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**MAGNETIC FORCE WELDING APPLICATIONS
AT BATTELLE-NORTHWEST**

R. F. BOOLEN

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By

R. F. Boolen
Materials Development Section
Materials Department

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MAGNETIC FORCE WELDING APPLICATIONS
AT BATTELLE-NORTHWEST

R. F. Boolean

INTRODUCTION

Magnetic force welding was originally applied to welding precious metals to contactor assemblies for use in the electrical industry. The process was applicable because of the large current pulses generated which are necessary to resistance weld the high conductivity parts.

The very high heating rates used require a special means of maintaining pressure on the parts during welding. An electromagnet is used for this purpose because it has a very fast response and therefore can be precisely synchronized with welding heat. The use of the electromagnet makes possible the high rate of change in forge pressure without undesirable over forging effects during or after weld cycle completion. The weld energy used (depending on material and cross sectional area) is adjusted by varying pulse time duration of the applied current. Some requirements are listed in Table I.

TABLE I. *Current-Time Requirements for Various Materials
Magnetic Force Welding*

<u>Material</u>	<u>Welding Current, peak A/in.²</u>	<u>Current on Time, msec</u>
Tungsten	1,500,000	5
Tungsten Cermet	1,500,000	7
TD Nickel	1,500,000	4
SAP	1,500,000	6
Zircaloy	500,000	12 (Two Pulses)
Beryllium	1,100,000	15 (Two Pulses)

Since magnetic force welding supplies sufficient energy and pressure to the work pieces to perform the weld in a few milliseconds, "tramp" element contamination or spread in highly reactive and refractory metals is minimized. Grain growth is minimized because the work pieces are not melted. Both these advantages greatly reduce the susceptibility of the weld to corrosion and/or cracking. Dispersion strengthened and cermet materials have been welded with little or no effect on the ceramic phase itself or its distribution.

EXPERIENCE

The introduction of magnetic force welding in the nuclear industry came as a result of studies on making end closures on zircaloy fuel rods. Following the construction and installation of a special horizontal 100 KVA magnetic force butt welder, it was demonstrated to be a very desirable process for making very reproducible high integrity fuel element closures in the Plutonium Recycle Test Program. The techniques developed under this program were then applied to many other materials of interest to the nuclear industry.

Investigations to date have included welding studies on materials in the ferrous, nickel base, reactive, and refractory metal categories--even graphite has been successfully welded by the process. The following is a partial list of the materials which have been studied:

- Stainless Steel
- Stainless Steel - UO_2 cermets
- Incoloy
- Nickel
- Tantalum
- Beryllium
- Tungsten
- Tungsten - UO_2 cermets

Thoria Dispersed Tungsten

Thoria Dispersed Nickel (reference included)

Molybdenum

Graphite (reference included)

The microstructures of cross sectional weld areas in a representative selection of the listed materials are shown in the appendix. In most cases studied, the welds are applicable to both capsule and fuel element closures. These studies also demonstrate that magnetic force welding is applicable to closures of capsules constructed of a variety of nuclear and space age metals.

POTENTIAL

In addition to the previously mentioned desirable qualities imparted to welded metals, magnetic force welding has some very special advantages in the encapsulation of various specific materials:

1. Due to the short welding time, very little heat is transferred to the capsule itself (the capsule is held in an electrode which acts as an excellent chill block). Materials with low melting or volatilization points may be easily encapsulated without damage.
2. Almost any desired atmosphere and pressure, including vacuum, may be incorporated in the finished capsule.
3. The process is particularly well suited to high production rates--being limited only by manual or automated transfers of the work pieces themselves.

Magnetic force welding techniques can be particularly applicable to isotope encapsulation processes because of all the aforementioned considerations.

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APPENDIX

Neg 0601074

FIGURE A-1. 100 KVA Special Horizontal Magnetic Force Welder

Neg 0660751

FIGURE A-2. Schematic Illustration of Magnetic Force Welder

Neg 061505-2

12X

50X

FIGURE A-3. Fuel Rod Closure Weld Made By Magnetic Force Butt Welding, Zircaloy-2 Material

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7X

50X

Neg 0652997-6

FIGURE A-4. *Zircaloy End Closure - Upset Free
Magnetic Force Welded*

10X

50X

Neg 0652997-8

FIGURE A-5. End Closure Cross Section Magnetic Force
Welded SAP Material (0.563 in. OD X 0.027 in.
Wall Tube--External Flash Removed--73,000 A--
6 msec)

Neg 061505-1

FIGURE A-6. *Magnetic Force Butt Welded - Beryllium*

Neg 0632345-7

12X

FIGURE A-7. Incoloy (0.500 in. OD Tube--0.025
Wall--29,000 A--8.3 msec)

50X

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11

12X

50X

250X

Neg 0632345-8

FIGURE A-8. Tantalum Weld (0.430 in. OD Tube--
1/32 in. Wall--35,000 A--8.3 msec)

Neg 4L 1653

20X

FIGURE A-9. Magnetic Force Welded SS Clad SS-UO₂ Cermet

Neg 5L 391B

100X

FIGURE A-10. Magnetic Force Welded Nickel End Closure

Neg 4K 618C

200X

FIGURE A-11. *Magnetic Force Welded TD Nickel Microstructure*

Neg 5K 621

8X

FIGURE A-12. *Magnetic Force Welded TD Nickel End Closure*

Neg 566326

36X

FIGURE A-13. *Magnetic Force Welded Tungsten*

50X

FIGURE A-14. *Magnetic Force Welded Molybdenum*

Neg 0622310

FIGURE A-15. Graphite Welding by Magnetic Force Closure Process: Closure Caps are Welded on the End of Graphite Tubes

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