Workshop on Containerless Experimentation in Microgravity

Compact rf Heating and Levitation Systems for the NASA Modular Electromagnetic Levitator

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The levitator demonstrates levitation of a 5mm diam aluminum sphere at 1 G using a small, compact rf levitator operating from a small 12-V battery. This system is designed to levitate and melt niobium in space; however, the small battery limits the power for melting demonstrations. This system was developed for NASA-MSFC in Huntsville, Alabama, as part of the Modular Electromagnetic Levitator development.

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PROBLEM STATEMENT

The primary goal of the MEL project is containerless induction-melting and processing of metals, e.g., niobium, in the micro-G environment of earth-orbit.

POWER LIMITATIONS

The maximum electrical power available on the shuttle is 2 KW for each MSL user. For the MEL operation, this power must be shared between the induction-heater and all peripheral equipment. A reasonable power allocation for just the induction-heater might be 1 KW.

INDUCTION-HEATER COIL EFFICIENCY

In the laboratory, containerless melting metals often accomplished by inductively heating the sample in a "cusp" coil. Such a coil consists of two coaxial coils connected series-opposed. These coils can levitate as well as heat a metallic sample. However, the heating efficiency of a cusp coil is rather poor because the sample is levitated at a point rather near the zero point in the magnetic flux of the coil. Figure 1 is a computer generated B-field map of a 4-turn cusp coil intended for use in a micro-G environment. Note that, in the plot, the two turns in the center are not activated and are not involved in generating the levitation field. The two center turns serve a different purpose. Connected series-aiding and driven from an independent rf source, this coil heats the sample much more efficiently than the cusp coil because the sample is held near the position of its flux maximum. Thus, we have a three-coil dual-frequency configuration. Although this system is more complex than the simple cusp coil, the added complexity is justified by the improved efficiency.

RF TRANSFORMER

A resonant toroidal current transformer provides the high circulating secondary currents necessary to achieve adequate power transfer to the sample while using a simple rugged heater coil.

POWER INVERTER

A pair of 30 ampere MOSFET switches in a push-pull class D circuit (Fig. 2) are link coupled to the resonant transformer previously discussed. Self-excitation is used to avoid any operation off-resonance that might result from load changes.

INVERTER PERFORMANCE HIGHLIGHTS

With the DC input current set to 28 amperes at nominal bus voltage, the rf current to the heater coil exceeded 300 amperes (Fig. 3). This was sufficient to levitate both tungsten and platinum (at 1-G). Set to a lower input current, 15 amperes, a platinum sample (Fig. 4), was heated to over 2600°C.

SYSTEM EFFICIENCY

An overall heating efficiency measurement was made. The input power was read from the DC inputs and the output power was measured calorimetrically as the thermal power delivered to a water-cooled 5- mm diameter inconel sphere (molten niobium equivalent resistivity).

Input power: 29 V X 17.5 A = 507.5 W
The thermal power to the sample was 178.8 W
Efficiency: 178.8/507.5 = 35.2% from the power bus.

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MODULAR ELECTROMAGNETIC HEATING AND LEVITATION COIL FOR THE MEL

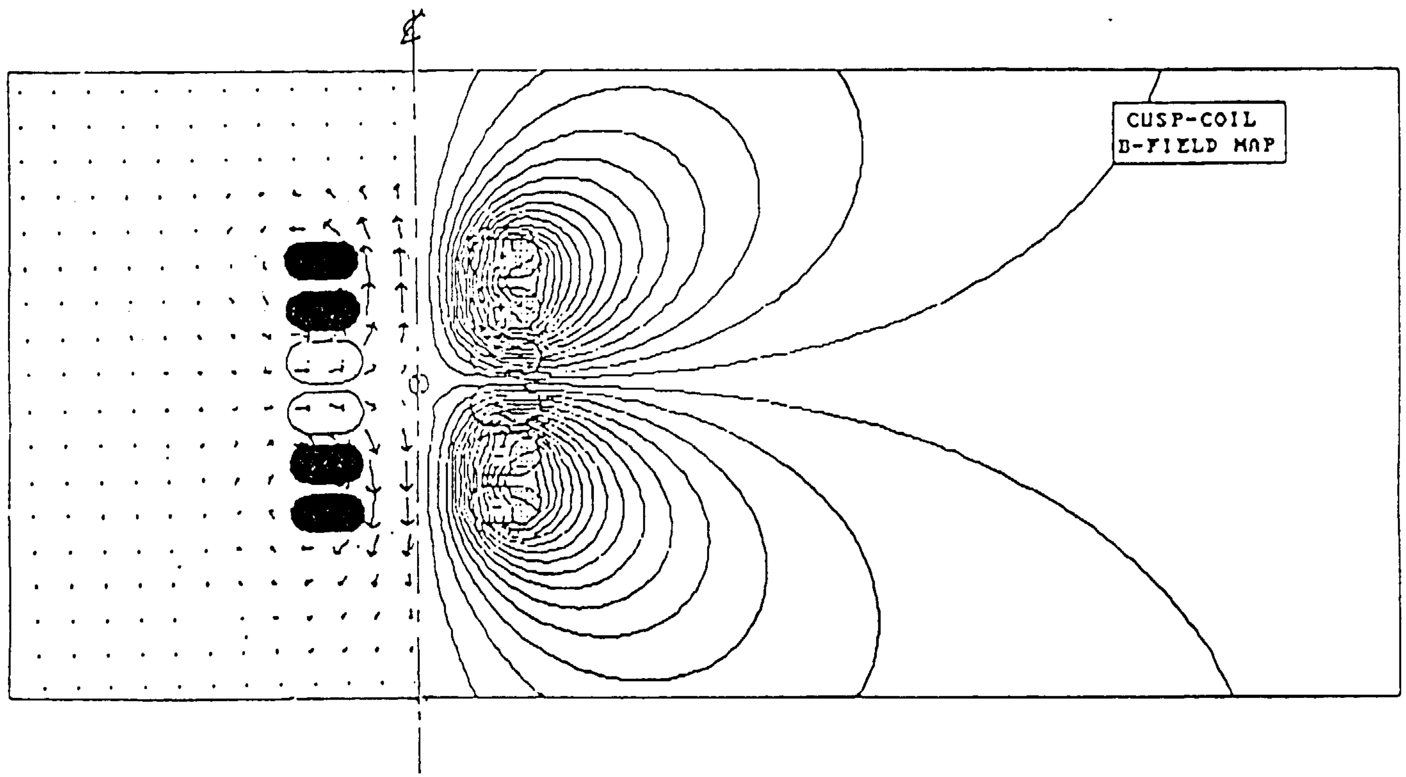

FIG. 1

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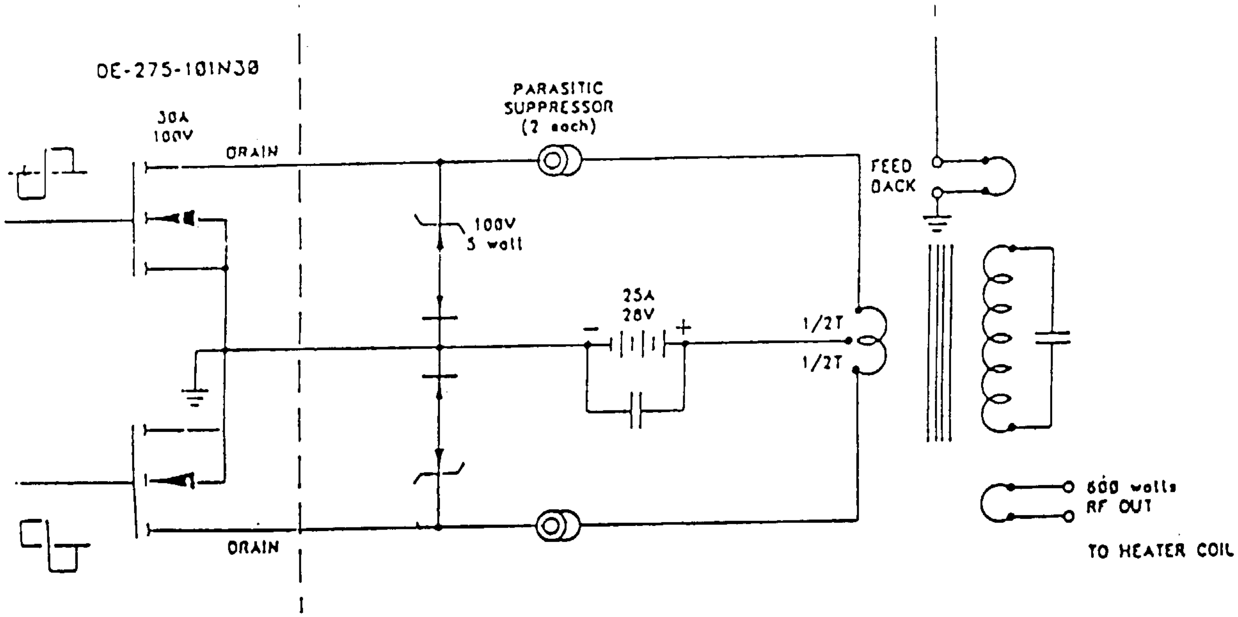

PUSH-PULL RF-POWER
SELF EXCITED

Fig. 2

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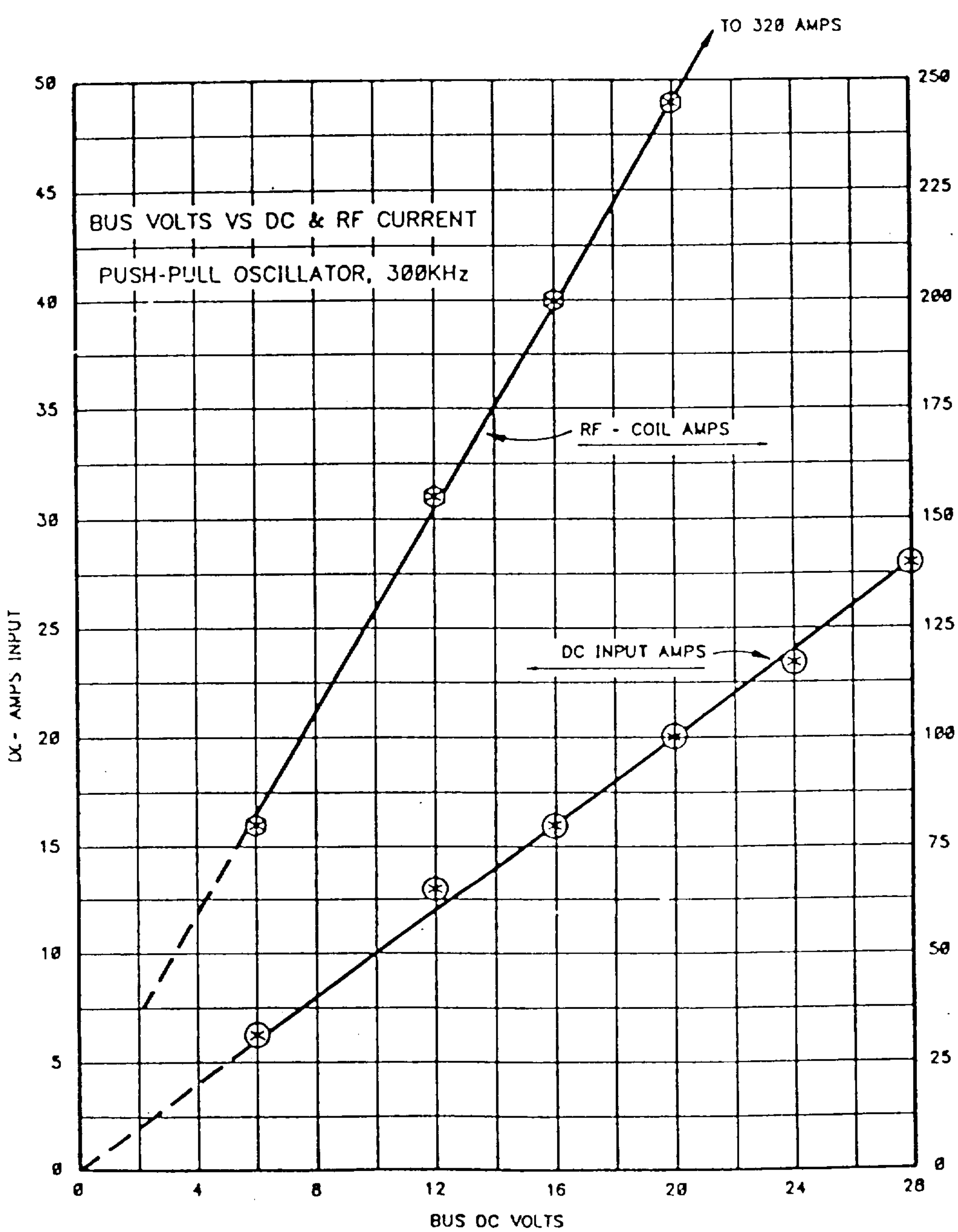

Fig. 3

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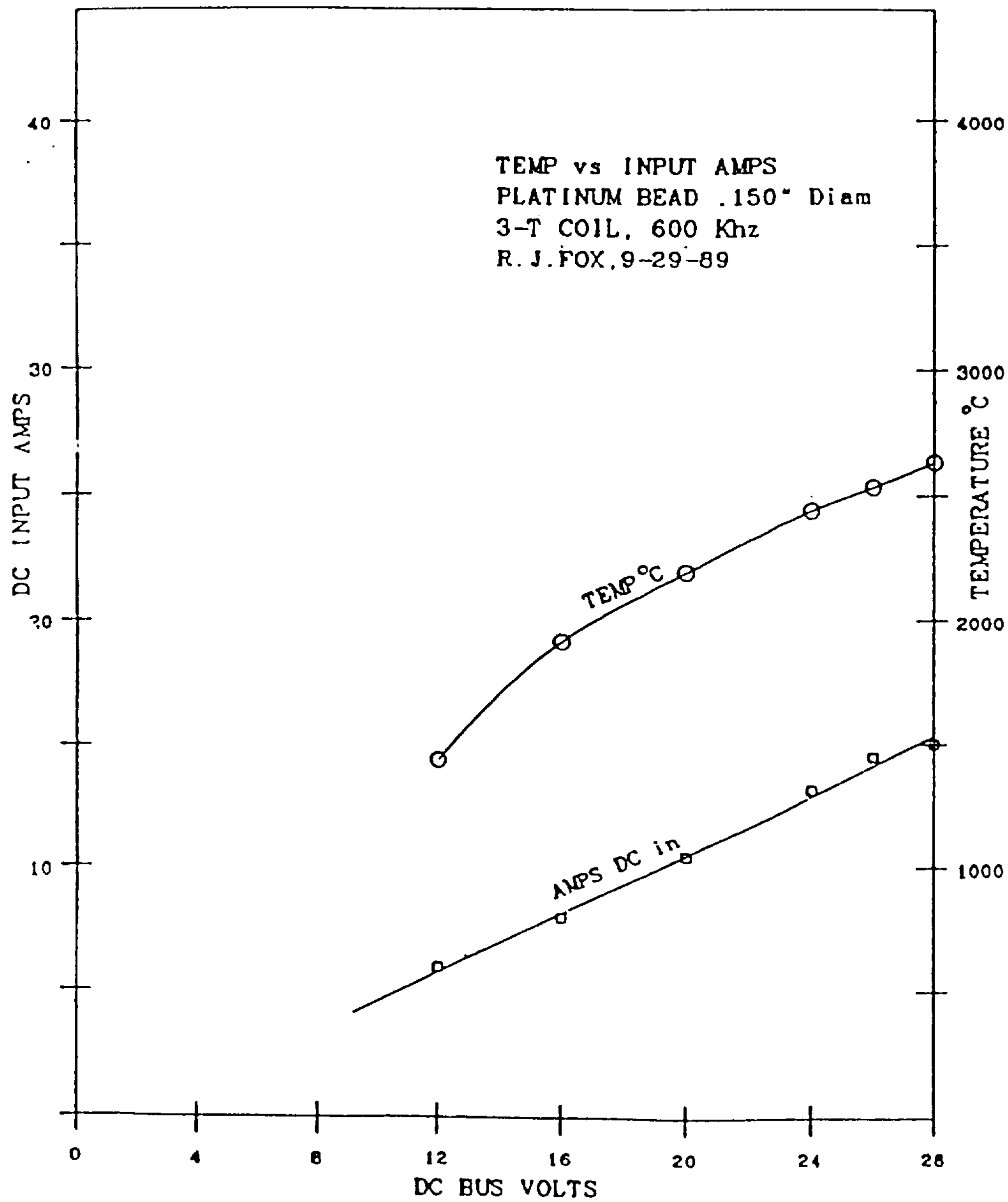

Fig. 4

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