3D TUNGSTEN WIRE

GENERAL ELECTRIC COMPANY
Lamp Components & Technical Products Division

PRODUCT DATA SHEET 7215-A
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INTRODUCTION

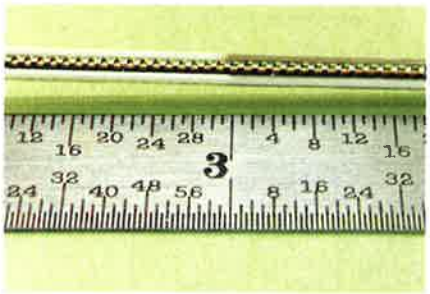
3D tungsten wire is a derivitive of 218 lamp filament wire and was developed by General Electric Company to meet specific performance objectives. An alloy containing 3% rhenium, 3D offers three distinct advantages over 218 wire:

- **Superior vibration resistance**
- **Improved ductility**
- **Higher resistivity**

The small addition of rhenium modifies the recrystallization behavior of 218 tungsten, resulting in a fine grain structure. After proper heat treatment, 3D is both vibration resistant and ductile. The higher resistivity of the alloy permits designers to use larger wire diameters in applications where strength is an important consideration. With its special combination of properties, GE 3D tungsten wire has become an important engineering material for high performance lamps, cathode ray tubes, traveling wave tubes, and numerous other applications.

GE 3D tungsten wire and ribbon are available in a wide range of sizes and in various containers.

A technician mounts a helix made of General Electric 3D wire into a traveling wave tube (Photo, courtesy of Varian Associates).



Tungsten 3D wire is redrawn by the user to achieve the close tolerances necessary for helix production. It is then formed, mounted around a mandrel and protected by supporting rods (Photo, courtesy of Varian Associates).

A UNIQUE ENGINEERING MATERIAL

The development of 3D is part of the continuing research effort that GE has conducted with tungsten wire since the early 1900's.

One of the early accomplishments of this research was a "non-sag" grade of 218 lamp filament wire, made by using grain growth controlling additives to modify the recrystallized structure. Later, in efforts to develop a tungsten wire that was more ductile after recrystallization, it was found that a 3% rhenium addition to the non sag 218 composition produced a wire with all the desired properties. It is much more ductile, and it retains excellent non-sag characteristics (see Figure 1). At about 3% rhenium, the annealed ductility peaks, so this became the optimum composition for the alloy.

After annealing at temperatures above 1500°C, room temperature ductility or % elongation of 3D tungsten wire can range up to 28% compared to 5% or less for doped lamp grade tungsten wire (See Figure 2). Formability is retained in 3D wire even after exposure to 2800°C.

WIDE RANGE OF USES

With the outstanding properties it offers, 3D wire and ribbon have made an important contribution in a number of applications.

In incandescent lamps, 3D provides up to 70% higher hot strength at operating temperatures of 1000-1300°C; its higher electrical resistivity allows a 10% increase in wire diameter for improved filament strength, and it is ductile after annealing (Figure 1).

Lamps and vacuum tubes exposed to higher than normal levels of vibration during manufacture and use exhibit up to five times the life when 3D tungsten wire is used for the filament.

For indirectly heated cathodes in vacuum tubes, 3D wire helps increase the life of the heater, lowers current climb during life, reduces brittleness, and improves shock resistance.

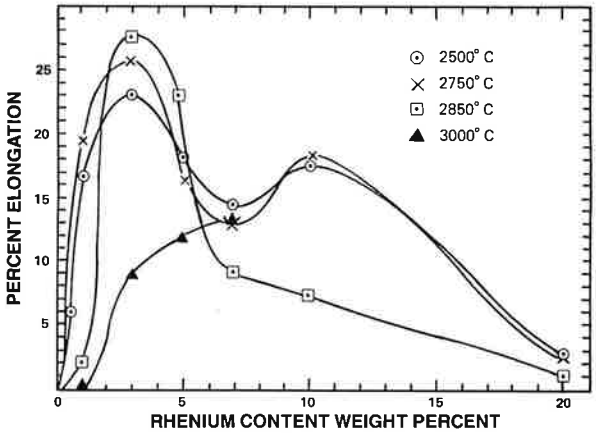
Type 3D wire improves the life and reliability of television and cathode ray tube heater coils, and contributes to the ease of manufacture of these products. When annealed to a tensile strength about 50 g/mg/200 mm, 3D wire has the degree of formability essential for heater coil fabrication. Its low spring-back behavior helps maintain tight dimensional control.

For thermocouples used at higher temepratures, up to 2600°C in some cases, the ductility of 3D greatly enhances handling characteristics after high temperature exposure. In this application, 3D is often mated with tungsten-25% rhenium, and is used in a non-oxidizing environment such as vacuum, inert gas, or hydrogen.

In aircraft and automotive vehicle windshields, 3D is often selected as the defroster wire because it has sufficient strength to tolerate high temperature fabrication, and offers higher resistivity than competitive materials.

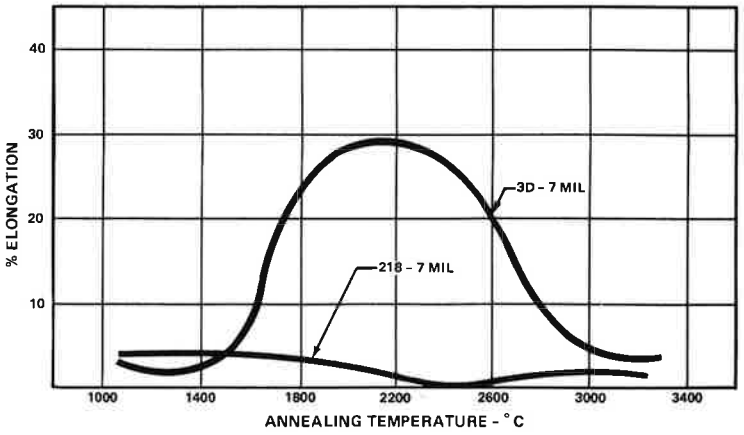
By taking advantage of 3D's unique properties, lamp designers have extended life and reliability up to five times for vacuum cleaner, refrigerator, showcase, aircraft, sign and vending machine lamps.

Figure 1 — ANNEALING TEMPERATURE EFFECTS



Effect of rhenium content on ductility of 0.008-inch diameter wire after annealing for three minutes at various temperatures.

Figure 2 — ROOM TEMPERATURE ELONGATION AFTER ANNEALING



0.008" diameter specimens annealed for three minutes in hydrogen prior to testing.

SUPERIOR VIBRATION RESISTANCE

The addition of rhenium to 218 non sag tungsten wire inhibits secondary recrystallization and stabilizes the fine grain microstructure for short time anneal temperatures up to 2800°C. By contrast, secondary recrystallization occurs in 218 wire at temperatures starting at approximately 2200°C, leading to a large grain, interlocked structure. This is shown in the photomicrographs (right) for 0.007″ diameter wire after a three minute anneal in a hydrogen atmosphere.

The increased grain boundary areas associated with the fine grain structure of 3D provides a sink for absorption of vibrational energy. The damping effect dissipates shock and promotes long life under severe vibration in service.

Berlec* studied the damping behavior of 218 and 3D wire materials using the internal friction technique. This research demonstrated the improved damping capacity of 3D wire. For wire diameters typically used in incandescent lamps, fine grain 3D structures proved more effective than 218 in dissipating shock and vibration for operating temperatures up to 2800°C, and operating times of 500 hours or more.

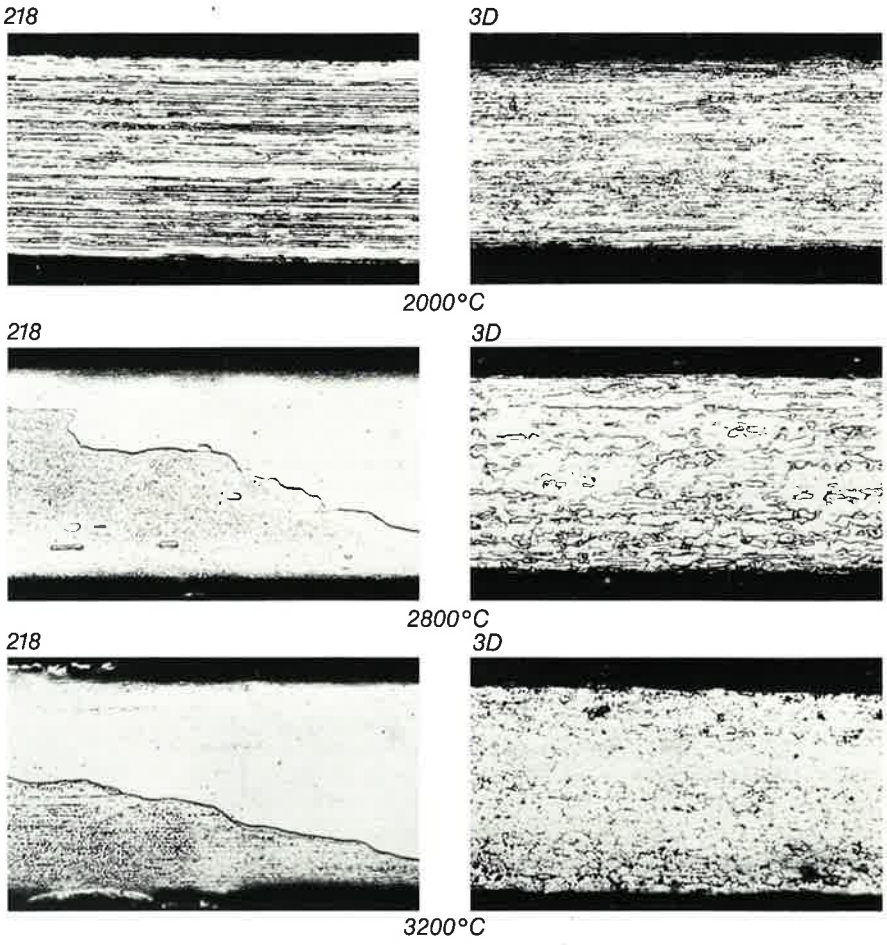
The excellent shock and vibration resistance of 3D tungsten wire has been attributed to these three factors:

1. Rhenium additions to 218 wire inhibit secondary recrystallization and stabilize the fine grain microstructure for temperatures up to 2800°C. The large number of grain boundaries provide many sinks for absorption of vibrational energy. With improved damping capacity, 3D wire is providing long life under severe service conditions.

2. For an equivalent operating temperature and voltage, 3D filament wire will be slightly larger in size, thereby contributing to filament strength.

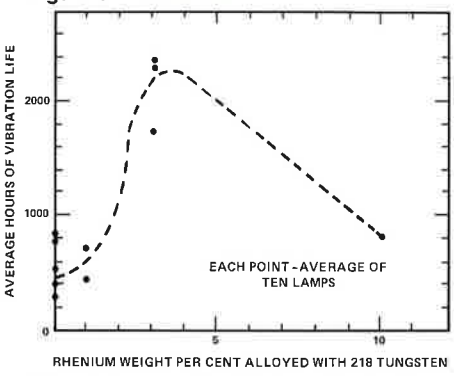
3. 3D's high ductility allows more plastic deformation to relieve stresses caused by shock or vibrational loading.

* Ivan Berlec
Volume 1, Metallurgical Transactions, October, 1970.



Microstructures for 7 mil 218 and 3D wire after annealing at various temperatures for 3 minutes in a hydrogen atmosphere.

Figure 3 — AVERAGE LIFE



Vibration tests for low-wattage vacuum lamps confirmed that those made with 3D wire had an average life up to five times longer than standard lamps.

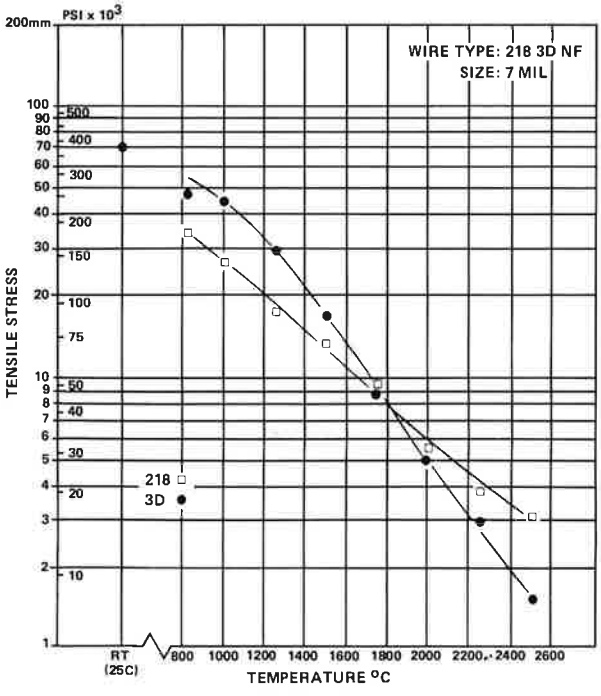
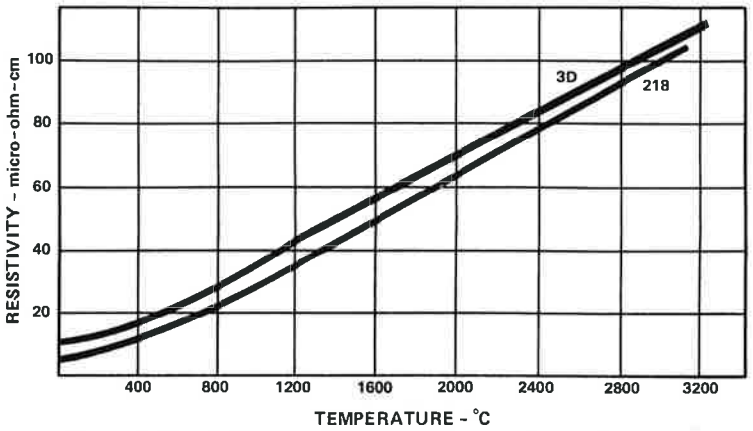


Figure 4 — TENSILE STRENGTH VS TEMPERATURE

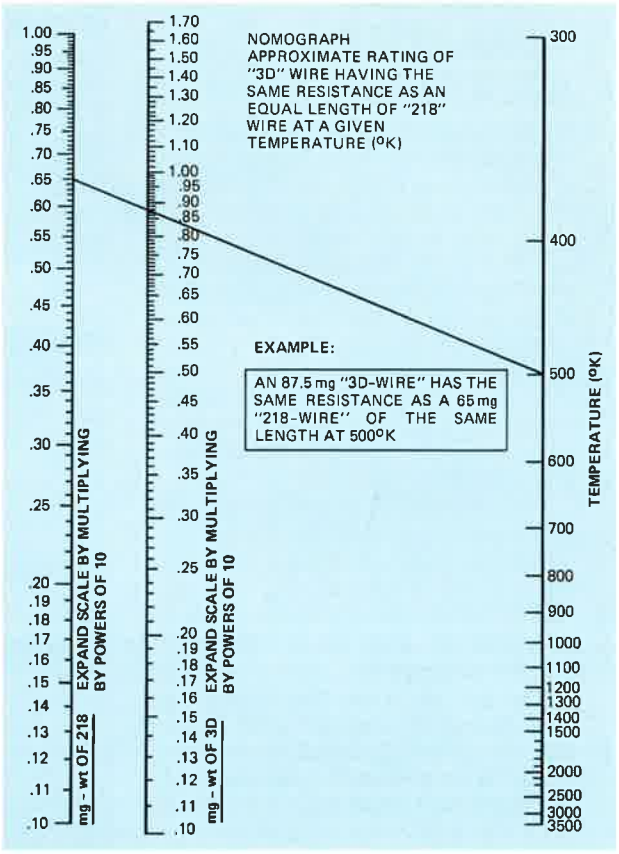
3D has a tensile strength advantage over 218 up to approximately 1800°C, with 218 being stronger above 1800°C.

Figure 5 — ELECTRICAL RESISTIVITY



The resistivity of 3D at a given temperature is equal to the resistivity of 218 plus 3.63 micro-ohm-cm. At 75°F, the resistivity of recrystallized 3D wire is 9.62 M-Ω-cm.

Figure 6 — NOMOGRAPH



ELECTRICAL RESISTIVITY

The resistivity of 3D increases rapidly with temperature and is higher than 218 over the entire range. For as-drawn wire (Figure 5), resistivity depends on the accumulated cold work since the last anneal, and can, therefore, vary considerably with wire size. To provide a common basis for comparison, all graphs and formulas are for recrystallized wire.

General formulas are helpful in relating resistance, resistivity and wire size.

1. $mg/200mm = 38.318 \frac{R}{R_m}$
2. $mg/200mm = 11.6822 \frac{R}{R_F}$
3. $R = 0.0856\, R_F\, (mg/200mm)$
4. $R(3D) = R(218) + 3.63$

Where: R = Resistivity at Specified Temperature (micro-ohm — cm)
R_m = ohms/meter
R_F = ohm/foot

CHEMISTRY

In addition to the rhenium in 3D wire, the 218 base material is intentionally doped with K, Al and Si to control recrystallization behavior. Total impurities are maintained at .05% or less:

Re 2.8 — 3.2%
Mo 100 ppm max.
K 80 ppm max.

Other impurities, each less than 25 ppm:

Al	Cr	Mn	Ti	Na
Ca	Ni	Mg	Pb	C
Si	Cu	Sn	Nb	O
Fe	Sr	Co	Zr	N

W, by difference 96.75%

TECHNICAL ASSISTANCE

General Electric Company helps users of 3D tungsten wire in selecting the optimum size, shape, and finish for their application. Our application engineering service includes tailoring properties to individual requirements, assistance on quality control procedures, and troubleshooting problems in manufacture or use.

ORDERING INFORMATION

To order 3D wire, call your Lamp Components & Technical Products Division sales representative; the Dover Wire Operation customer service representative (216) 343-8841, or the Marketing & Sales Operation headquarters:

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Glass & Metallurgical Products
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