Metal Heat Treatment in Prosthetics

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The knight in olden times depended on his "trusty sword of Damascus." These swords were famous because of their careful forging and heat treatment. However, the heat treatment was a mysterious art. Today thermal treatment of metals is a very exact science.

To the orthotist-prosthetist, knowledge of the possible conditions of metals is very valuable. The manufacturer can increase strength and decrease weight of component parts by using the correct materials and heat treatment. The fitter also needs to know if heat can be applied to a certain metal, and, if so, how much.

Let us consider first the iron alloys. The manufacturer finds considerable use for the straight carbon steels. Cold rolled steel cannot be hardened by heat treatment unless extra carbon is added by carburizing. This process adds carbon to the surface and produces a hard "skin" or "case" on the steel. If the orthotist-prosthetist heats a carburized part above 400° the part begins to lose hardness.

Higher carbon steels such as spring steel are hardened by heating to about 1450° F. and quenched in oil or water depending on the steel. They are then drawn or tempered at temperatures between 400° and 600°. If the part is polished and heated in an open flame, temper colors ranging from straw to blue result from these temperatures. Blue clock spring is tempered at about 570°.

The alloy steels have been developed to serve specific purposes and are hardened at 1450° to 1850° and are drawn at 350° to 1100°. Stainless steels are divided into two

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TABLE

Material	Main Elements in Composition	Heat Treatment	Strength (Tensile)
Cold rolled steel S.A.E. 1020	iron 0.20% carbon	Not possible in "as-is" condition. Additional carbon can be added to surface by carburizing. Then steel can be case hardened by heating to 1450° F. Quenching in water and drawing at 400° F.	60,000 p.s.i.
Spring steel	iron 0.95% carbon	Heat to 1450° F. Quench in oil or water (depending on the exact kind of steel). Draw at 400°-570° F.	80,000 p.s.i. annealed up to 300,000 p.s.i. depending on heat treatment.
Type 302 Stainless Steel	18% chromium, 8% nickel + iron, etc.	Cannot be hardened by usual heat treatments. Hardens by working and rolling.	90,000 p.s.i. annealed to 200,000 p.s.i. severely cold worked
Type 416 Stainless Steel	12% chromium + iron, etc.	Heat to 1800° F. Quench in air blast or oil. Draw at 900°-1200° F.	75,000 p.s.i. annealed. 180,000 p.s.i. hardened drawn at 900°
24ST4 Aluminum Alloy	4.5% copper, 1.5% magnesium, 0.6% manganese + aluminum	Heat 2-3 hrs. at 920° + 20°. Water quench.	27,000 p.s.i. annealed 60,000 p.s.i. hardened
14ST6 Aluminum Alloy	4.4% copper, 0.8% silicone, 0.8% manganese, 0.4% magnesium + aluminum	Solution heat treat 2-3 hrs. at 940° + 20° F. Water quench. Follow by precipitation heat treatment 10 hrs. at 340°. Water quench.	27,000 p.s.i. annealed 70,000 p.s.i. hardened

groups. The chromium-nickel group is generally non-magnetic and does not harden with heat treatment. It does work-harden as many will testify who have tried to drill it with a dull drill. Type 410 or 416 is hardened to 1800° and quenched in oil or air. Tempering if necessary is done at about 1,000°. The cutlery grade of stainless, 440C, attains a hardness near that of tool steel. It is hardened at 1850°, quenched in oil or air, and drawn at 400°-600°. An interesting new development is the P.H. stainless which hardens by heating to only 900°.

The orthotist-prosthetist cannot, therefore, heat carbon steels such as springs or cables above the melting point of solder, applied with an iron, without softening the material. Non-magnetic stainless steel and hardened magnetic stainless steel are not affected greatly by heat up to 1000°. However, heating to red hot will result in some loss of strength.

Aluminum alloys generally are supplied in the hardened or "ST" condition. The much-used 24S alloy has been solution heat treated at 920° for three hours, quenched and precipitation treated for ten hours at 375° when supplied in the 24ST86 condition. The alloy designation, 24ST4, indicates a naturally aged solution heat treated alloy. The forging alloy, 14ST, would be designated as 14S0 in the annealed condition, 14ST4 in the solution heat treated condition and 14ST6 after both solution and precipitation heat treatment. A temperature of 775° will anneal most aluminum alloys and temperature above 400° will seriously affect the strengths of most hardened alloys.

In conclusion, many books are necessary to supply the manufacturer with all the information he needs. In general, the orthotist and prosthetist would do well to remember not to heat hardened carbon steels, cutlery grades of stainless steel or hardened aluminum alloys above the melting point of 50-50 solder (about 400°) and the hardened stainless steels of low carbon content should not be heated above 1000° if the strength of the part is important. Often adjacent parts such as ball bearings are ruined if temperature above 400° are allowed to reach them.

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