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IMPROVING CORROSION AND WEAR RESISTANCE BY SALT BATH NITROCARBURIZING PLUS OXIDIZING IN AUTOMATED FACILITIES

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I. INTRODUCTION

Crankshafts, camera parts, furniture fittings, piston rods, tools, gear wheels and many other parts have been salt bath nitrided in mass production for many years. A combination of high fatigue strength, good wear properties and high resistance to corrosion are achieved by this process. It is not harmful to the environment and can be performed in fully automated facilities. Salt bath nitrocarburizing is carried out at a relatively low temperature and can be used for treating all ferrous materials. It is widely used throughout the world and its popularity is ever increasing.

2. PROCESS OPERATION

Salt bath nitrocarburizing works at 580 °C. The salt melt consists of alkali cyanate and alkali carbonate. It is operated in a pot made from a nickel-based material and equipped with an aeration device.

A reaction between the surface of the ferrous components and the salt melt takes place during the process. This causes the formation of atomic nitrogen, which diffuses into the steel surface, and the formation of alkali carbonate in the melt. This carbonate is converted into active cyanate during regeneration of the bath. A resin-type regenerator, which is actually an organic compound of carbon, nitrogen and hydrogen, is used for this purpose. The regenerator does not cause an increase in volume, therefore salt does not have to be bailed out.

After salt bath nitrocarburizing the parts are cooled in an oxidizing salt bath called AB 1. One of the tasks of the cooling bath is to destroy the small amount of cyanide which forms during nitrocarburizing, and the cyanate. This ensures that harmful substances adhering to the parts are destroyed before they can reach the rinsing water. The AB 1 cooling bath is operated at 330 - 400 °C. Figure 1 shows the detoxification of cyanide and cyanate in relation to bath temperature and reaction time. The tests were carried out under severe conditions, that is to say, large quantities of liquid nitriding salt were put into the cooling bath. After only a short time at the recommended operating temperature, both cyanide and cyanate were completely destroyed by converting to carbonate.

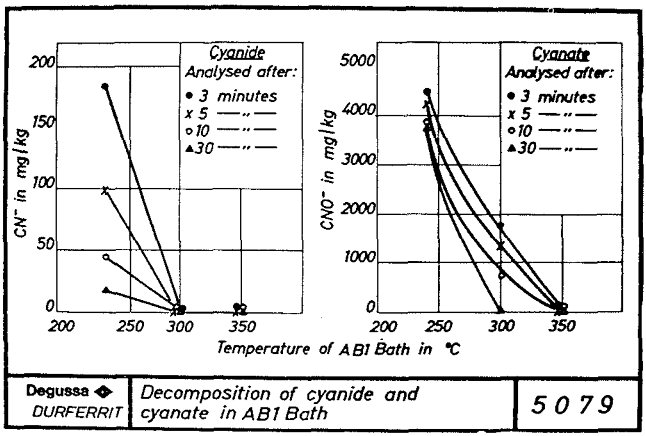

FIG. 1

Apart from destroying harmful substances and its oxidizing effect, the cooling bath also has a beneficial effect on the dimensional stability of the cooled parts. In-service experience has repeatedly confirmed this.

A new development of recent years is the QPQ process, which has led to a considerable improvement in the corrosion properties achievable hitherto. QPQ stands for QUENCH - POLISH - QUENCH and denotes the sequence of treating as shown in Figure 2. After preheating and salt bath nitriding the components are cooled, as usual, in an AB 1 bath. To reduce roughness the parts are mechanicall processed, for example by lapping, polishing, drum polishing or other methods. Re-immersion into the oxidative salt melt after mechanical polishing gives unalloyed and low alloyed steel parts a dark blue shiny surface and a resistance to corrosion superior in many cases to surfaces produced by galvanic processes.

3. PLANT

A process can only be performed satisfactorily if the appropriate plant and equipment are available. For a long time, salt bath processes had the reputation of

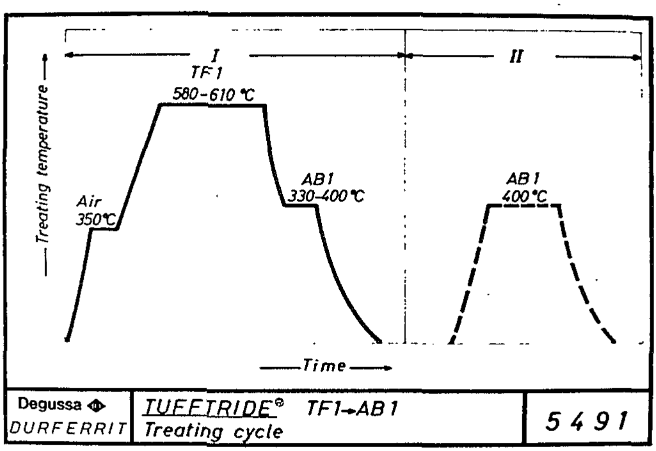

FIG. 2

being technically out-of-date, harmful to the environment, dirty and not capable of being automated. The development of new processes and installations over the past ten to fifteen years has changed this situation completely.

A schematic diagram of an automated salt bath installation is shown in Figure 3. Such a system guarantees constantly uniform results, great economy and a minimum of manual

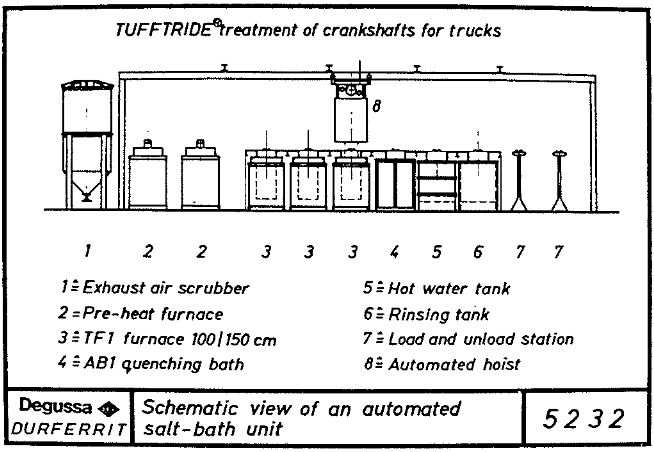

FIG. 3

work. Figures 4 and 5 show views of an automated plant used in treating piston rods. Figure 6 shows the latest development - it is a plant provided with rectangular "pots" instead of round ones. Loading and unloading are performed by robots. The throughput is 8,000 camshafts per day. All such installations are controlled by microprocessors and provided with a transportation bell.

Every company makes a comparison of costs prior to introducing a new process. Various factors determine the outcome of the calculation. These include the number, size, weight and surface area of the parts, labour and energy costs, capital investment and company-internal elements. In numerous cases QPQ is more economical than galvanic processes for example and it gives better

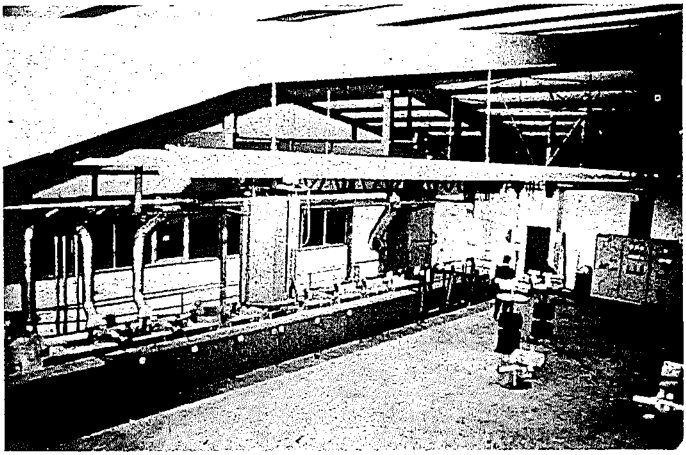

FIG. 4

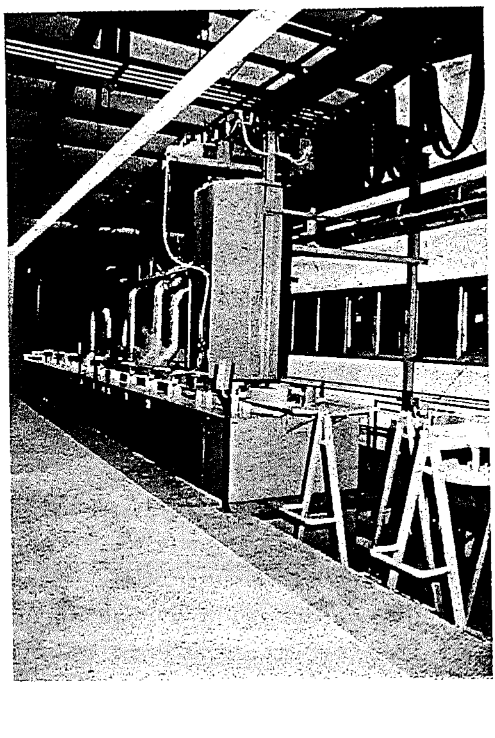

FIG. 5

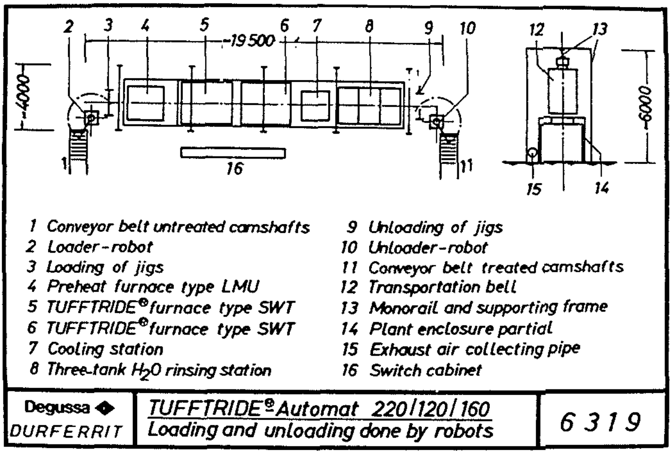

FIG. 6

corrosion and fatigue strength properties. Figure 7 shows such a comparison of costs.

4. RESULTS OBTAINED BY NITROCARBURIZING

During nitrocarburizing a layer consisting of a compound layer on the outside and a diffusion layer subjacent thereto is formed on the surface of the component. The compound layer is usually made up of hexagonal ε-nitride and in many instances a thinner γ'-Fe_4N layer thereunder. The surface of the compound layer consists of a porous zone representing about 30 % of the total thickness of the layer. Composition, structure and properties of the compound layer are virtually uninfluenced by the parent material used. Due to its composition, the compound layer does not possess metallic properties. It is particularly resistant to wear, seizure and corrosion as well as being durable almost to the temperature at which it was formed. Depending on material used, it has a hardness of about HV 0.1 = HV 800 - 1500. Metallographically there is no difference between water cooled compound layers and AB 1

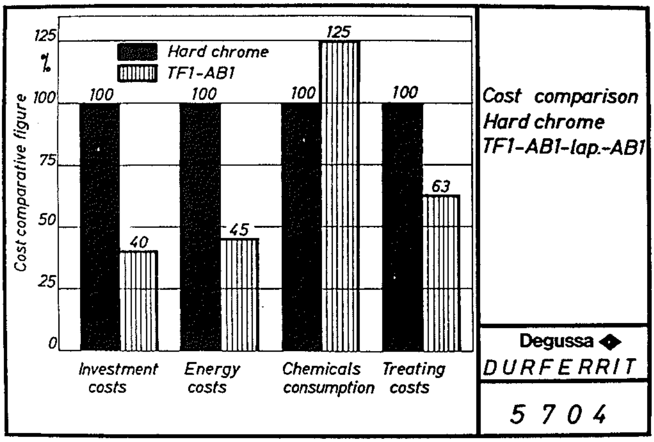

FIG. 7

cooled ones. The composition shows the main difference as being the heavy enrichment of the surface with oxygen during AB 1 cooling, see Figures 8 and 9.

Depth and hardness of the diffusion layer are largely influenced by the material. The higher the alloy content of the steel the lower the nitrogen penetration depth. Hardness, however, increases with the alloy content. In the case of unalloyed steels the structure of the diffusion layer is influenced by the rate of cooling after nitro-

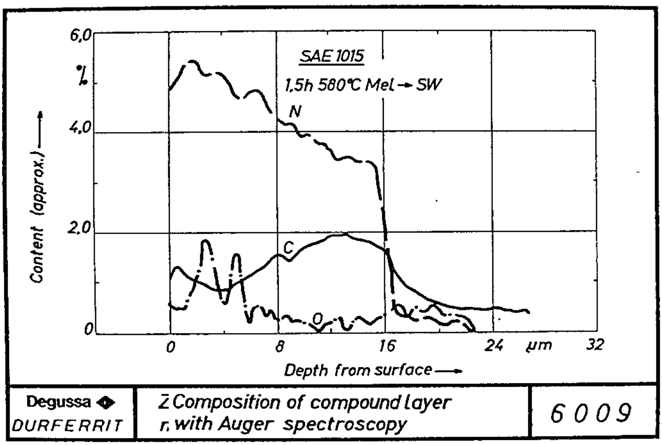

FIG. 8

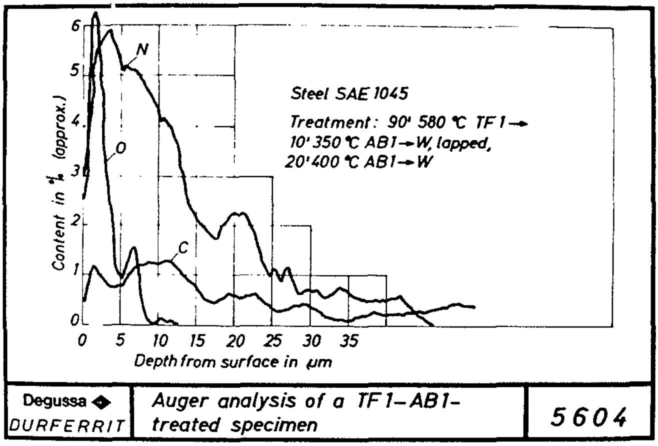

FIG. 9

carburizing. After rapid cooling in water, the diffused nitrogen remains in solid solution. If cooling is done slowly, or a subsequent tempering is carried out, some of the nitrogen can precipitate in the form of iron nitride needles in the outer region of the diffusion layer on unalloyed steels.

Unlike unalloyed steels, the structure of the diffusion layer on alloyed materials is metallographically easy to define from the core structure. This is due to the improved etchability.

The compound layer is responsible for the excellent wear and corrosion properties of nitrided components and the diffusion layer for the increase in fatigue strength. Salt bath nitrocarburized components are less susceptible to cold welding and, in turn, adhesive wear. This is due to the intermetallic structure of the compound layer.

Figure 10 shows the scuffing load limit of gears made from various materials (according to Niemann Rettig). It was established by applying torque to the tooth flank and increasing this until galling occurred. Austenitic steel containing 18 % chromium and 8 % nickel had the lowest galling resistance. Nitrocarburizing raised the scuffing load limit of the materials tested 2 - 5 times.

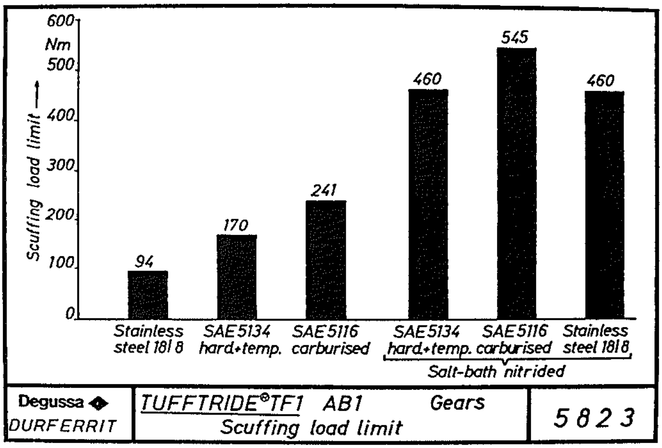

FIG. 10

Another interesting factor in connection with the wear resistance and running behaviour is the coefficient of friction of the surface layer. Figure 11 shows various pairings under dry running conditions and after lubrication with oil type SAE 30.

As already mentioned, the nitrogen present in the diffusion zone raises the fatigue strength of the components quite considerably. Figure 12 gives an impression of the

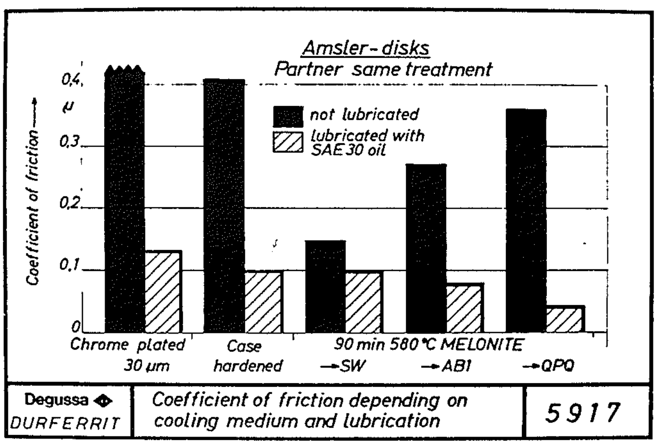

FIG. 11

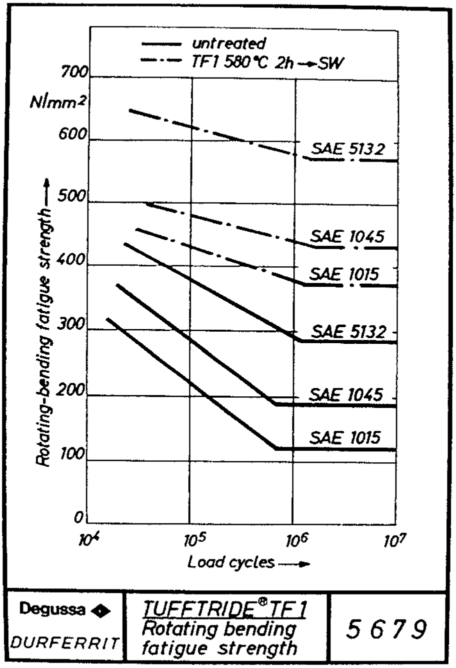

FIG. 12

increase possible. As is well known, many galvanic processes cause a considerable drop in fatigue strength (see Figure 13).

To establish the corrosion resistance of samples and work pieces, salt water spray test (German Standard DIN 50 021 and US Standard ASTM B 117) and total immersion test (German Standard DIN 50 905/part 4) are usually carried out. Figure 14 shows the results of a salt water spray test carried out in the USA by an automobile manufacturer. Results of a total immersion test are summarized in Figure 15.

5. APPLICATIONS

Numerous laboratory tests have been made to investigate corrosion and wear properties and fatigue strength.

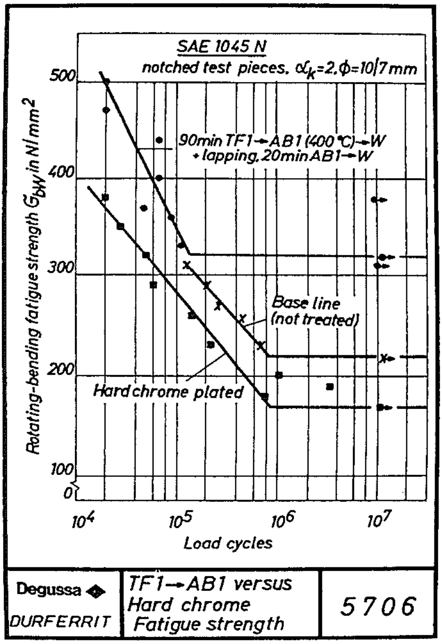

FIG. 13

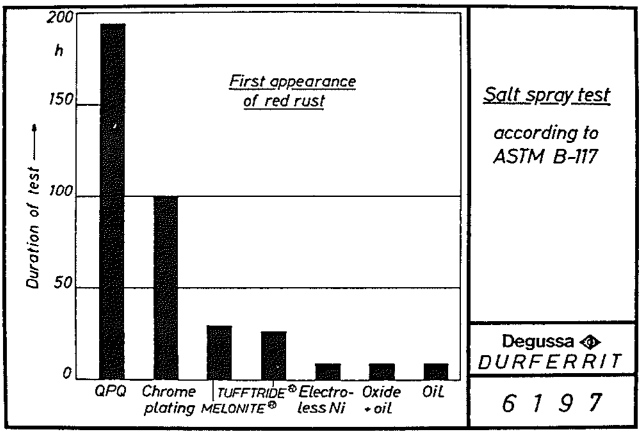

FIG. 14

These could, however, only be reported on very briefly here. In spite of all efforts such tests can in no way be a substitute for everyday experience.

Piston rods for gas springs have become one of the biggest applications for QPQ. These parts require good

Results of immersion tests according to DIN 50 905, part 4
Medium: 3 % NaCl, 0,1 % H_2O_2
Material: SAE 1045

Layer / treatment	Loss of weight in g/m^2 per 24h
90' TF 1 → 10' 350 °C AB1 → W, polishing, 20' 400 °C AB1 → W	0,34
12 µm hard chrome	7,1
Double chrome: 20 µm soft- 25 µm hardchrome	7,2
Nickel: 20 µm Kanigen, hardened	2,9
Triplex: 37,0 µm copper 45,0 µm nickel 1,3 µm chrome	0,45

Results of corrosion tests
DIN 50 905

Degussa
DURFERRIT
5 6 1 5

FIG. 15

wear and corrosion properties. These are obtained simply and economically by QPQ.

Sometimes the complete QPQ cycle is not used, instead of which the parts are only nitrocarburized, cooled in AB 1 and polished (called QP). This cycle is particularly used if a bright surface appearance is required. As Figure 16 shows, the corrosion resistance of parts treated in this way is lower than after QPQ but distinctly higher than after hard chrome plating.

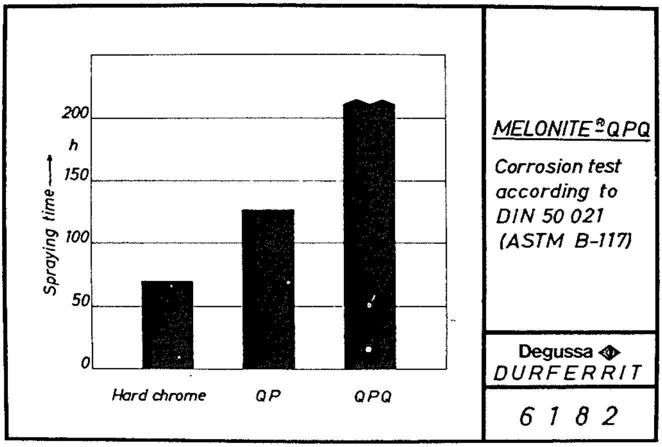

FIG. 16

Another interesting and growing application is safety nuts used to hold components in hot areas of engines. Zinc plated components proved unsatisfactory because after a certain time the zinc brazed to the surface and it was very difficult to loosen the nut. This problem has now been resolved by using the full cycle QPQ treatment. Furthermore, the corrosion properties, necessary in this case, are greatly increased.

Camera parts have been treated for many years. One of the first applications was at Kodak in Germany. By introducing the oxidizing salt bath, the necessary wear and corrosion properties and black appearance are now all obtained by one process. These parts are used by many of the large camera producers in Japan, for example Canon, Fuji, Ricoh and others, see Figure 17.

Figure 18 shows the drive shafts of electric motors of automatic aerials and window winders of passenger cars which were formerly made from austenitic steels of type 18/8. QPQ has made it possible to change from the expensive and difficult to machine material to an unalloyed case hardening steel. QPQ gives parts the required corrosion and wear resistance. By changing to another material

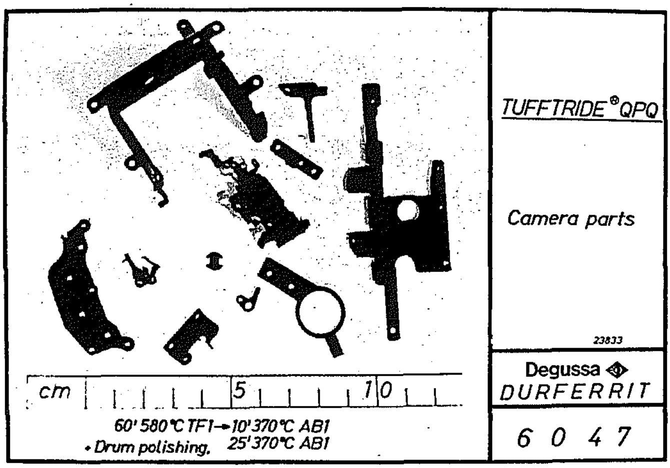

FIG. 17

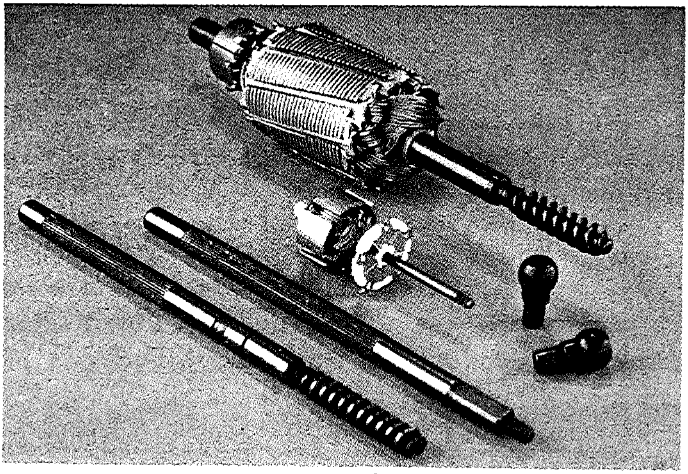

FIG. 18

and another process the installation has paid for itself within a short time. Drum polishing is used in the mechanical processing of the drive shafts.

Another very interesting application is shown in Figure 19. The hydraulic parts of off-shore hammers which anchor bore rigs to a depth of 300 m below sea level are being QPQ treated. This is another instance of salt bath nitrided parts giving greater reliability

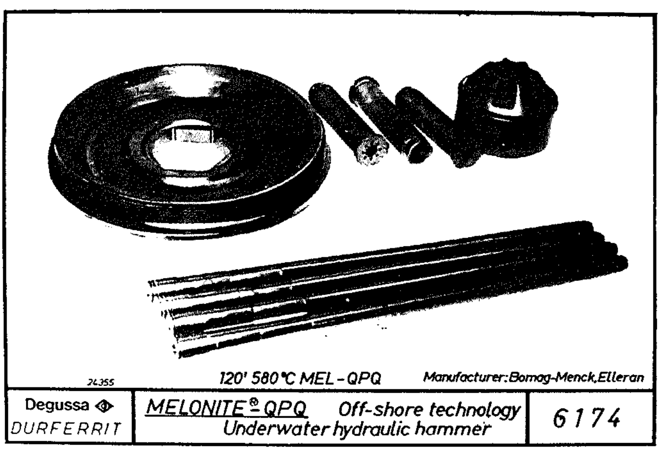

FIG. 19

and quality than competitive processes. An important factor with regard to this application is that the off-shore hammers must last one complete anchoring period otherwise additional costs of some hundred thousand German Marks will be incurred.

Crankshafts are a very old application. The AB 1 salt bath has given this application new impact. Step cooling in AB 1 reduces distortion considerably and straightening is unnecessary.

Figure 20 shows the results of a test recently carried out at the Technical University in Darmstadt, Germany. Actual crankshafts approximately 1 m long and weighing about 100 kg were used. Various treatments were investigated. One was TF 1 followed by water cooling which, in the case of SAE 1045 steel, produced the highest fatigue strength. Two treatments involved different AB 1 temperatures, 350 and 400 °C. Note the decrease in fatigue strength in Figure 20, which is as to be expected, but which is still an improvement of approximately 65 % over the untreated sample. The strength is, however, adequate for this specific application. Thus it is

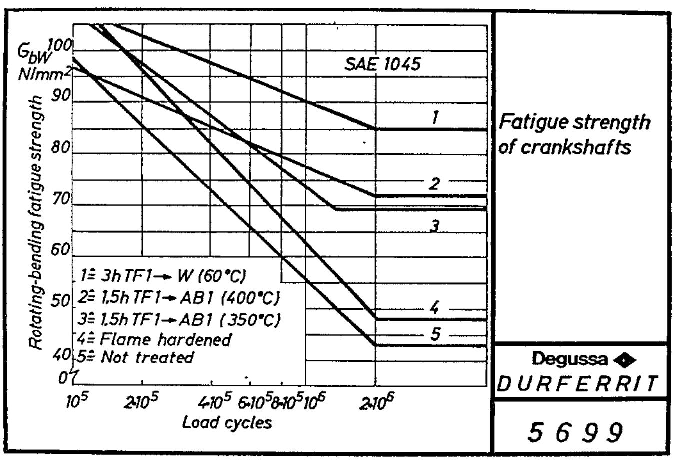

FIG. 20

possible to use step cooling in the AB 1 bath and eliminate distortion as mentioned above.

That was just a small selection from the vast range of industrial applications for QPQ. If I were to continue, the other Speakers would have no time to deliver their Presentations.

The last picture, which is Figure 21, shows various automobile, domestic appliance and textile machinery parts which are being QPQ treated in mass production in the USA.

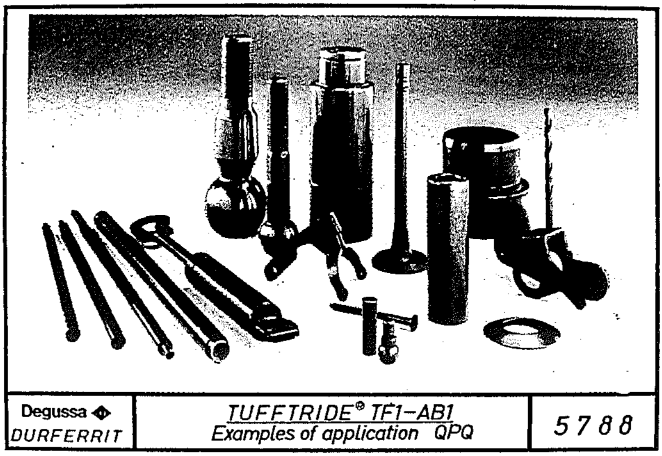

FIG. 21

S U M M A R Y

Salt bath nitrocarburizing, known by the names of TENIFER and TUFFTRIDE, has been well established for more than 30 years.

Although a steady growth in popularity was always to be observed throughout this period, the first really dynamic increase took place with the development of the QPQ process and automated salt bath installations.

It is also to be expected that the excellent corrosion properties obtainable by salt bath nitrocarburizing will cause it to expand further at the expense of galvanic processes. In addition, this process has technological and economic benefits over some of the standard heat treatment processes, for example case hardening. In our opinion, there will a trend toward nitrocarburizing instead of other processes in this sector also.