



## Manufacturing & Prototyping

### **Making Superconducting Welds Between Superconducting Wires**

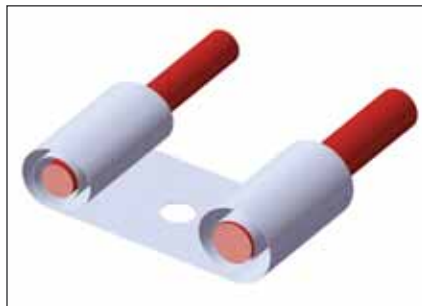
**Parts of a superconducting circuit can be made from different metals.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A technique for making superconducting joints between wires made of dissimilar superconducting metals has been devised. The technique is especially suitable for fabrication of superconducting circuits needed to support persistent electric currents in electromagnets in diverse cryogenic applications. Examples of such electromagnets include those in nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI) systems and in superconducting quantum interference devices (SQUIDS).

Sometimes, it is desirable to fabricate different parts of a persistent-current-supporting superconducting loop from different metals. For example, a sensory coil in a SQUID might be made of Pb, a Pb/Sn alloy, or a Cu wire plated with Pb/Sn, while the connections to the sensory coil might be made via Nb or Nb/Ti wires. Conventional wire-bonding techniques, including resistance spot welding and pressed contact, are not workable because of large differences between the hardnesses and melting

temperatures of the different metals. The present technique is not subject to this limitation.



One or More Wire(s) can be spark-welded to the inside of a tube made by rolling a piece of Nb foil.

The present technique involves the use (1) of a cheap, miniature, easy-to-operate, capacitor-discharging welding apparatus that has an Nb or Nb/Ti tip and operates with a continuous local flow of gaseous helium and (2) preparation of a joint in a special spark-discharge welding geometry. In a typical application, a piece of Nb foil about 25  $\mu\text{m}$  thick is rolled to form a tube, into which

is inserted a wire that one seeks to weld to the tube (see figure). The tube can be slightly crimped for mechanical stability. Then a spark weld is made by use of the aforementioned apparatus with energy and time settings chosen to melt a small section of the niobium foil. The energy setting corresponds to the setting of a voltage to which the capacitor is charged.

In an experiment, the technique was used to weld an Nb foil to a copper wire coated with a Pb/Sn soft solder, which is superconducting. The joint was evaluated as part of a persistent-current circuit having an inductance of 1 mH. A current was induced in a loop, and no attenuation of the current after a time interval 1,000 s was discernible in a measurement having a fractional accuracy of  $10^{-4}$ . This observation supports the conclusion that the weld had an electrical resistance  $<10^{-10} \Omega$ .

*This work was done by Konstantin I. Penanen, Inseob Hahn, and Byeong Ho Eom of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45931*

### **Method for Thermal Spraying of Coatings Using Resonant-Pulsed Combustion**

**High-volume, high-velocity surface deposition allows protective metal coatings to be applied to otherwise vulnerable surfaces.**

*John H. Glenn Research Center, Cleveland, Ohio*

A method has been devised for high-volume, high-velocity surface deposition of protective metallic coatings on otherwise vulnerable surfaces. Thermal spraying is used whereby the material to be deposited is heated to the melting point by passing through a flame. Rather than the usual method of deposition from the jet formed from the combustion products, this innovation uses non-steady combustion (i.e. high-frequency, periodic, confined bursts), which generates not only higher temperatures and heat transfer rates, but exceedingly high im-

pingement velocities an order of magnitude higher than conventional thermal systems. Higher impingement rates make for better adhesion. The high heat transfer rates developed here allow the deposition material to be introduced, not as an expensive powder with high surface-area-to-volume, but in convenient rod form, which is also easier and simpler to feed into the system. The nonsteady, resonant combustion process is self-aspirating and requires no external actuation or control and no high-pressure supply of fuel or air.

The innovation has been demonstrated using a commercially available resonant combustor shown in the figure. Fuel is naturally aspirated from the tank through the lower Tygon tube and into the pulsejet. Air for starting is ported through the upper Tygon tube line. Once operation commences, this air is no longer needed as additional air is naturally aspirated through the inlet. A spark plug on the device is needed for starting, but the process carries on automatically as the operational device is resonant and reignites itself with each 220-Hz pulse.