ti, tungsten, B-33, and C-103 is in process, and efforts to procure small quantities of B-66 and FS-82 are being made.

* A summary of this research effort, including communication with various manufacturers, will be included in a later report.

Future Work

1. The completely assembled power-force program system will be utilized in exploratory welding of materials on which much data is available: aluminum alloys, 304 stainless steel, and Inconel-X with the view to determining the effects on strength, and weld-quality variation.
2. Continued effort to obtain quality materials.

REFERENCES

1. Aeroprojects Incorporated, "Ultrasonic Welding of Refractory Metals", under Navy Contract No. N0w-61-0410-c.
2. Jones, J. B., H. L. McKaig, and J. G. Thomas, "Investigation of Ultrasonic Welding of All-Beta Titanium Alloy." Research Report 61-77, Navy Contract N0w 60-0643, September 1961.
3. Aeroprojects Incorporated, "Development of Ultrasonic Welding Equipment for Refractory Metals - Phase II", under Air Force Contract No. AF 33(600)-43026.
4. Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft, "Fundamentals of Ultrasonic Welding, Phase I." Research Report 59-105, Navy Contract N0as 58-108-c, May 1959.
5. Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft, "Fundamentals of Ultrasonic Welding, Phase II." Research Report 60-91, Navy Contract N0a(s) 59-6070-c, December 1960.

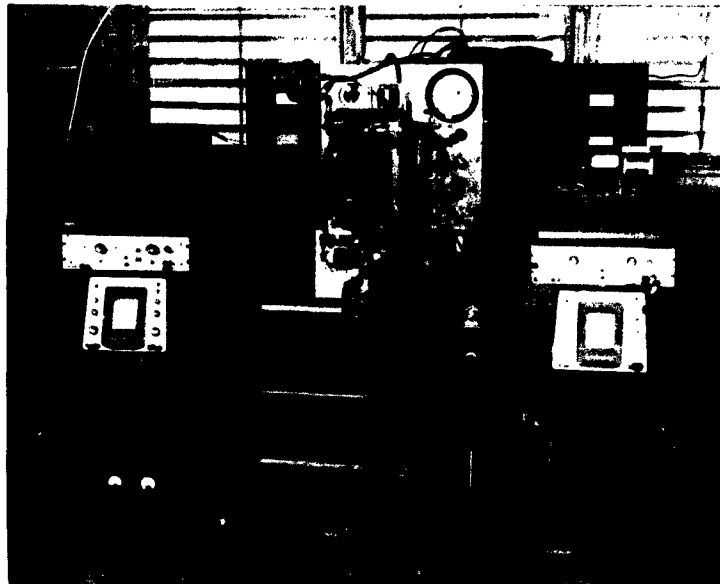
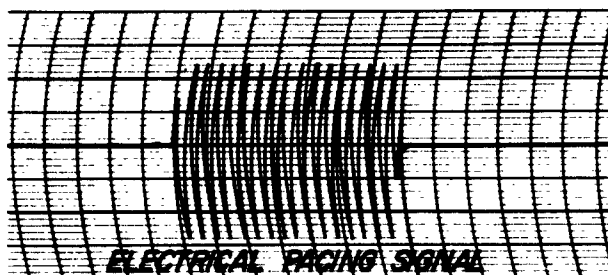
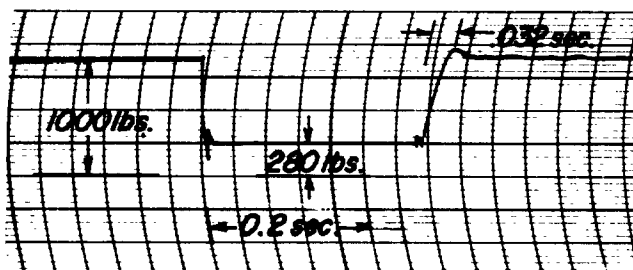
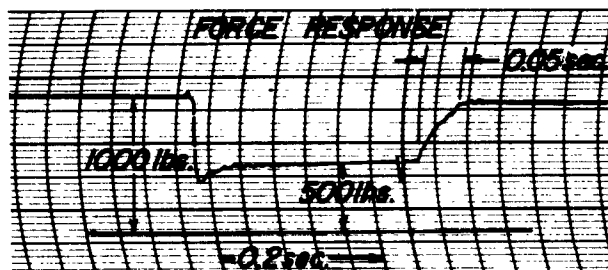


Figure 1

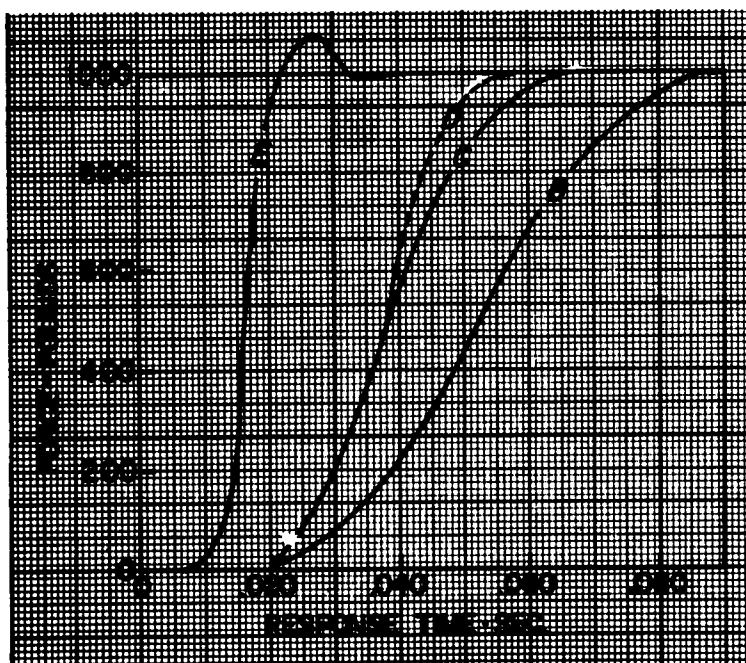
4-KILOWATT ULTRASONIC WELDER WITH EXPERIMENTAL POWER-FORCE
CONTROLS AND ASSOCIATED RECORDING INSTRUMENTATION



A RESPONSE CURVE TO SINGLE-STEP CONTROL AND 60-CYCLE PACING SIGNAL (SHEAR-SEAL VALVE)



B RESPONSE CURVE TO SINGLE-STEP CONTROL (SERVO VALVE)



C FORCE RESPONSE CURVES

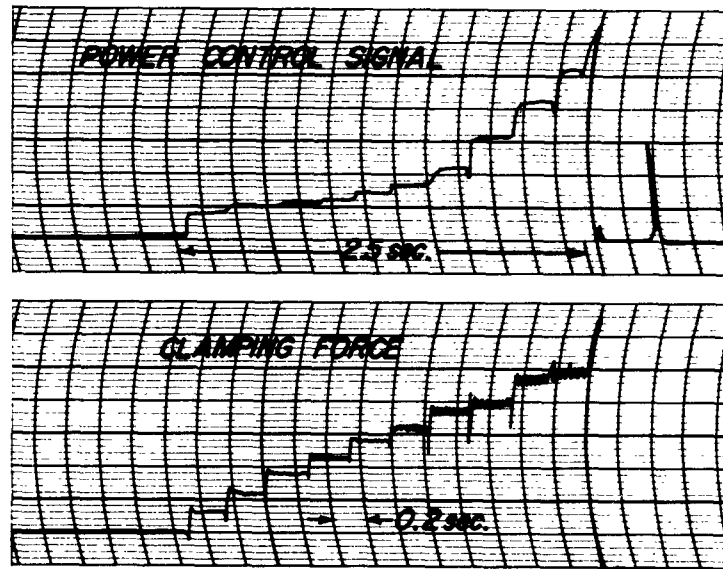
- B - Solenoid-Controlled High-Response Shear-Seal Valve
- C - Addition of Low Pressure Cut-off in Control Line
- D - Estimated Response of "C" Condition with Addition of Pressure Accumulator
- E - Response with Servo-Valve By-Pass Control

Figure 2

RESPONSE CURVES FOR SHEAR-VALVE AND SERVO-VALVE FORCE CONTROL



A POWER-FORCE PROGRAM CONTROL PANEL SET FOR PROGRESSIVE INCREASES OF EACH PARAMETER



B RECORDED POWER CONTROL SIGNAL AND RECORDED CLAMPING FORCE FOR SETTINGS SHOWN IN "A" ABOVE

Figure 3

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