THE MOLY-PERMALLOY CORE

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The first loading coil cores used in the telephone system were made about the turn of the century from iron wire drawn down to a .004 in. diameter and formed into a toroidal core. These cores sufficed until the demand arose for cores which would have high stability with time, temperature, and accidental magnetization. This led to the development of the electrolytic powdered iron cores which satisfied the stability requirement. However, because of their cost and size, investigations were continued for new material which led to the development and subsequent use of Permalloy. Powdered Permalloy permitted a reduction in the size of the core as well as an improvement in the quality. Continuing research led to the discovery that the addition of a small percentage of molybdenum to Permalloy increased its permeability and electrical resistivity, and decreased its eddy current and hysteresis losses. This material, which is presently being used, is designated 2-81 molybdenum-permalloy and contains approximately 81 per cent nickel, 17 per cent iron, and 2 per cent molybdenum. The use of molybdenum-permalloy powder in the production of magnetic cores permitted a still further reduction in the size of the core without sacrificing coil performance.

The sequence of operations presently used to manufacture powdered molybdenum-permalloy cores is shown in Figure 1.

The alloy is made by melting nickel, iron and molybdenum in an electric furnace. A small amount of sulphur is added to the melt to make the resulting alloy brittle and facilitates reducing it to a fine powder. The alloy is cast in ingots and rolled into 1/4 in. thick fragments. The fragments are reduced to a fine powder by the use of a hammer mill and an attrition mill; at this point the powder is sieved through a 120 mesh screen. An average particle size of approximately 40 microns is obtained from powder sieved through a 120 mesh screen. Since the alloy has been work-hardened in the pulverizing process, it is annealed in a continuous calcining furnace at 1300°F in a forming gas atmosphere. Talc is mixed with the powder to prevent sintering during this annealing operation. The annealed powder is next insulated by coating the individual particles with a thin layer of ceramic-type material to prevent the flow of eddy current between particles. The insulating material is applied to the powder in four stages. In each insulation stage, a powdered talc is mixed dry with the annealed

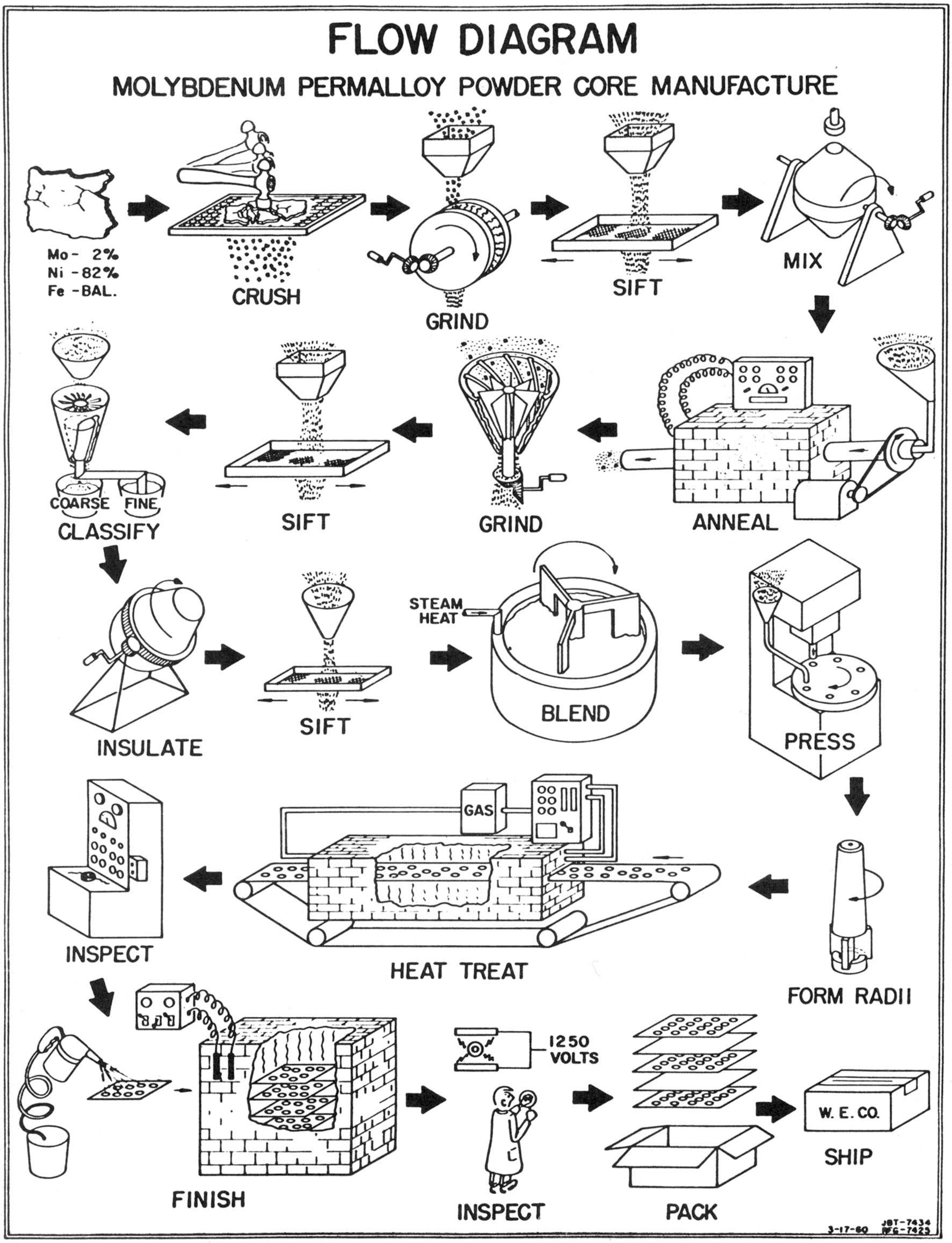
FLOW DIAGRAM
MOLYBDENUM PERMALLOY POWDER CORE MANUFACTURE
Mo- 2%
Ni -82%
Fe -BAL.
CRUSH
GRIND
SIFT
MIX
ANNEAL
GRIND
SIFT
COARSE
FINE
CLASSIFY
INSULATE
SIFT
STEAM HEAT
BLEND
PRESS
FORM RADII
GAS
HEAT TREAT
INSPECT
FINISH
1250 VOLTS
INSPECT
PACK
W. E. CO.
SHIP
3-17-60
JBT-7434
MFG-7423

Figure 1

powder. A mixture of water, sodium silicate and milk of magnesia is then added to the powder which is then evaporated to dryness with constant stirring. The total amount of insulation per unit weight of powder is altered as required to meet the permeability requirements. The resultant insulation on the particles is approximately 0.5 micron thick. This thin insulation must not break away during the pressing operation where pressures between 190,000 psi and 280,000 psi are used to form the insulated powder into cores nor burn away during the heat treating of the core at 1200°F. It must be chemically inert throughout the life of the core. Various lots of insulated powder are blended together to obtain the desired characteristics.

All molybdenum permalloy cores were originally made in a three section split steel die. This method required as many as five operators to perform all the necessary operations such as cleaning, lubricating, and filling the die with powder, leveling the powder in the die, pressing and removing the core from the die. A means of using automatic equipment to perform all of these operations has been developed and is presently in effect where the volume of production is justified. Solid tungsten carbide dies are mounted in an index table on a hydraulic press and as the table moves from station to station the operations which were formerly manually performed are now done automatically. A radius is machined on top of the cores after pressing, and they are conveyed to the heat treating furnace where the pressed cores are given a final annealing in a dissociated ammonia atmosphere at about 1200°F. This annealing operation improves the magnetic characteristics of the core by relieving strains introduced into the magnetic particles by the pressing operation. At this point the cores are then inspected for mechanical and electrical requirements. Specified organic finishes are then applied.

New Development

The latest innovation in molybdenum permalloy core manufacture is the development of a 205-permeability core at Hawthorne which will permit the production of cores smaller in size and weight than the ones now used in the loading coil and certain inductors. At present work is being done to develop production methods for making high permeability molybdenum permalloy powder and producing core rings from this powder on a volume basis. The manufacturing procedures originally proposed were based on laboratory work done at Hawthorne. The standard silicate base insulation normally applied to the powder was cut in half and the insulated powder was treated with mineral oil thinned with an organic solvent. Cores were pressed at pressures 10-20% higher than normal and soaked in a 10% solution of sodium aluminate prior to heat treating.

However, when the production of larger size lots was attempted under shop conditions with close engineering supervision, several difficulties were encountered. Permeability varied from batch to batch to an unsatisfactory degree.

The cores were very soft after pressing resulting in a high drop-out due to breakage. Besides adding an extra operation to the manufacture of the core, the sodium aluminate solution was very unstable. The powder did not have the type of flow characteristic necessary for use on the automatic presses. Since there is a question as to whether the mineral oil acts solely as a lubricant or reacts chemically with the basic insulation, it was decided to try various lubricants in place of the mineral oil. A lubricant was found that was soluble in water, and when substituted for the oil-solvent solution produced powder which had excellent flow properties, could be pressed into high permeability cores, and eliminated the need for soaking the cores in sodium aluminate solution prior to heat treating.

However, cores pressed from powder prepared with this new lubricant were very soft when pressed and there was considerable breakage during the pressing and de-burring operations. A small amount of an organic binder, which is soluble in water, was added to the powder and found to increase the strength of the cores in the as-pressed state to a point where they could be handled in the same manner as standard shop cores.

Studies are now being made to determine the reliability of this procedure. Test cores made from various lots have met all the magnetic requirements and shown that the process was not greatly affected by minor variations in preparation and quantity of additives. This new method will not require extensive modification of existing equipment or production rate.

There has recently been a demand for cores having a positive permeability-temperature coefficient which will compensate the negative capacitance-temperature coefficient of polystyrene capacitors in order to manufacture tuned LC networks having requirements on resonant frequency versus temperature. The present unstabilized permalloy powder cores do not have a requirement on permeability variation with temperature. These unstabilized bare cores presently exhibit a linear slope varying from +40 to +100 ppm/°F before finishing. These cores are finished with green alkyd enamel whose primary prupose is to provide dielectric insulation between the core and subsequent wire windings and add mechanical strength to the cores. It also provides some barrier against penetration of moisture. The finish tends to alter the temperature coefficient downward to a smaller positive slope.

The polystyrene capacitors have an average negative linear slope of -72 ppm/°F which indicated that a core with a positive linear slope of about 75 ppm/°F is needed. Development work has been started to find a means of controlling the inherent slope of the temperature versus inductance curve of the unfinished cores. Since temperature coefficient is believed to depend largely on the difference in thermal expansion of the metal particles and insulation film, variations in the present insulation are being made.

The problem of temperature coefficient and finishes is further complicated by the hygroscopic properties of the core. Therefore work is also being done with the object of developing a moisture tight finish which will not greatly affect the temperature coefficient of the bare core.

Hawthorne is currently manufacturing some 80 different toroidal cores, involving 20 diameters, 5 permeabilities, two basic core finishes and and four temperature stabilization ranges. Current trends in core design are in the direction of more stringent requirements on stability of inductance with respect to temperature, time and frequency. This indicates that more and more special tests and requirements will be specified on individual cores, with an increase in the number and variety of cores required to meet apparatus requirements.

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