

An Introduction to

SALT BATH HEAT TREATING

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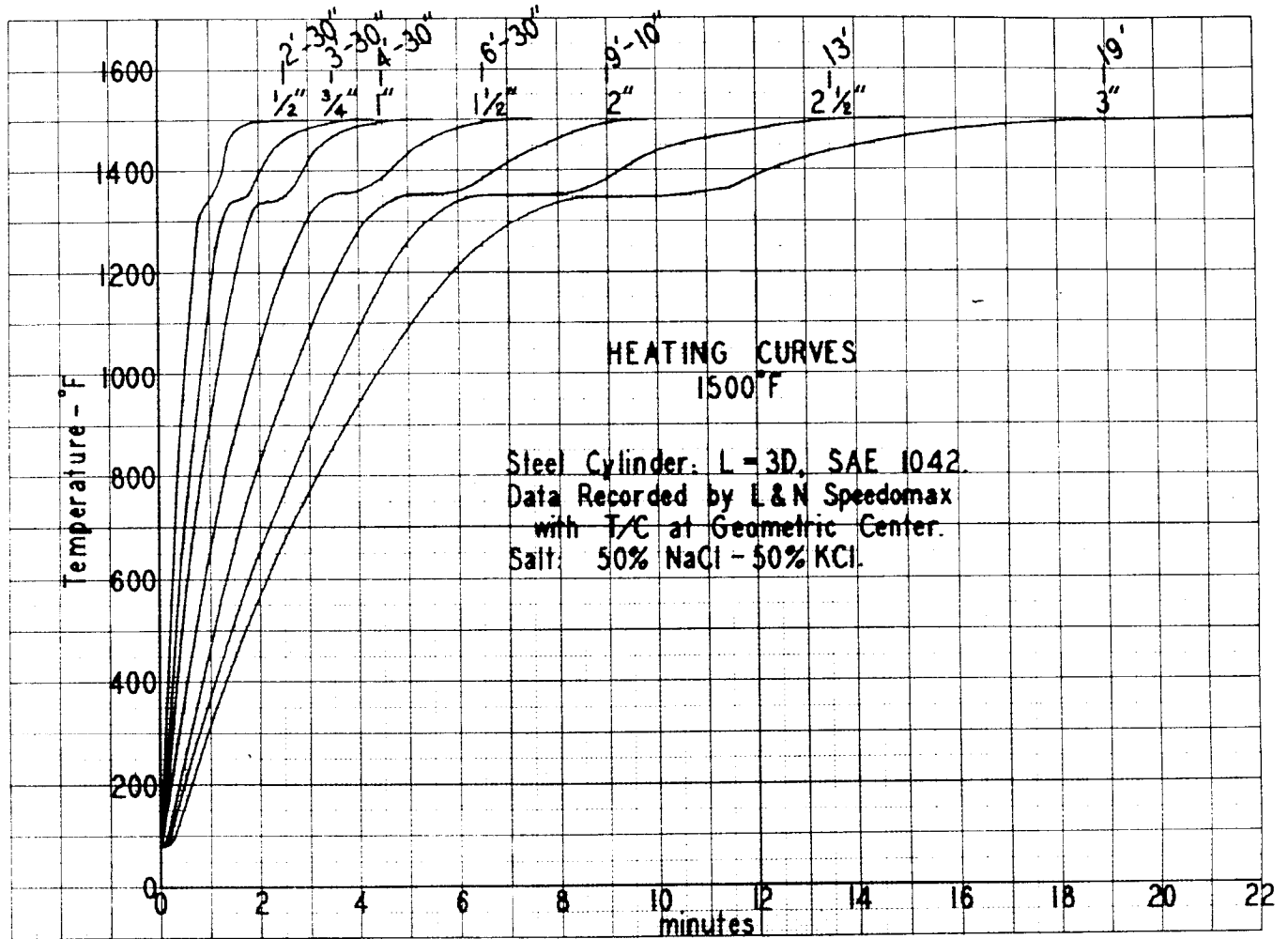


Figure 1
Rate of heating curve shows the time required to heat a part of given dimensions.

Part I

Salt bath heat treating

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WHEN WORK is fully immersed into a salt bath furnace, no air can contact it. Steel scaling, oxidation and decarburization can be avoided. It is common to process low, medium, and high-carbon steels in the same medium without surface carburization or decarburization. This is particularly advantageous for a variety of batch-type heat treating work. A thick salt film adhering to the surface serves as protection which continues when the work is removed and transferred (in the case of hard-

ening) to the quench operation.

Conduction heating. When the work is immersed, heat is transferred by direct contact with a heating medium of high capacity. This is 4 to 6 times faster than possible in radiation or convection type methods. For example, the time required to heat a part of given dimensions, at 1500°F,* the rate of heating is approximately

*All temperatures in this discussion are Fahrenheit.

Immersing metals, ceramics, or plastics in a molten salt makes possible unique characteristics.

5 min/in of thickness or $\frac{1}{4}$ the time required in radiation type equipment, see Fig. 1.

Automatic preheat. Upon immersion into molten salt, a frozen salt cocoon forms around the part. Layer thickness and the time required to melt it depend upon size and shape of the part, bath operating temperature and salt melting point. As a result, the work is subjected to an automatic preheat which prevents excessive heat shock and distortion damage of cracking. Furthermore, heat is transferred to the work over its entire surface uniformly. One side will not heat faster than the other. As the part gradually heats to the salt's melting point, the cocoon melts leaving only the molten salt contacting the work. It is impossible for the work to be higher or lower than the bath's temperature control.

Buoyancy. An important property in molten salt is molten salt weight; it may be 2 to 3 times that of water. Thus the piece's immersed weight is appreciably decreased 25 to 35 per cent of the original. This helps hold work distortion to absolute minimum.

Furnace development

About 30 years ago, the first important salt bath furnace installation was made in this country. Since then they've gained wide recognition and the number has grown—not only in number but in size and capacity. The 5000 in use today range in size to 43 ft L x 20 ft D x 8 ft W. In use, the unit contains 300,000 lbs of salt. Many operate with connected loads over 2500 km.

The furnace has a ceramic or metal container filled with molten salt. The work can be immersed for either heating or cooling. The

bath's composition consists of one or more salts, nitrates, chlorides, carbonates, cyanides, caustics, or additives in small amounts. The additives can be sulphates, fluorides, etc.

Heat is transferred between work and molten salt by conduction. The salt lends itself to either heating or cooling within a 300° to 2400° range, as required. Compatible salt mixtures are selected with proper operating ranges and often are formulated to meet specific temp-range requirements.

Operating principle

The electrode furnace generates direct heat in salt by using its resistance to current passage. Salts, while insulators in the solid state, are excellent high-resistance conductors in the molten state. Potential is applied to the molten salt by use of heavy electrode bars. These are connected to the secondary of special multiple voltage air cooled transformers. Electrodes are located in a recessed area of the bath and cause salt circulation by electromagnetic forces when energized. A strong magnetic field is created between electrodes when located close together.

Using Maxwell's Law, this field will cause salt particles between electrodes to move downward in a whirlpool fashion. This electrodynamic circulation assures absolute temperature uniformity through the bath and eliminates danger of undesirable differentials.

Design features

Furnace size and shape can be almost anything desired. One design uses a metal pot for temperatures up to 1750°. With this arrangement, electrodes must enter from the top and are usually located along the back wall free of the work area, see Fig. 2. All external walls are heavily insulated and radiation losses from surfaces are minimized by a suitable cover. The metal pot in this type furnace is used whenever salts contain appreciable amounts of cyanides, carbonates, and caustic soda, or for low temperature applications using nitrates and nitrites.

A different type furnace is preferred for higher temperature applications in the 1200° to 2400° range. The pot is of interlocking ceramic tile. Electrodes are replaced without costly downtime. The tile is merely raised, the old electrodes removed, the new or rebuilt electrodes installed, and the tile replaced.

A third type furnace, radically different from those above, is primarily intended for cooling rather than heating. The isothermal quench furnace is for martempering, austempering and isothermal heat treating operations (of which there are many hundreds). This

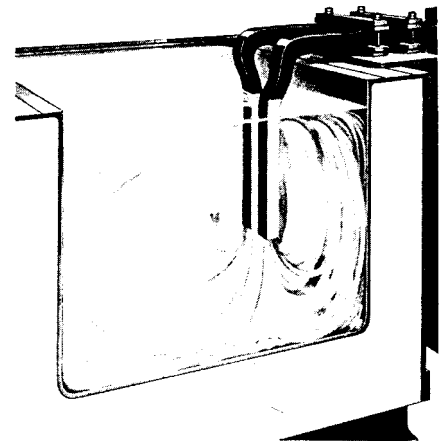


Figure 2

Ajax Type H Furnace has a metal pot with electrodes entering from the top. This type furnace is preferred for cyanide hardening, carburizing, descaling, desanding, and cleaning.

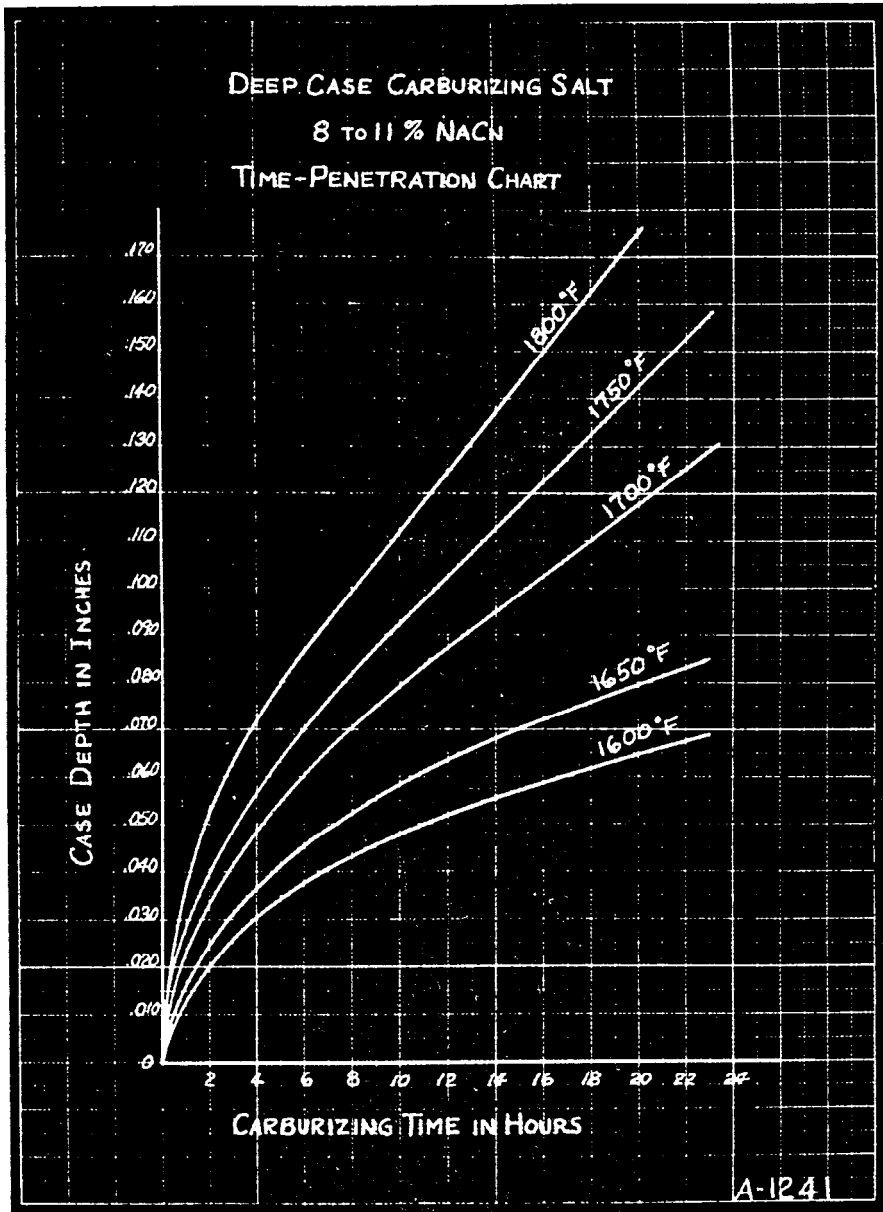


Figure 3
Carburizing curve shows time penetration needed to get desired case depth at various furnace temperatures.

type furnace will always have a metal port heated by either resistance heaters or gas fired immersion tubes. The external pot surface is frequently finned and air under pressure is circulated around the outside to extract heat. Both heating and cooling cycles are automatically controlled to maintain a constant and uniform $\pm 10^\circ$ temperature.

For quenching, salt must be properly agitated. This is done with a propeller driven pump which forces the molten nitrate-nitrite salt through the quench header. Whenever high temperature chloride salts are carried by

the work into the nitrate-nitrite, a separating chamber continuously clarifies the bath. Chloride salts settle to the chamber bottom and are removed periodically. This type furnace normally operates within 400 to 750°.

By eliminating pumps, separating chamber and cooling chamber, the furnace can also be used for heating applications with in the range of 400 to 1100°. It can be heated by either resistance heaters or gas-fired immersion tubes.

Applications

Liquid carburizing. This method

is used for diffusing carbon and small amounts of nitrogen into steel surfaces. It will alter physical properties of the surface by materially increasing strength and wear resistance. Liquid carburizing is done in baths, operating at 1450° to 1750°. All carburizing steel grades, carbon and/or alloy, may be liquid carburized with case depths of 0.005" to 0.250". A uniform carburization rate is controlled by maintaining sodium cyanide concentration—the source of carbon and nitrogen, see Fig. 3.

Salt samples are removed from the bath daily, and are analyzed for cyanide content. Replenishment salt is then added to maintain cyanide content at the required operating level. Since cyanide oxidizes in contact with air at these temperatures, the bath operates with a carbonaceous scum cover which serves two purposes: 1) It reduces radiation losses by 50 per cent or more—thus saving power; and, 2) it reduces cyanide oxidation.

It's interesting to note, a carburizing bath doesn't fluctuate chemically—radically or rapidly. It normally consists of a carbonate, chloride and cyanide mixture. With cyanide oxidation, carbonate is formed and this requires periodic dilution by adding fresh salt. Proprietary salt replenishments are available in varying concentrations of the above chemicals, to maintain proper chemical balance. Generally, it is only necessary to maintain the sodium cyanide operating level.

For example, the carbonate concentration in a deep case carburizing bath should not exceed 30 to 35 per cent with a sodium cyanide content of 8 to 12 per cent. Otherwise, carburizing potential or the bath's ability to do it is adversely affected. A higher cyanide content will also account for greater breakdown to carbonate. If drag-out losses on the work surface are low, it may be necessary to bail a portion of the bath each day to maintain proper chemical balance by adding fresh salt. As we point out above, chemical change is not rapid and considerable variation can exist without affecting carbon potential.

ure of its effect on the steel surface being treated. A more conclusive examination is made by processing steel test coupons, then examining the surface hardness using micro-hardness or superficial hardness testers or microscopically examining a cross section. Besides oxidants, the chloride salts can be contaminated with other materials such as contaminated work and fixtures in the bath. This is particularly true if the surfaces haven't been properly cleaned. Naturally, any contamination carried into the furnace will cause costly maintenance for removal.

To maintain acceptable bath neutrality, removing dragout loss on the work surface and fresh salt replenishments are usually sufficient. However, where contamination is greater or dragout minimal, a rectification practice may be used. Rectifier selections, either solid or gaseous, are available and each method is selected to meet individual requirements.

Methyl chloride gas rectification is used in chloride type salts operating at 1400° to 2000°. Its principal action is to chemically convert oxides to the original chloride and remove oxygen from the bath as carbon monoxide and carbon dioxide. Since by-products are gaseous, there is no residual contamination and the bath can be restored to its original composition. However, metallic or non-metallic contaminations are not removed by this practice. It may be necessary to resort to use of solid type rectifiers for more complete contamination removal.

Commonly used solid-type rectifiers are proprietary. Use of cyanide as the organic Dicyanamid essentially neutralizes bath oxides by creating a temporary reducing action. But this is soon dissipated, and additional rectifier must be added periodically. The main disadvantage here is that cyanide eventually decomposes into a carbonate, which is considered contamination. As pointed out above, with methyl chloride rectification, the Dicyanamid doesn't remove solid contamination and if allowed to accumulate beyond a safe limit, other means must be employed.

Rectifiers incorporating silicon carbide, metallic silicon and silica are commonly used effectively and will carry contamination to the furnace bottom as sludge. This can be removed by desludging tools. While this rectification method is effective, it's a disagreeable task. In a large operation, it could involve considerable time for the maintenance crew.

However, a "Chill Block Method" is available, where a heavy steel section is quickly lowered to the furnace bottom, allowed to remain a few seconds, then immediately removed. Sludge attaches to the cocoon forming on the block surface and upon removal, the sludge is quickly picked up and removed. After cleaning, the block is returned as many times necessary to remove sludge completely. This method is particularly effective in furnaces 15 to 20 ft deep and equally successful for those only 2 ft deep but 10 to 20 ft long.

High speed tool steel hardening

This requires the most exacting control of all heat-treat applications. A significant majority of quality tool manufacturers use salt bath furnace treatment. Any type high speed steel can be hardened with equal ease and safety merely by a change in furnace temperature setting. No special provision is required to adjust bath chemistry for the hardening of high-chrome high-carbon, moly or tungsten type steels. By providing close control instruments using either time proportioning or stepless control, temperatures can be controlled within $\pm 1^\circ$.

One customer uses the furnace operating at 2200° for treating a Sendzimer Roll, see Fig. 4. The furnace handles work pieces 12" dia x 108" long. Rolls to 3200 lbs each can be accommodated. Using the furnace for preheat, high-heat, quench and draw, the installation enabled him to control distortion, decarburization, maintain uniform high-hardness and meet all rigid QC specifications. By quenching directly from the austenitizing temperature into a bath 1000°, then transferring to a second quench about 600°, the double salt

bath quench achieved a consistently higher uniform hardness level than obtainable by air cooling.

Surface scaling is eliminated since there is no contact with air while cooling through the oxidizing and scaling temperature range. Since a better surface is obtained, less grinding stock is removed after hardening - thus reducing finishing cost.

An all-chloride hardening system is preferred for high-speed steel hardening installations. The preheating furnace (normally 1450° to 1550°F) can be operated with either sodium and potassium chlorides or barium, sodium and potassium chlorides. The high-temperature furnace at 2000 to 2350° usually operates with 100 per cent barium chloride. The pre-heating salt carry-over into the bath presents no problem because lower melting salts will volatilize at higher operating temperature. When transferring from high temperature furnace to salt quench, barium chloride is carried into the bath at about 1000 to 1100°. Since the quench mixture usually consists of barium, calcium, sodium and potassium chlorides, excess barium settles and must be periodically removed. Metallurgical requirements are easily met by quenching into this salt since cooling rate exceeds that possible by air.

On steel sections over 5 or 6", it is desirable to incorporate a 600° quench using an agitated nitrate-nitrite salt. This further insures cooling of the work from 1000° to 600° so that all sections, whether light or heavy, will be brought to a lower temperature from which the austenitic material can be safely air cooled to room temperature. In this case a more uniform steel transformation from surface to center is obtained, with minimum thermal and transformational stresses. Also, surface oxidation is avoided, and higher hardness is usually obtained. ■

Steels carburize at faster rates with higher temperatures - and this is another economy factor. With increased temperature-carbon diffusion rate also increases. Obviously, greater production can be maintained from a given carburizing furnace size by raising operating temperature; for example: a case depth 0.070" at 1700° requires 8 hrs. At 1800°, the same case depth can be obtained in less than 4 hrs. Thus, with an increase of 100°, capacity has doubled. Higher production rates are possible, obviously; and it is necessary to design the furnace with adequate power to accommodate the required lbs/hr.

Carburizing, cyaniding and nitriding operations are applied to a variety of work involving use of either sodium or potassium cyanides as the active agent. For example, one of our furnaces carburizes outboard motor crank shafts. A 0.045" case depth is obtained at 1700° in 4½ hrs. The work is then conveyed through the furnace with a push-pull mechanism. Upon reaching the end, it is removed and allowed to air cool to a subcritical temperature. The work is then reheated in a neutral bath at 1500°. There is sufficient cyanide salt carry-over into the neutral chloride reheating bath to protect the surface. The work is then martempered in a nitrate-nitrite salt at 400° in an agitated isothermal quench operating with approximately 1 per cent water addition for increased quenching severity. The work is then allowed to air cool to room temperature and then is drawn at about 300°.

After grinding, surface hardnesses are held within 0.005" run-out. Cyaniding is similarly carried out in a salt bath furnace provided with a steel port and over-the-top electrodes. Operating 15 to 30 per cent with cyanide content, both carbon and nitrogen are added to the steel surface and case depth is usually limited to about 0.010". Generally, operating within the

1400° to 1600° range, the salt is a mixture of cyanide, chlorides, and carbonates. Cyanide hardening is usually applied to obtain a superficially high-quality, wear-resistant surface for the more light-duty applications.

Salt bath nitriding is carried out within the 950° to 1050° range using a steel pot container for cyanide, chloride, carbonate and heated by over-the-top electrodes. Thirty to 60 minute immersion in the liquid nitriding bath is preferred for some high-speed steel cutting tool applications where maximum wear resistance is required. Case depth is usually measured in 0.0001"-0.0005" terms.

Nitriding bath modifications have been made to obtain special effects; for example: by bubbling ammonia through the bath, a higher nitrogen potential is obtained. This improves case depth and nitrogen content in the steel. Adding sulphur compounds, a sulfurizing treatment avoids seizing and galling. Still another process takes advantage of bubbling air in the bath to purposely oxidize the cyanide to a higher cyanate level. This changes the case characteris-

tic so that it is file-hard but flexible. It also permits, in some cases, severe part bending before case fracture.

Neutral hardening

Hardening ferrous alloys in chloride salts without harmful surface attack (scaling, pitting, etc.), is called "neutral-hardening." Carbon, alloy, stainless, hot work and high-speed steels are commonly neutral hardened in furnaces operating over a 1400° to 2350° range. Since the salts provide the immediate environment surrounding the work, attention must be given to the bath's chemical condition to maintain neutrality.

As the chloride salt is operating continuously with air contact, it is subject to contamination and accounts for increase in salt alkalinity. This is measured either in terms of pH or by wet chemical analysis in terms of per cent sodium oxide or barium oxide. It is generally accepted when chloride salt increases in alkalinity, it increasingly tends toward decarburization. However, alkalinity or pH of the bath is not a direct meas-

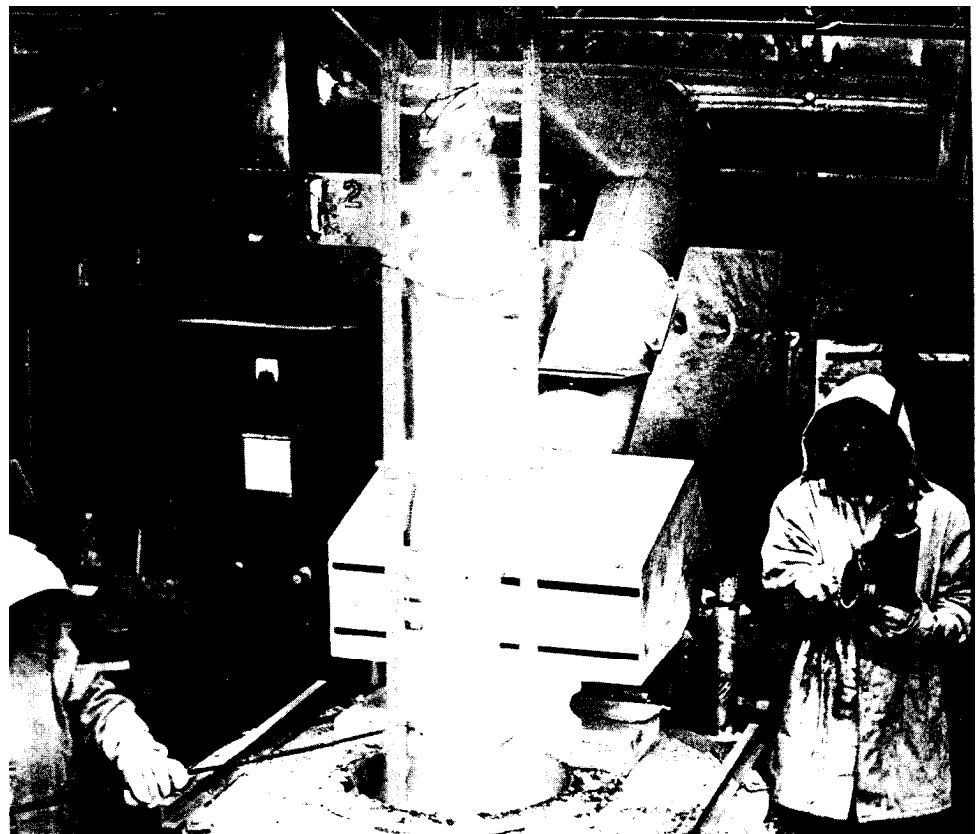


Figure 4
A Sendzimer Roll being removed from a salt bath furnace used for high speed tool hardening.

PART II

Salt bath heat treating

This final part of Mr. Mehrkam's discussion will cover **Annealing, Brazing, Aluminizing, isothermal Quenching, Martemper and Ausforming, and Cleaning.**

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SALT BATH FURNACES are used in a wide variety of annealing and solution heat treating applications. We have an installation where low carbon steel wire (C-1008), in 36" dia x 30" coils, is annealed in a nitrate type salt at 1000°, see Fig. 1. It is done in a steel pot with over-the-top electrodes. The furnace is 42" L x 48" W with a 48" salt depth. The connected load is 160 kw. which is capacity rated at 1000 lbs/hr. As the wire surface enters the salt, it has an organic lubricant which oxidizes and burns away. The resulting surface exhibits a bluish-black oxide readily removed by mild pickling.

Steels of 0.35 carbon or less are given a "process anneal" in a carbonate-chloride or tenary salt consisting of barium, sodium and potassium chlorides. This treatment is applied as a relief to recover original ductibility as wire is drawn to smaller diameter. Coils are either air cooled or quenched

directly from the bath. The surface is scale-free and exhibits only a slight oxidation responding to mild pickling to prepare for drawing lubricants. The process is done at 1250 to 1300° and cycle time is within 20 to 30 min for 200 to 300-lb coils.

Salt baths have also been successfully used to anneal stainless and nickel-chrome alloy products. Both 300 and 400 series stainless fittings have been annealed within 1550 to 2100°. Total cycle time falls within the 5 to 30 min range. Work is water-quenched directly after removal from the furnace. The surface is slightly oxidized, but it is quickly restored by a short acid dip.

Maintaining bath chemical balance presents no problem. While alkaline earth and other metallic oxides may build up, they are not harmful to low carbon stainless steels. However, the baths can be rectified in the same manner previously discussed.

When using methyl chloride or cyanide rectification methods, sufficient time should elapse afterward to prevent possible carbon pick-up.

Copper and copper base alloys are successfully annealed in carbonate-chloride salts (1100-1500°). Copper-chrome alloy rods, 12 ft long, can be suspended ver-

tically for solution annealing in chloride salt. Parts are immersed at 1825° for 30 min, and rods are then quenched in water. As treated, the surface has only a slight oxidation and is completely scale-free.

Nitrate salts provide an excellent heating medium for solution heat treatment of aluminum alloys. High-heat reflectivity properties are no problem since salt heating is by conductivity as salts contact the surface. Salt heating is several times faster than air furnaces. After a few minutes immersion time, the work is water quenched leaving the surface metallically clean, while nitrate salt oxidation, by air, causes increase alkalinity in the bath and may cause slight etching. In most applications, this condition is avoided by replenishing dragout losses with fresh salt. Otherwise, the salt can be rectified by adding sodium or potassium dichromate.

Brazing

Salt bath brazing is a limited but attractive method for a number of jobs. All types of brazing materials can be used: silver solder, aluminum, brass and copper. Both ferrous and non-ferrous base materials can be joined or combinations thereof which influence joint

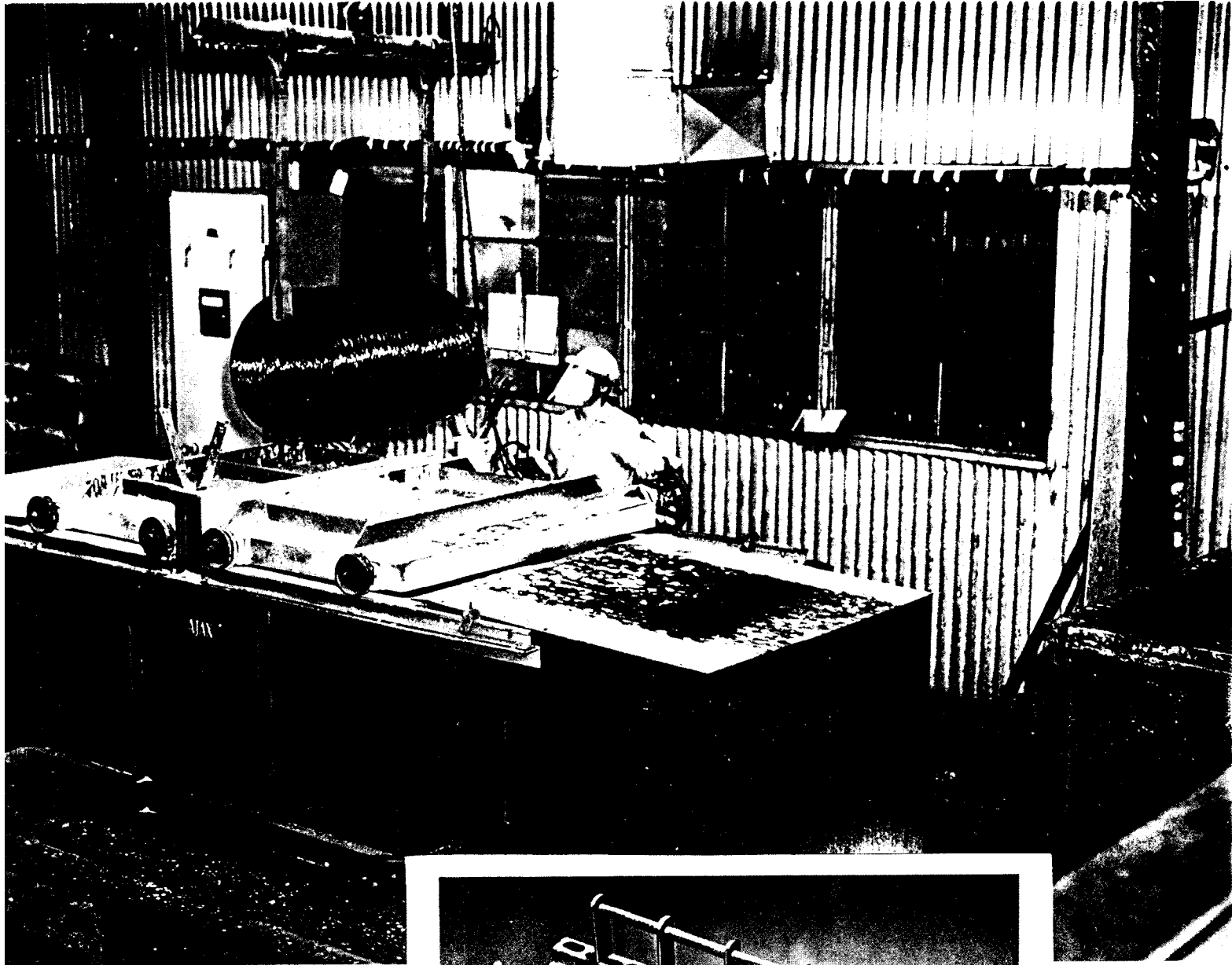


Figure 1
 Low carbon steel wire is annealed in this steel pot furnace with over-the-top electrodes. The furnace uses nitrate salt at 1000F.

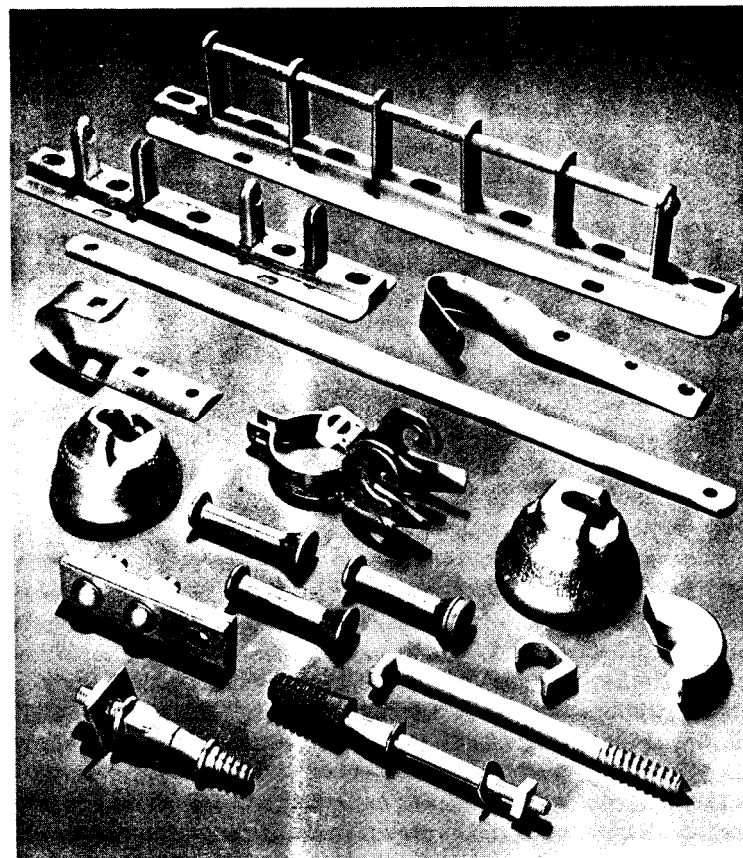


Figure 2
 Typical parts that are aluminized for better corrosion resistance.

design and brazing alloy location, the same for salt bath brazing and other methods. Here brazing alloy can be applied in the form of wire, shim, washers, sheets, etc. And, in joint areas which do not permit preplacement of preformed material, paste form brazing alloy can be applied.

Salts are generally a chloride mixture, but also can be modified

by adding reactive ingredients. While salt immersion excludes air contact and oxidation, it is necessary to provide a fluxing environment to obtain good flow and penetration of the brazing alloy throughout the joint area.

For silver solder, brass, and copper brazing, it is not uncommon to apply a fluoride-borax type flux to the joint area before immersion. Since these fluxes are usually water mixtures, it is essential that

then it is selectively immersed in a chloride salt at 1600° so that the carbide is exposed above the bath.

The alloy begins melting in about 6 to 8 minutes, and the bit's shank is thoroughly austenitized while the carbide slots are adequately flooded with molten silver solder. The bit is then lifted vertically and transferred to a selective isothermal quench where the shank rapidly cools with the carbide exposed. The alloy is added

brazing. The reason brass brazing is not more widely used with other heating methods is because of melting instability. Zinc is readily volatilized, when melted, when in contact with the atmosphere. When lost from the base alloy, the physical properties of the remaining alloy are completely altered. Dezincification is avoided and brass alloy fluidity is easily maintained in a neutral chloride or carburizing type salt used to impart a slight carburizing case to the part's surface.

In an application using SAE-1010 for bicycle forks, for instance, flux is applied by dipping or spraying. Alloy rings of 60-40 brass are located in contact with the joints for brazing. This installation indicates what can be done in a fully mechanized operation using a revolving unit with six stations through which parts pass. They are: 1) Load and unload, 2) dry, 3) furnace braze, 4) air cool, 5) hot water wash and 6) hot water rinse.

The mechanism is operated by a hydraulic cylinder which raises and lowers the central shaft and rotates one position every 3 min. The operator loads 14 assembled forks on each fixture at the first station, with a 30 second interval between part transfer. In this, the furnace is maintained at 1700° temperature.

The forks can also be copper brazed. Here the assembly is fluxed, dried and partially immersed in a neutral chloride salt at 2050° for 2 min. Assemblies are then air cooled to about 1500° for 15 to 20 seconds, then water quenched followed by a hot water wash. The operation is semi-automatic, by a push-button causing the fixture to be raised and lowered for a specified time cycle.

An interesting modification combines carburizing and brass brazing in one step. A carburizing bath provides an excellent self-fluxing heating medium, simultaneously giving a superficial carburized surface for wear resistance. A good example is a pair of vise-grip pliers, where all component parts are SAE-1010. The small jaw insert is carburized at 1675°, for 30 minutes, in a water soluble

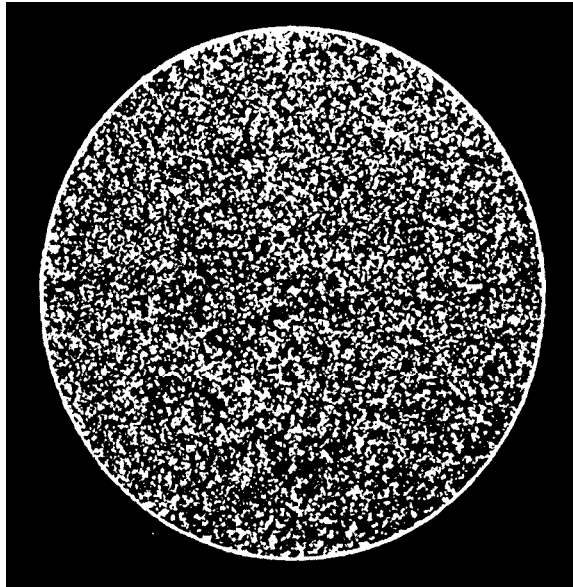


Figure 3
Photomicrograph shows cross section of a 5/8" diameter bolt. Note the uniformity of the aluminum coating.

the flux assembly be thoroughly dry before immersion to prevent splattering. Applying flux to the joint locally creates a temporary fluxing atmosphere, necessary for steel surface etching and oxide contaminant removal, just prior to wetting and flow of the brazing alloy. The flux is normally displaced by the alloy and dissipated into the molten chloride salt. Since these fluxes are flushed away from the part surface, there is no cleaning problem.

Carbides are successfully silver-solder brazed to 9" dia medium alloy steel drill bits. The bit is held vertical with the carbide end up. And the carbide is generously coated with a brazing flux. The silver solder alloy and carbide is then inserted. The bit is preheated to approximately 1000° to drive off moisture from the flux;

continuously to the carbide area until the silver solder is completely solidified. This replaces shrinkage cavities that tend to develop.

For brazing ferrous assemblies, the trend has been toward the use of brass alloys, such as 60-copper 40-zinc. Compared to silver solder, brass is only a fraction of the cost. Also, brass brazing is done in the 1675 to 1750° range. When replacing copper, it eliminates grain coarseness and requires only half the power. Brass alloys accommodate a greater variation in joint tolerance without strength loss; clearances to 0.010" have been brass brazed successfully, although this is not recommended.

Brass brazing with a 60-40 type will yield average shear stress values within 42,000 to 46,000 psi. This compares favorably with results usually obtained by copper

carburizing salt before assembly.

After an air-cool to room temperature and a water wash, the jaw and a hairpin clip are pressed into position. The round bushing and brass alloy ring are inserted at the other end, and the parts are rack loaded. They are then immersed in the bath for 20 minutes at 1675°, then quenched in oil, washed and drawn at 500°. The resulting hardness is Rc 48-51. The brazed joints pass an acceptance test of 40,000 psi-minimum. The handle portion of the assembly has a slight case approximately 0.004"-0.005" which is abrasion resistant and serves well as a final finish.

When brazing aluminum, it is necessary to penetrate the thin oxide coating to obtain a sound bond. This requires an active flux during the entire brazing cycle to insure good flow and alloy penetration. The aluminum brazing alloy is particularly vulnerable to oxides or oxygen in the bath; and it is, therefore, essential to pre-clean the assembly thoroughly with various alkaline and acid before brazing. The function of the bath is to melt the alloy in an environment completely oxidation free and provide fluxing for surface coat removal of the parent metal.

The aluminum dip brazing salt is essentially a chloride mixture with small percentages of either aluminum or sodium fluoride. The fluoride acts as reducing agent and reacts with any oxides present. The bath operating at 1080 to 1120° from which the volatile and corrosive fumes are removed by an exhaust system. Two basic procedures maintain a proper bath: since it operates relatively close to freezing, it is necessary to make periodic additions of lithium chloride for fluidity; and the self-fluxing characteristic is continuously depleted so it is necessary to make periodic fluoride additions.

In a bath with sufficient drag-out, adding fresh salt is usually sufficient to maintain proper chemical balance; but, due to the hygroscopic nature of the aluminum brazing salt, moisture enters the bath and becomes a contamination which must be removed. Al-

loy flow and penetration failures are often indications of water content. The bath is easily rectified by immersing an aluminum sheet, where oxygen is picked-up on the surface and the hydrogen is driven from the bath surface burning on contact with air. The sheets are reimmersed, after cleaning, as needed for bath dehydration.

Aluminum dip brazing furnaces can be built to meet most dimensional requirements. Furnaces 20 ft deep and 15 ft long have been built successfully. They are almost always heated by immersed electrodes and have ceramic tile pots.

Aluminizing

Coating the surface of ferrous material with aluminum gives better corrosion resistance. This finish resists many types of atmospheres from room temperature to 1500°, see Fig. 2.

To prepare for the process, parts (such as pole line hardware and industrial fasteners, see photomicrograph Fig. 3) are descaled in a descaling furnace salt bath, pickled, preheated in a flux-type chloride-fluoride salt at 1300° and remain there about 10 to 15 minutes. During this time the baskets containing parts are progressively moved from right to left, while the bath reacts with the oxides on the part surfaces so that aluminum wetting-out is precluded. The baskets are then quickly transferred to a pot of molten aluminum at 1290° and held there for 1 to 3 minutes. During this time parts are agitated so all surfaces are covered completely with a coating of from 0.002 to 0.025" thickness depending upon dipping time and temperature.

The bath performs two functions: it preheats material to proper temperature and chemically reacts to residual oxides that would interfere with the aluminum wetting the surface and diffusing into the base material. Bath maintenance is similar to that for aluminum brazing and dragout loss replenishment is sufficient for chemical balance.

Isothermal quenching

In steel hardening, distortion and

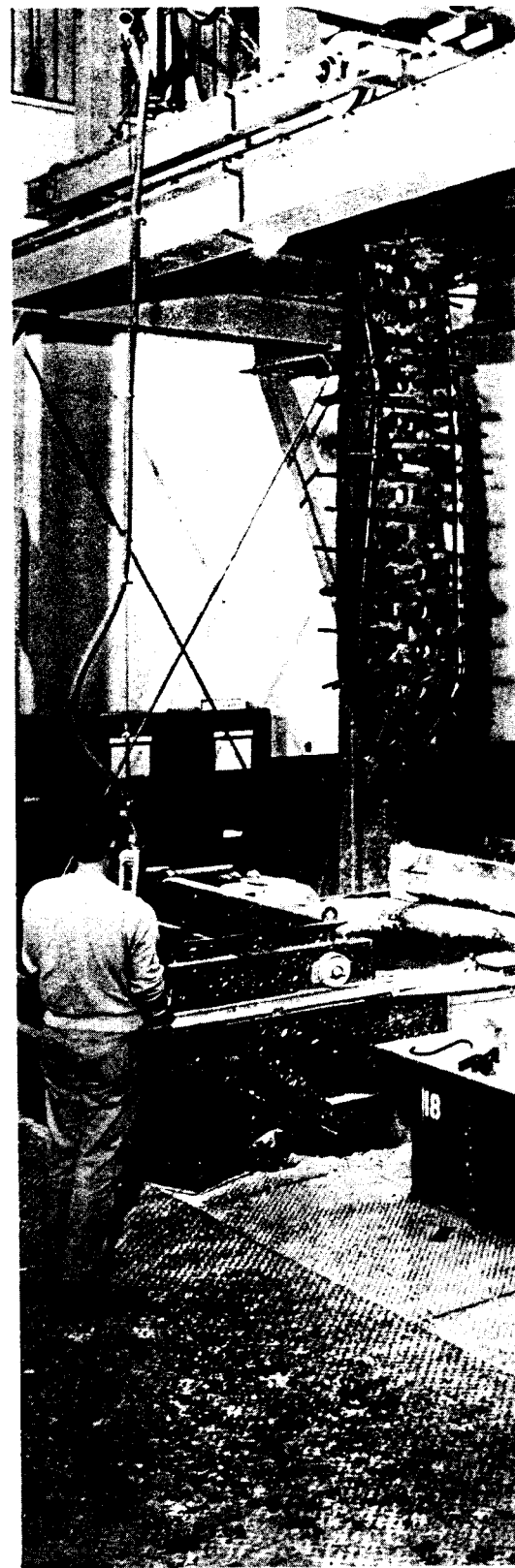


Figure 4
Martempering the 9-ft. wing flap track in the Boeing 722 jetliner.

cracking are often associated with water and oil quenching. However, distortion is considerably reduced and cracking avoided by quenching in a molten nitrate-nitrite salt within the 400 to 750° range. Martempering and austempering processes are also successful for parts ranging in size from typewriter bars to automotive bumpers.

Austempering is usually applied to carbon steels 3/8" or less, alloys to 2", where hardness falls between Rc 35 and 54, and where toughness or bendability without breaking is required.

In one installation for austempering rotary mower blades of SAE-1070, they are rack-loaded, austenized in a neutral chloride type salt at 1550°, and transferred to the bath where they are quenched at 640° for 27 minutes. The final structure is bainitic and provides a toughness superior to oil quench and temper. Salt quenching provides a means by which heat can be extracted quickly to prevent the steel from transforming into undesirable high-temperature material. Austenite can transfer to the desirable bainitic product by the isothermal quench temperature.

Quenching severity is enhanced by adding water-particularly successful for borderline hardenability applications. Water is added to the nitrate-nitrite by spraying it on the surface of the salt then mixing mechanically into the bath-water being about half the weight of salt explaining why the two must be mechanically mixed.

Agitation is essential for extracting heat, because it is necessary to move the quenching medium past the surface of the work being quenched. Salt, completely dehydrated, does not have a vapor phase within the normal operating temperature range; however by adding water, moisture is driven off-which provides faster cooling. The addition of water also improves quenching severity so that heavier steel sections can be quenched satisfactorily. Because thermal and transformation stresses are held to a minimum,

distortion is minimized and cracking eliminated.

Martempering is generally for any steel that responds to oil quench hardening. By martempering within the 400 to 750° range, lower thermal and transformation stresses are involved so less distortion is encountered. As in austempering, water addition results in improved hardness.

A 9-ft-long wing flap track for the Boeing 722 jet is a good example of martempering, Fig. 4. The parts are a modified SAE-4330 and 4340 steel held to ± 0.010 " machining tolerances. Both austenitizing and isothermal quenching will handle pieces up to 2000 lbs. The austenitizing furnace operates at 1600° with a connected load of 140 kw, and measures 5 ft dia x 16 ft deep. The quench furnace is rated also at 140 kw, having working dimensions of 5 x 7 x 15 ft deep.

When parts are removed from a nitrate-nitrite salt, a thin salt film adheres to the surface. The mixture is one of the most soluble used in heat treating and will respond to a hot water wash and rinse, leaving a bluish-black oxide finish. Contrasting with oil removal by alkaline cleaners, water washing for salt removal permits savings in equipment and maintenance. This is in addition to the metallurgical advantages.

Martemper and ausforming

Meeting space-age demands has required new design and fabricating methods, even though many steels have common fabricating problems. Many materials are difficult to form to the desired shape without excessive part distortion during heat treatment. Instead of forming structural members, then heat treating them, it is possible by using isothermal quenching equipment to form and harden simultaneously. The steel is austenitized at normal temperature, then isothermally quenched in a nitrate-nitrite salt within the steel's bainitic range.

While the steel is still austenitic, forming machinery (part of the isothermal equipment) forms the part. After this operation, parts are removed and air cooled to

room temperature. Dimensions are held accurately, and the part is fully heat treated ready to draw without distortion. This heat-treat and forming method has been successful for alloy and stainless steel sheet, plate and rod. The process also improves physical properties over conventional treatment.

Another contributing advantage of hot forming is the salt's lubricating effect. Whether the forming machinery operates beneath the quench bath surface or parts are removed from the bath and formed, the salt film adhering to the surface provides lubrication. In drawing cups from discs, fairly high reductions have been made possible due to the lubrication effect of salt at 600°.

Cleaning

Maintaining and operating extruding and forming equipment is a problem that has plagued the plastics industry. Dies, plates, screens, etc. become contaminated with plastic materials that resist removal by alkali and acid solvents. Hand cleaning was necessary and costly. Using salt bath cleaning furnaces in the industry, they now find cleaning time reduced from hours to minutes.

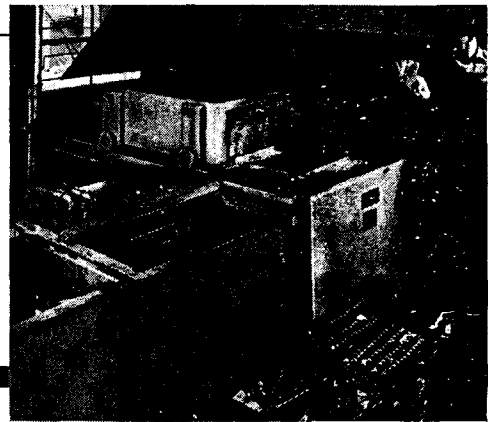
Polymers have been successfully removed from steel mold surfaces by immersing them in an oxidizing type salt. All polymer materials under go decomposition by complete removal unless brought into contact with molten salt.

Using a caustic-nitrate type salt at 650 to 950°, polymers will decompose and burn-off as combustion products in minutes. Total time cycle is usually less than 30 minutes for complete organic contamination removal, leaving the part with a bluish-black oxide coat.

In some cases, a residue results from material breakdown. Inert substances not reacting with the bath will fall to the bottom as sludge which must be removed periodically. There is little chemical deterioration in the bath; so adding salt from time to time, to replace that lost in dragout, is adequate to maintain cleaning efficiency. ■

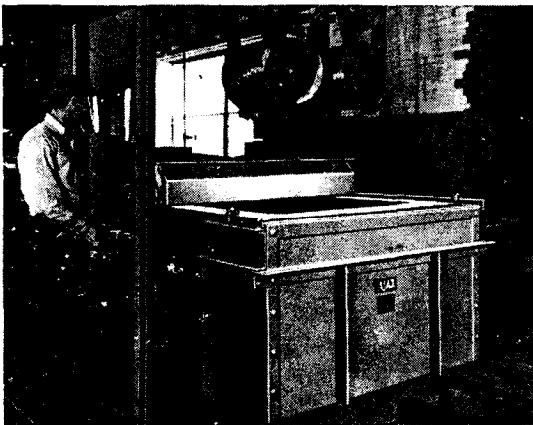
Wondering about versatility?

Some people think that salt baths can be used for only one type of work. They're wrong. For example, this 65Kw Ajax salt bath at Ledex, Inc. handles four operations with the same salt . . . carburizing, brazing, simultaneous carburizing and brazing, and hardening. Installation includes oil quench and automatic controls. Savings in the first eight months: \$37,000. How much versatility do you want?



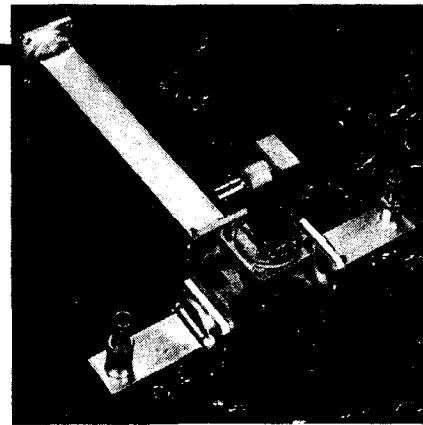
AT AJAX, WE'VE ANSWERED A LOT OF TOUGH QUESTIONS ABOUT SALT BATHS

Can we answer one for you?



Need fill-in on annealing?

We'll pre-test for you in the Ajax Metallurgical Service Laboratory. Then, talk techniques, project specific savings in time, costs, better quality control . . . and give you proof. For instance, Hanover Wire Cloth Division anneals over 19,000 pounds of window screen wire in a two-shift day with this one 160Kw Ajax salt bath. Gets more uniform annealing since bath temperature varies less than 10°F throughout, resulting in longer drawing and weaving runs and better screening.



Want latest slants on dip brazing?

Ajax molten salt baths let you heat all parts of a component uniformly, control distortion, reach joints that are inaccessible by other methods and maintain the closest tolerances. Typical of microwave work is this aluminum harmonic generator and balanced mixer brazed at United Shoe Machinery in Ajax salt baths. Thirty separate parts are brazed into one assembly. Want more on dip brazing? Just ask!



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