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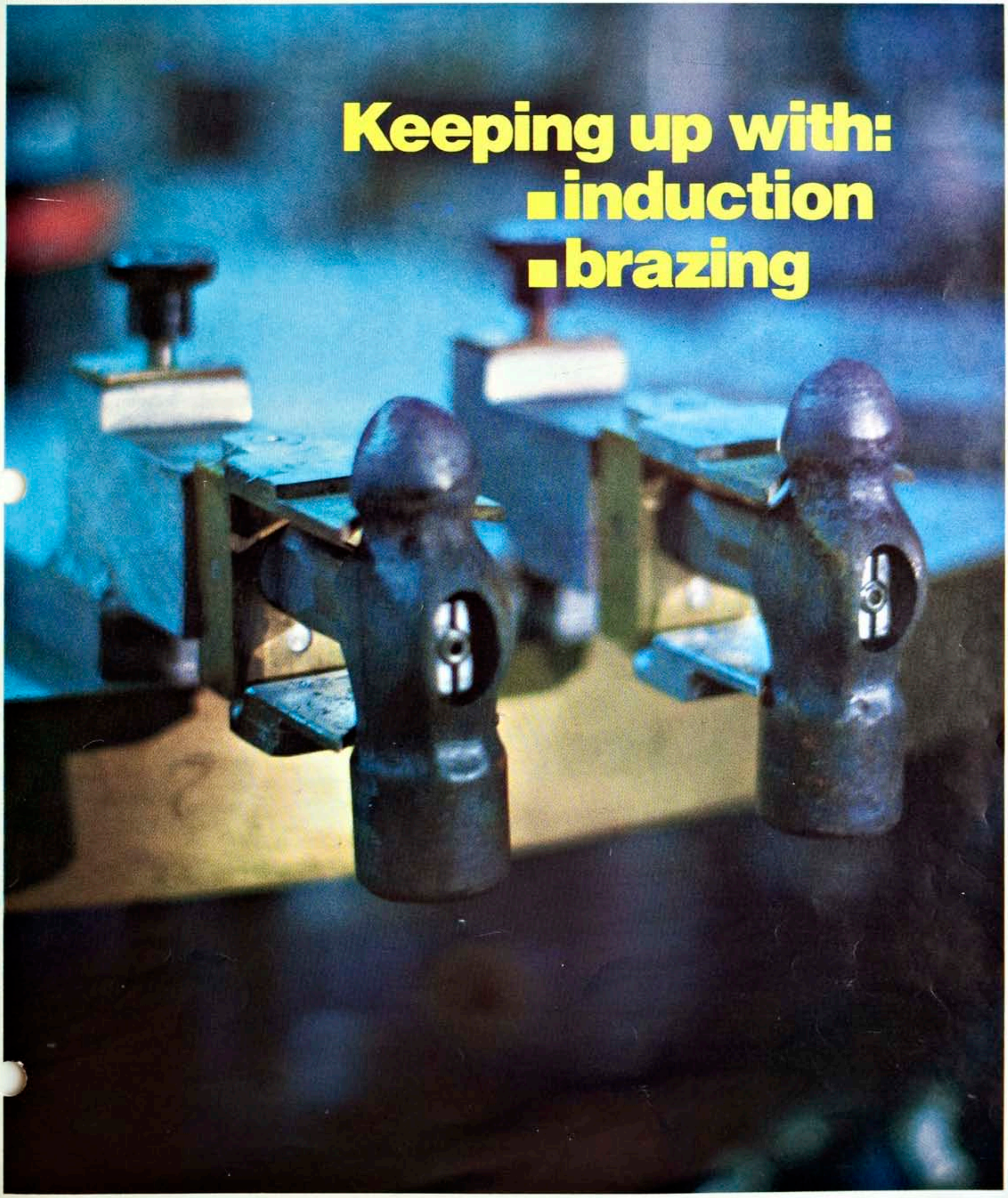


Multi-frequency, differential-quench

by STANLEY ZINN

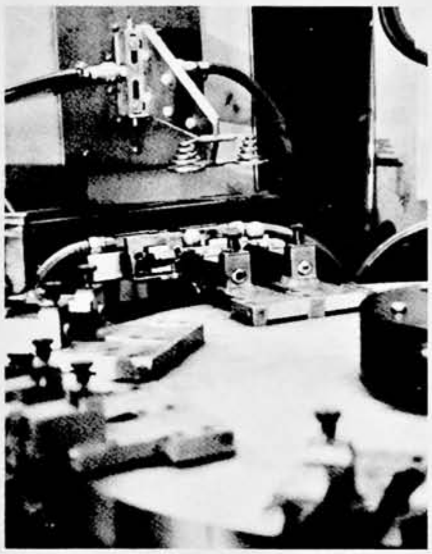
In deciding on the proper power supply to be used for induction hardening, careful consideration is generally given to two main factors: power required and frequency. Interaction of the two affects depth of case hardness; therefore, when a piece of dedicated equipment is being considered, careful selection of both is the key to optimization. However, there are other considerations often overlooked in the original analysis that can also greatly affect this decision.

A good case in point is the heat treating of hammer heads that range from ball peens through a variety of claw styles. Each presents a unique problem with regard to processing. The multi-frequency, multi-quench system supplied to several manufacturers by American Induction Heating Corp., Detroit, incorporates a series of unique approaches that can be applied to many similar applications.

The first area of a hammer to be hardened, in most cases, is the striking face of the hammer **(Fig. 1)**. Here, maximum hardness of Rc55-58 is required with a 1/4-inch average depth of case. Based upon the steel, the small part diameter, and the required depth, a frequency of 450 kHz was initially considered. However, this requires a long heat cycle to achieve case depth, during which the surface tends to overheat proper depth is attained—resulting in "blown grain" at the surface. It was decided that a frequency of 3 kHz should be utilized.

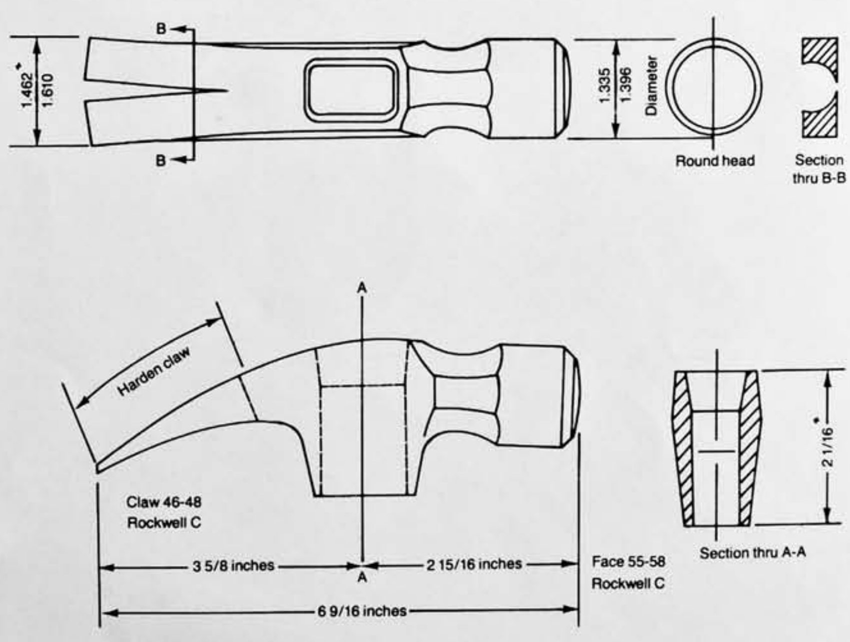
This, too, presents several problems. First, since the part diameter is fairly small, use of a pancake or spiral coil leaves a cold spot on the surface where hardening temperature is never reached. Second, the forged part dimensions vary considerably from piece to piece. The parts are fixtured from the eye of the hammer, and the dimension from this point to the hammer face varies with each forging. If a fixed coil-to-hammer-eye positioning device is used, the coupling distance from hammer face to coil varies with each part. Thus, the heat in each part is not constant.

To compensate for forging variations, the holding fixtures are hinged. The work coil is fitted with a ceramic pin that engages the face of the hammer as the heat station rises to the hardening position. As the pin engages each hammer face, it establishes a fixed coupling distance to the



Turntable viewed from first 3-kHz face hardening station. Counterclockwise: 10-kHz claw station; 450-kHz claw station; stripper arm at oil quench station; and load station.

Fig. 1
Claw hammer schematic and hardening requirements



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induction hardening of hammers

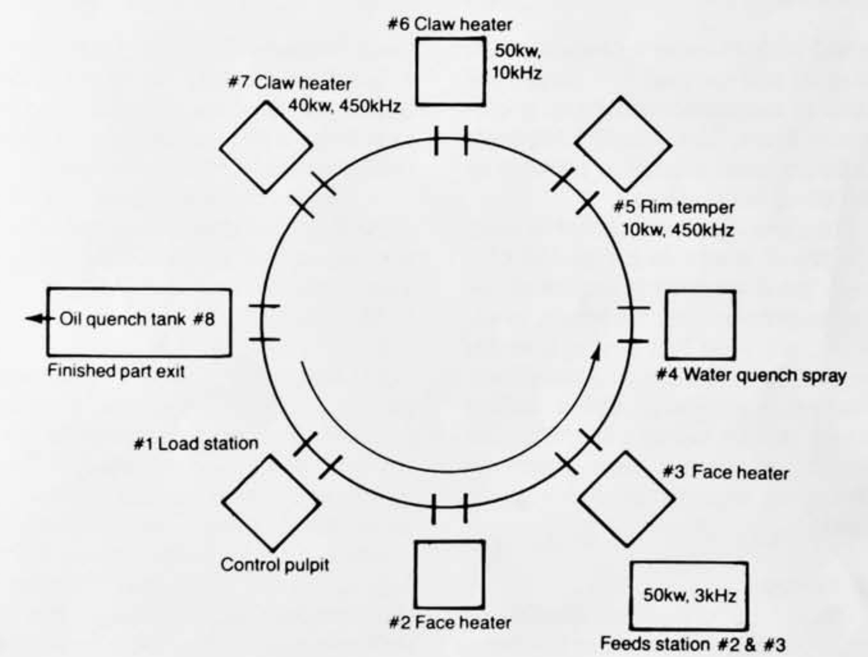
coil as the fixture moves on its hinge. To accommodate the 3-kHz heating cycle and the pancake coil "dead spot," a long heat cycle and extended soak at low power density are called for.

Heating uneven sections

The second major design problem occurred in heating the cross section of the claw hammers. As shown in **Fig. 1,** the tail of the claw is comparatively thin. This would normally dictate RF heating. However, at the crotch (Section B-B), the hammer has both a thin edge and a heavy cross section. Use of RF (450 kHz) in this area would produce proper heating of the thinner cross section. However, a prolonged soak to attain even heating at the heavier section would cause melting at the thinner

Hammer peens can be seen being hardened at 10-kHz station. Index stations 6 and 7 are used for heating peen portion of hammer.

Fig. 2
Automatic, eight-position index turntable



member. It was decided to try dual frequency.

In practice, the multi-turn coils are moved into position around the claw and brought to temperature with 10 kHz. This provides an even temperature in the thicker cross section. The thinner members heat only by conduction, and further, because of the high surface-to-mass ratio, dissipate sufficient energy so they do not come to hardening temperature.

The parts are then automatically indexed to a second set of coils where they are heated at RF frequencies. Here, the thin sections are uniformly heated and additional power is added to the previously heated core to allow for loss during index.

All functions are performed automatically on an eight-position index turntable **(Fig. 2).**

Position 1 is a load station with the operator's control pulpit and a conveyor bringing in forged hammer heads in tote boxes. Two parts at a time are loaded on the fixtures with the striking face pointed downward. Parts are located by the "eye" of the hammer and interchangeable fixtures are provided for different eye dimensions.

The table indexes on an automatic cycle, processing two hammers at each index station for a production rate of 850 parts per hour.

First position

In the first index location, the coil and heat stations rise to the part as a unit. Here, the insulator pin in the center of each coil engages the hammer face as the station rises. Each hammer fixture pivots on the hinge and the pin sets the coupling distance between the individual hammer face and the work coil. A 3-kHz power supply is energized to heat the hammer face below the critical hardening

Hammers

temperature. The heat station is lowered and the table indexes to the second heat station. This index time provides a soak period to equalize the heat in the hammer head at the dead spot.

The second station is a duplicate of the first position. Here, additional heat is applied to the hammer face to raise it to hardening temperature and achieve final depth. The part then indexes to the quench at station 3 with the index time providing a final soak to equalize temperature.

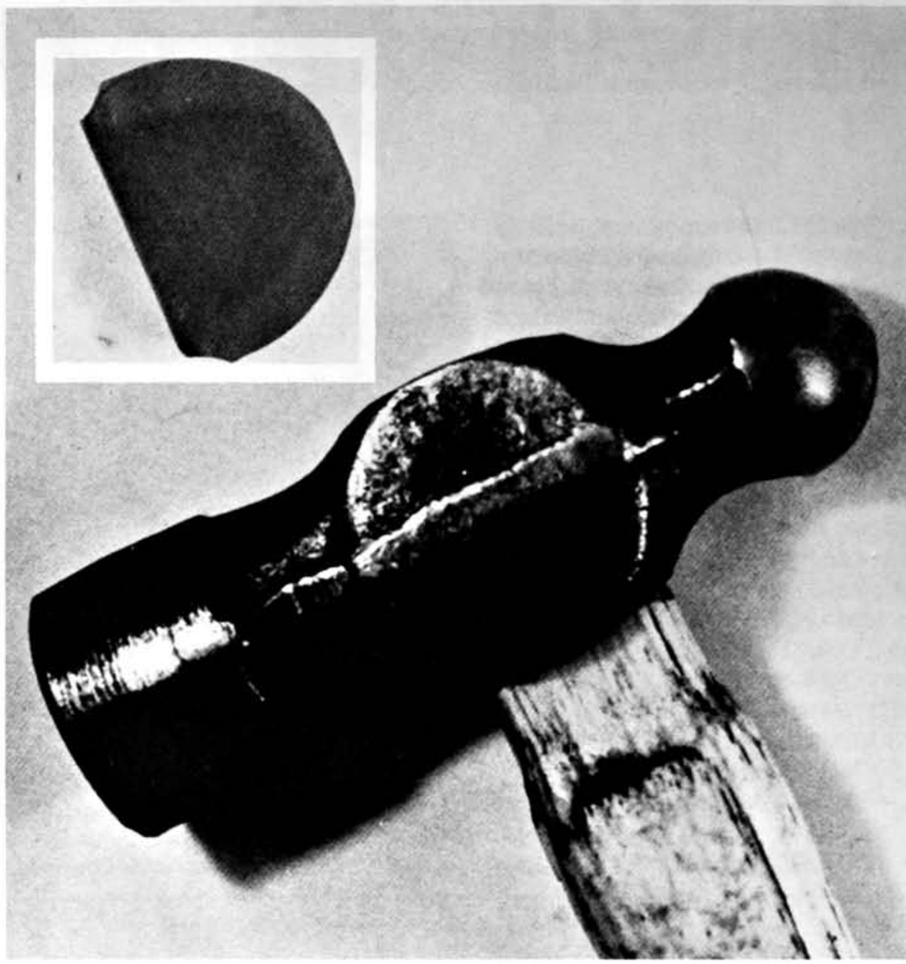
The hammer face must achieve a hardness of Rc 55-58; therefore, the quench is a water spray with sufficient flow to lower the part temperature rapidly to achieve maximum hardness.

At this point the material is brittle, and striking a nail at the hammer edge might cause fracture and chipping, a serious potential problem in product liability. Index position No. 5, therefore, is a rim temper, performed by a 10-kw RF generator whose low-power, high-frequency coil treats only the periphery of the hammer face. In all stations, the work coils are moved into position around the part area being processed.

Index positions No. 6 and 7 are utilized for hardening the claw or peen portion of the hammer. Because of their comparatively large, uniform cross section, peens are not a problem and they use the two stations as simple heating systems. Typical case cross section is shown in the photo on this page.

Claw hammers, as previously noted, provide a more complex structure due to their cross section. In addition, claw curvatures very among the different hammer styles and all of these must be accommodated.

In index position No. 6, a cam-controlled heat station and work coil combination moves the coil into position over the claw. The coil is designed with as loose a coupling as is feasible, and the cam adjusts the coil travel to accommodate the claw curvature. Here, 50 kw at 10 kHz heats the larger cross section of the claw to hardening temperature.



Typical case cross section for peen end of hammer is shown above. Because of their comparatively large, uniform cross sections, peens do not pose the hardening problem that claws do.

The parts are then indexed to position No. 7 where 40 kw at 450 kHz raises the thinner cross section of the claw to temperature, replacing, in addition, any heat lost during transfer from the prior location. Actual temperature is somewhat above critical as heat will be lost in transfer to the quench. However, temperature is limited to prevent excessive grain growth.

Last stop

The last index position consists of a stripper bar that removes the hammers from the fixtures and drops them into an oil quench tank. Since a hardness of only Rc 46-48 is required on the claw, oil was selected to provide a differential quench from that used on the hammer face.

A flight conveyor removes the parts from the quench tank and they are subsequently passed through the user's washer and belt temper for further processing.

It is through this multi-stage, multi-frequency, multi-quench approach that a variety of heat treating problems on a single part can be performed on a single machine. Eliminating a variety of materials handling problems between heat processing operations is made feasible by separating the individual treatment requirements and handling them as separate and unique operations on a single system. **HT**