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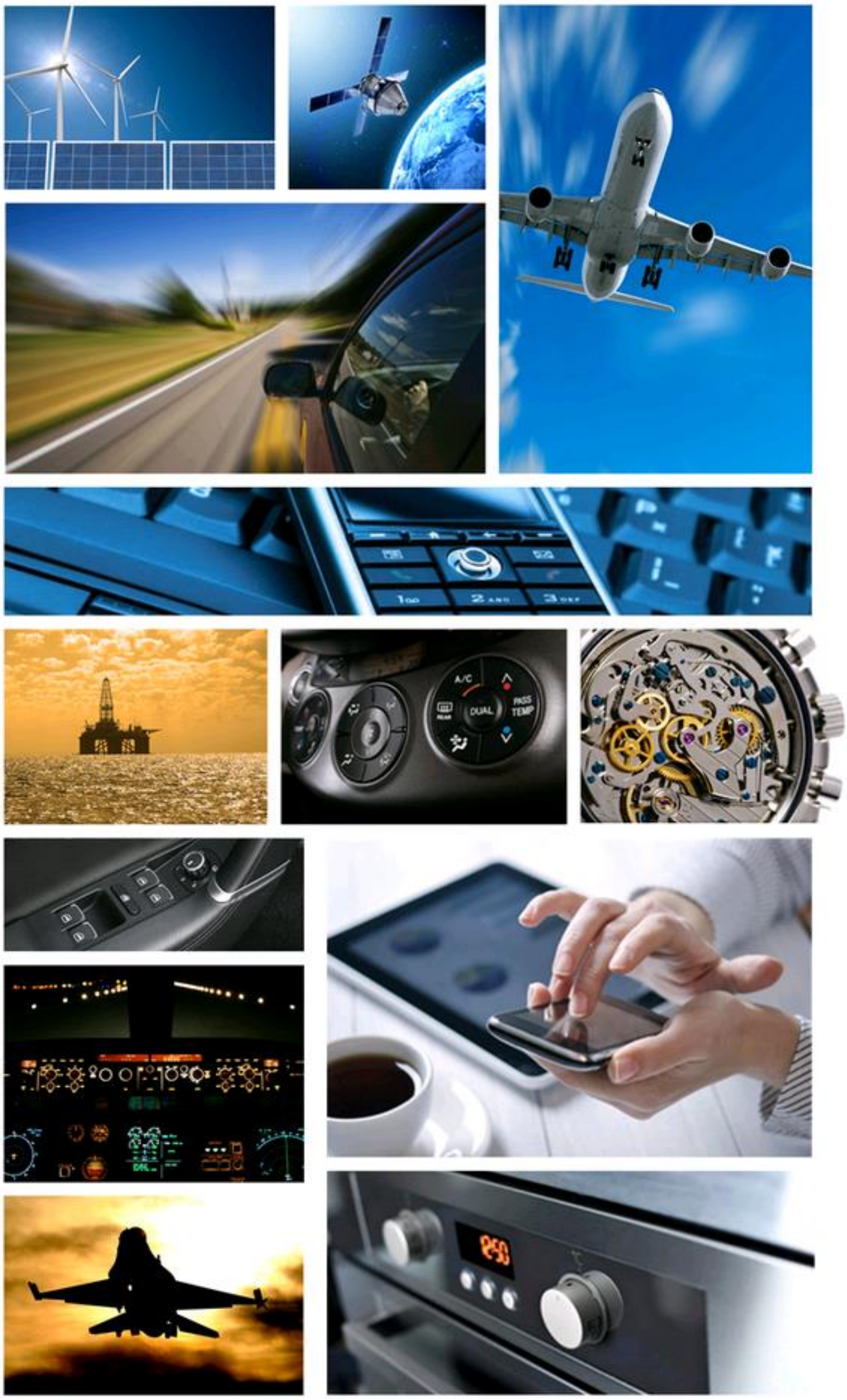
Beryllium Copper Alloys

Heat-treatment



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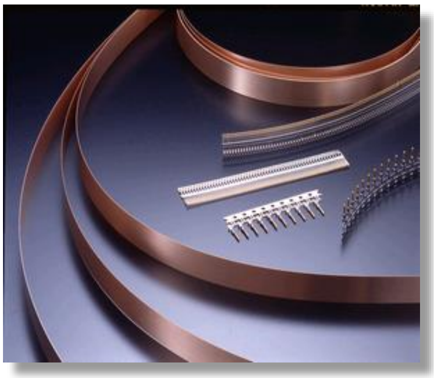
Introduction

For the user the advantages of working with copper beryllium are its easy fabrication (by machining or forming) and the simplicity of obtaining the desired final properties by a low temperature heat treatment. This makes copper beryllium the most flexible of all copper base alloys.



For most other copper based alloys, parts must be manufactured from metal which already has the final properties of the finished part. This can make the fabrication difficult, if not impossible, due to the reduced elongation and formability issues resulting from the higher mechanical properties.

Copper beryllium can be supplied in the form of strip, rod, bar, wire or tubing as cold worked product.

These shapes are produced either by rolling or drawing. The heat treatment for copper beryllium is done in two stages:

1) The solution annealing consists of heating the metal, followed by rapid quenching. This softening process is almost always performed by the supplier and is not recommended to be undertaken by the user.
2) The structural ageing or precipitation hardening treatment is usually carried out by the user.

Choice of temper condition

NGK Berylco can supply Berylco alloys in the following tempers listed below in increasing order of hardness:

- Annealed (A)
- 1/4 Hard (1/4 H)
- 1/2 Hard (1/2 H)
- 4/4 Hard (H)
- Mill Hardened

The mill hardened tempers will not be covered here since they have already been subjected to age-hardening at the plant prior to dispatch to customers. Mill-hardened metal is particularly used for parts which do not necessitate high formability and to avoid distortion during age-hardening treatment.

The choice of the supplied temper is determined by the degree of cold deformation required for the part, the basic rule being: **select the hardest temper which will still permit the manufacturing process of the part.**

Soft annealed material (A temper) should be used only for deep drawing operations. As regards other conditions, users are referred to our General Information Sheet describing applications in terms of bending which are possible with the various “as-supplied” conditions.

In the rare instances where fabrication requires an excessive degree of deformation, it may be necessary to re-soften the metal by a second solution annealing treatment (heating and quenching) in order to continue the cold working operations. Our technical department will be pleased to advise you in connection with specific applications.

Precipitation treatment of copper-beryllium alloys

Forming and/or machining is followed by precipitation hardening (or age hardening) to obtain the desired final properties for the application of the part concerned.

These properties are determined by the initial condition of the metal as supplied, as well as by the duration and temperature of the heat treatment. Since the first of these factors is conditioned by the shape of the part to be obtained, it is possible to vary the other two factors to obtain various permutations in terms of tensile strength, yield strength, ductility, electrical conductivity, hardness, and impact resistance. Hence, precipitation treatment time and temperature will be determined by the particular application in consideration.

In order to ensure that full advantage is taken of the properties of available from beryllium-copper alloys which can be obtained by experimenting with treatment time and temperature, preliminary tests should preferably be conducted, particularly where high temperatures and short treatment time are envisaged.

The curves presented at the end of this booklet illustrate the effects of precipitation treatment. Tensile strength, yield strength and hardness increase with treatment time and temperature up to a maximum peaks value, after which they decline. The opposite occurs in the case of elongation values. The higher the temperature of treatment, the faster the rate of change. However, over a certain temperature range, the curve tends to flatten out and no great change will be observed over a period of several hours treatment. Conductivity increases with precipitation treatment time and temperature.

Precipitation treatment time and temperature

Alloys Berylco 25, 165 and 33/25 can be age hardened over a range of temperatures extending from 260 and 440°C. Maximum hardness values, which are not always necessarily desirable, are obtained by treating the alloy for 2 to 3 hours at 310-340°C, depending on the initial metal condition.

In the case of alloy B165, maximum hardness values are obtained by using temperatures of some 10-15°C higher than B25.

Two types of graph are shown for alloys B25 and B33/25:

1) Curves for a given treatment time (3 hours) showing the mechanical properties obtained as the treatment temperatures are varied.

These curves clearly show the effects of the precipitation treatment:

- The region prior to the maximum is referred as the under-aged region.
- The region after the maximum is referred as the over-aged region.
- The spread of mechanical properties due to differences in condition prior to treatment is less in the over-aged than in the under-aged region. This is an initial pointer to the choice of treatment designed to obtain finished items with the smallest possible deviation in properties..

2) Curves illustrating the effect of treatment at various temperatures. It should be noted that:

- Where treatment temperature is less than 300°C, precipitation is a slow process, so that a long time will be required to obtain properties near to the maximum.
- However, where the treatment temperature is higher than 350°C, the rate of precipitation is accelerated and hardening is obtained within a very short time.
- The curves exhibit a steep slope at the start of the precipitation treatment and then flatten out or fall off (at temperatures above 340°C). However, the curve does not slope steeply in the over-aged region, thus leaving some latitude as regards treatment time.

In practice, when maximum hardness is not a requirement, it will be preferable to employ over-ageing, which will reduce the dispersion of final properties. Again, it will be seen that for a treatment time of 3 hours, most of the curves exhibit only a slight slope or a pseudo-plateau, so that **over-ageing with extended treatment time is preferable**.

However, considerations of productivity may frequently call for a reduction in treatment time. Here again, it will be preferable to employ over-aging, using the highest temperature consistent with the desired final properties, since under-ageing combined with short treatment time can give uncertain results owing to the steep slope of the curve in this region.

Finally, it should be kept in mind that the temperatures employed may lead to a differential expansion and that the precipitation process causes beryllium-copper alloys to shrink slightly (about 1-3mm per m).

Where it is desired to obtain high-precision parts, and to minimize inevitable distortion which occurs during the precipitation treatment process, under-ageing at comparatively low temperatures and for long periods should be employed. Alternatively, a jig should be used to prohibit movement during the treatment.

The considerations outlined above can best be illustrated by an example:

Starting with metal in the 1/2 hard condition, it is desired to obtain a 0.2 % yield strength value of about 1000-1100 N/mm². Assuming a treatment time of 3 hours, over-aging will occur at a temperature of approximately 370°C and under-ageing at approximately 260°C. Normally, the treatment used will be 3 hours at 370° C. However, if distortion is suspected and a jig cannot be used, treatment of 3 hours at 260°C will be carried out. Again, if a high rate of production is sought and very accurate equipment is available, treatment at 400°C for only 30 minutes could be employed; in which case, preliminary tests will be required for accurate determination of a suitable treatment temperature and time.

Heat treatment jig

In special cases, precipitation treatment may have to be carried out on parts held in formers or jigs while undergoing treatment. This is only necessary where dimensions have to be held to within very close tolerances. The preferred treatment will normally be over-ageing and extended treatment time.

If the mass of the jig used is very high as compared to that of the parts to be treated, a thermocouple should be employed to measure the actual temperature of the furnace containing the parts being treated.

Where high dimensional accuracy is required in the case of very small parts, it is not usually practicable to use jigs. In this case, the age-hardening treatment can be carried out in a bed of inert powdered material, such as sand. This will generally support the parts sufficiently to prevent the amount of distortion which can occur.

Precipitation treatment furnaces

The use of air circulation furnaces is recommended. Controlled atmosphere systems can be used to obtain bright surface treated products, but care should be taken to avoid any contamination of the atmosphere by chlorine products.

Salt bath furnaces, which exhibit the advantage of rapid and uniform heating, give good results over the entire temperature range used for precipitation treatment of beryllium-copper. They can be beneficial, where the treatment time is short and where a precise means of controlling temperature is required.

Commercially available salt mixtures with melting points in a range 135-220°C are normally used. Nitrate-based salts dissolve readily in hot water, but require the observance of certain precautions as specified by the suppliers.

Air or controlled atmosphere furnaces which do not provide circulation can only be used for quite long treatment times of about 3 hours. The use of vacuum furnaces is not recommended because of the low rate of heat exchange obtained with this type of furnace.

Since the rate of cooling is not critical, parts leaving the treatment furnace can be quenched in cold water, thus simplifying handling and setting a definite limit to the treatment time employed.

Cleaning, pickling and brightening

Where the precipitation treatment is not carried out in a controlled atmosphere and it is desired to obtain a clean surface and bright finish after heat treatment, a number of precautions and finishing operations will be required.

All parts to be treated should be absolutely free of grease. Should this not be the case, parts should be carefully degreased.

Parts should be pickled after heat treatment. A simple method consists of immersing the parts in a 20-30 % sulphuric acid bath used at 80-90°C. The parts should be pickled for 15-30 minutes, depending on the degree of oxidation (or until the dark film on the surface has been removed). The pickling operation should be followed by rinsing in cold water.

Pickling may be followed by brightening. However, when brightening treatment is to be employed, extra care has to be taken with pickling, otherwise dull or pitted areas may persist after brightening. The maximum permissible pickling time can be determined by noting the subsequent results obtained on brightening.

A variety of brightening processes exist, some of which merely restore the original color of the metal, two examples are:

1) Immersion in a cold 15-30 % nitric acid and water solution. The parts should be withdrawn as soon as gas bubbles appear.

2) Immersion for 30-45 seconds in a cold 2.5 % (in volume) sulphuric acid solution to which has been added 50-60 g/litre of sodium bichromate.

In both the above cases, the brightening stage should be followed by thorough rinsing in cold water and drying.

Other brightening baths, such as “White” baths (sulphuric/nitric acid mixtures at various concentrations) give better results, but require some skill and experience in their operation in view of the possible rate of attack on the metal.

The bichromate bath is not recommended where brightening is to be followed by electroplating.

Precipitation treatment effects

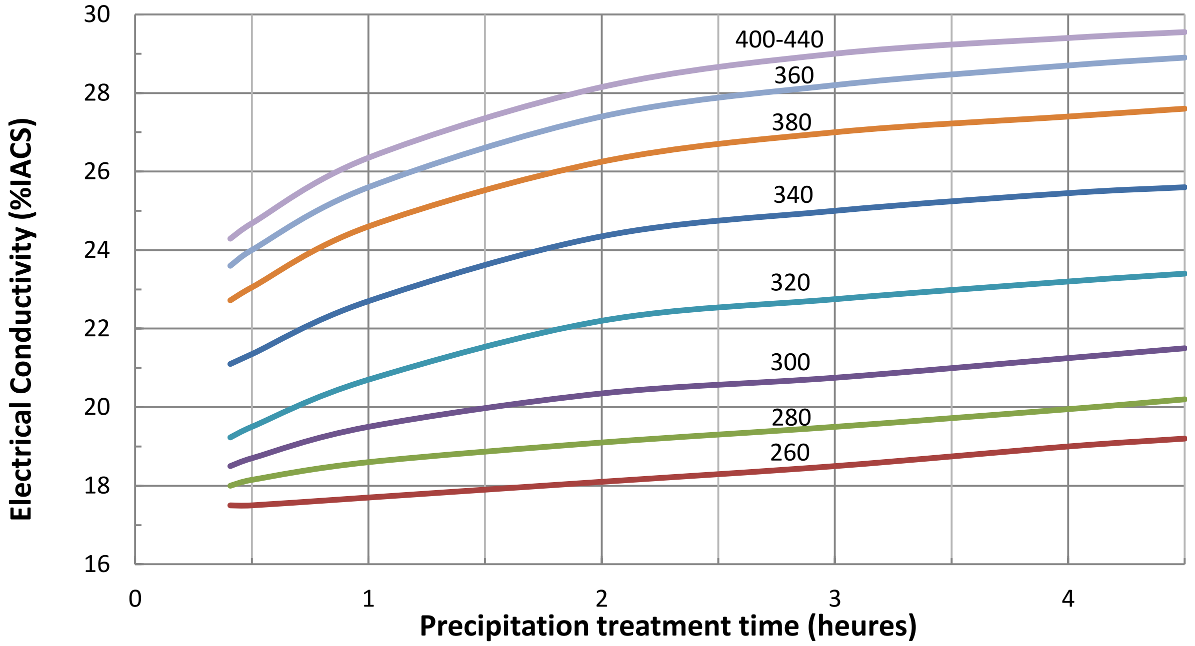
The various graphs shown in this booklet illustrate the effect of precipitation treatment on the properties listed below:

- Ultimate tensile strength (UTS)
- 0.2% yield strength (YS 0.2%)
- Elongation (%) on a 50mm gauge length
- Vickers hardness (HV or VPN)
- Fatigue life
- Electrical conductivity

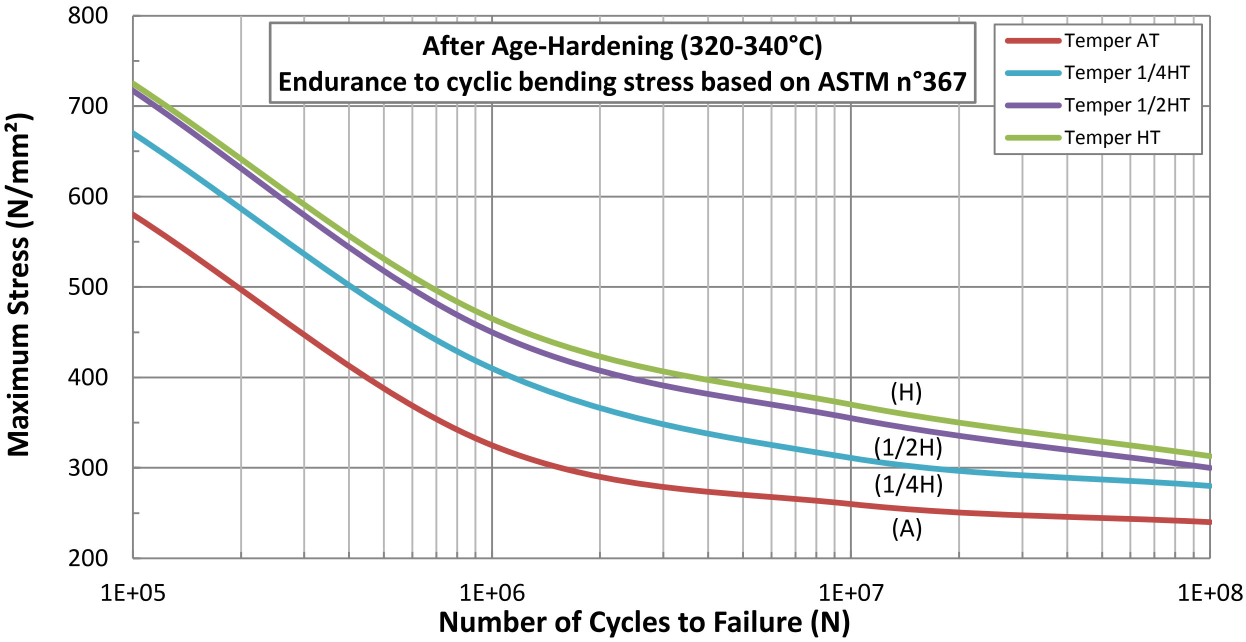
These graphs are only a guide to the effects of precipitation treatment and should not be taken as indicating precise treatment times and temperature required to yield particular properties.

The fatigue life curves are extrapolated from the data given in ASTM N°367. Longevity will depend on a variety of factors such as the shape of the item, stamping defects, surface condition, etc.

Electrical conductivity in % I.A.C.S.

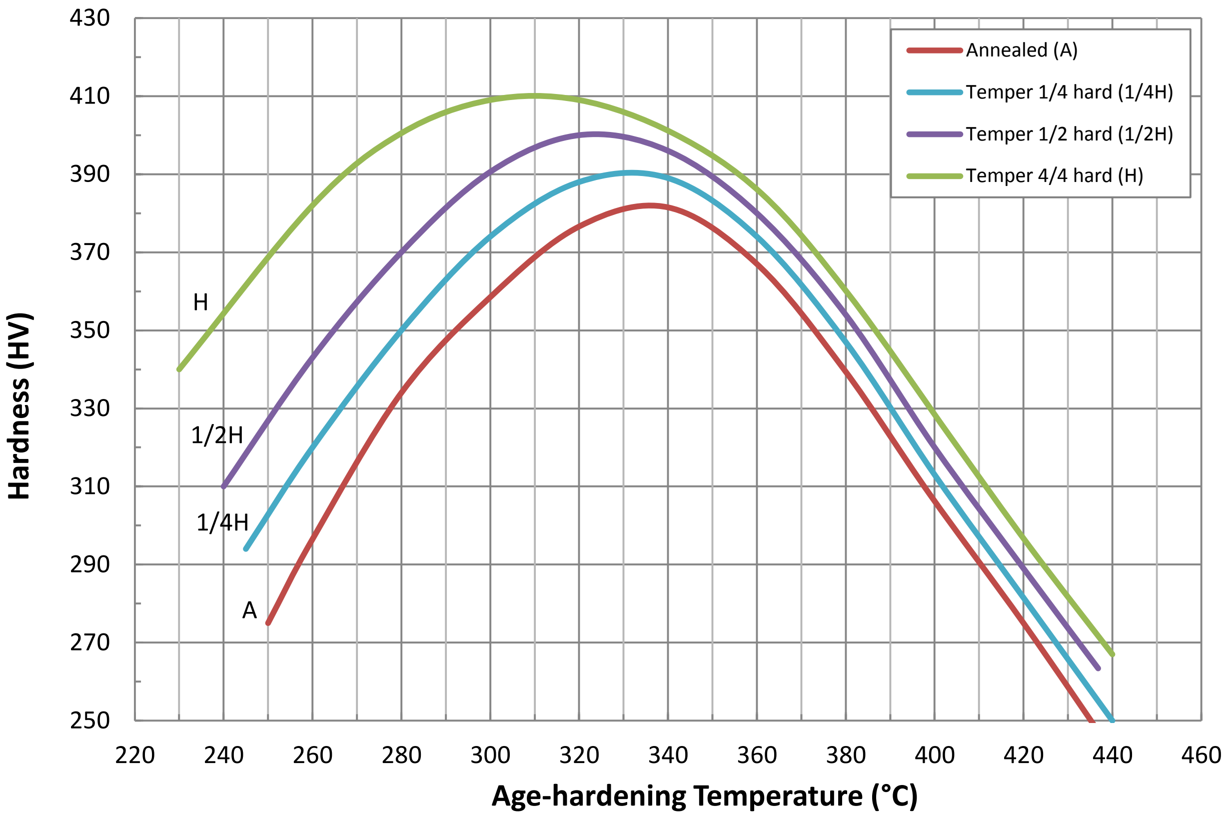


Fatigue life

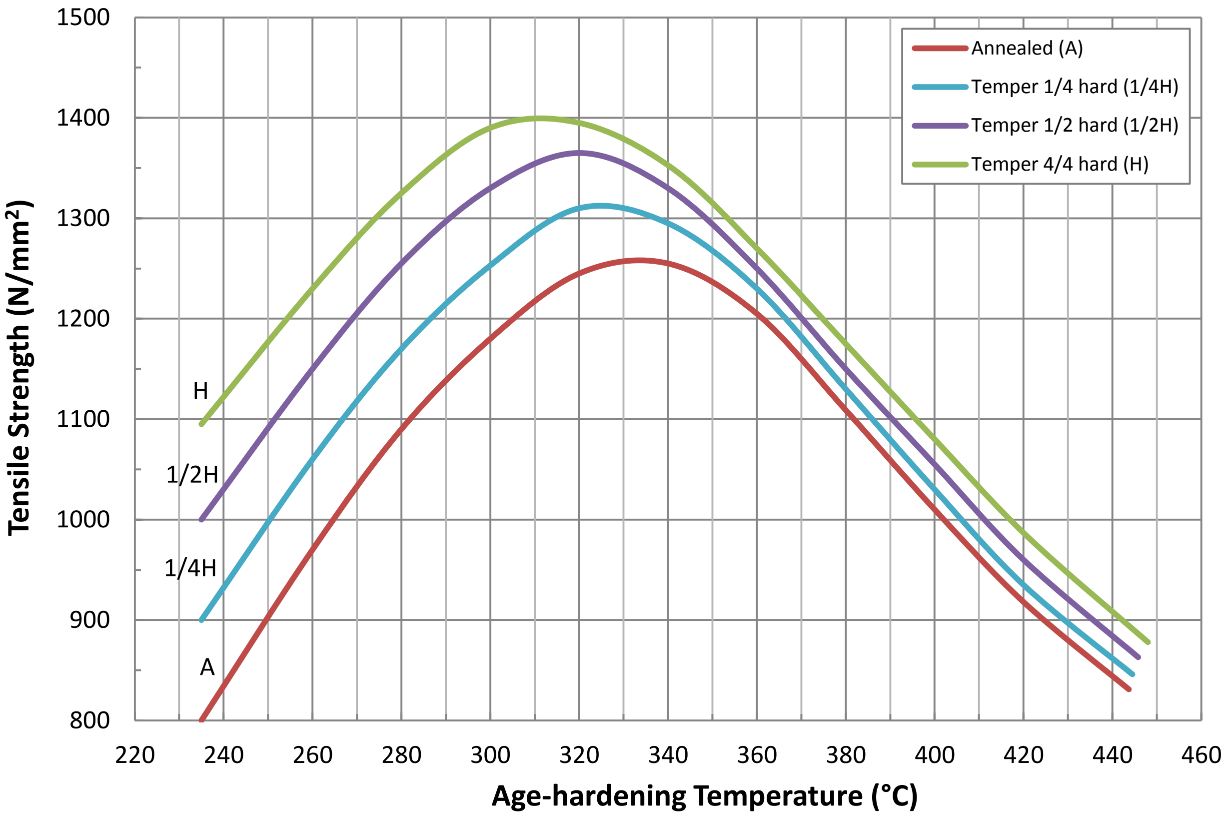


B25 and B33/25 ALLOYS
effects of 3-hour precipitation treatment according to condition

Vickers Hardness

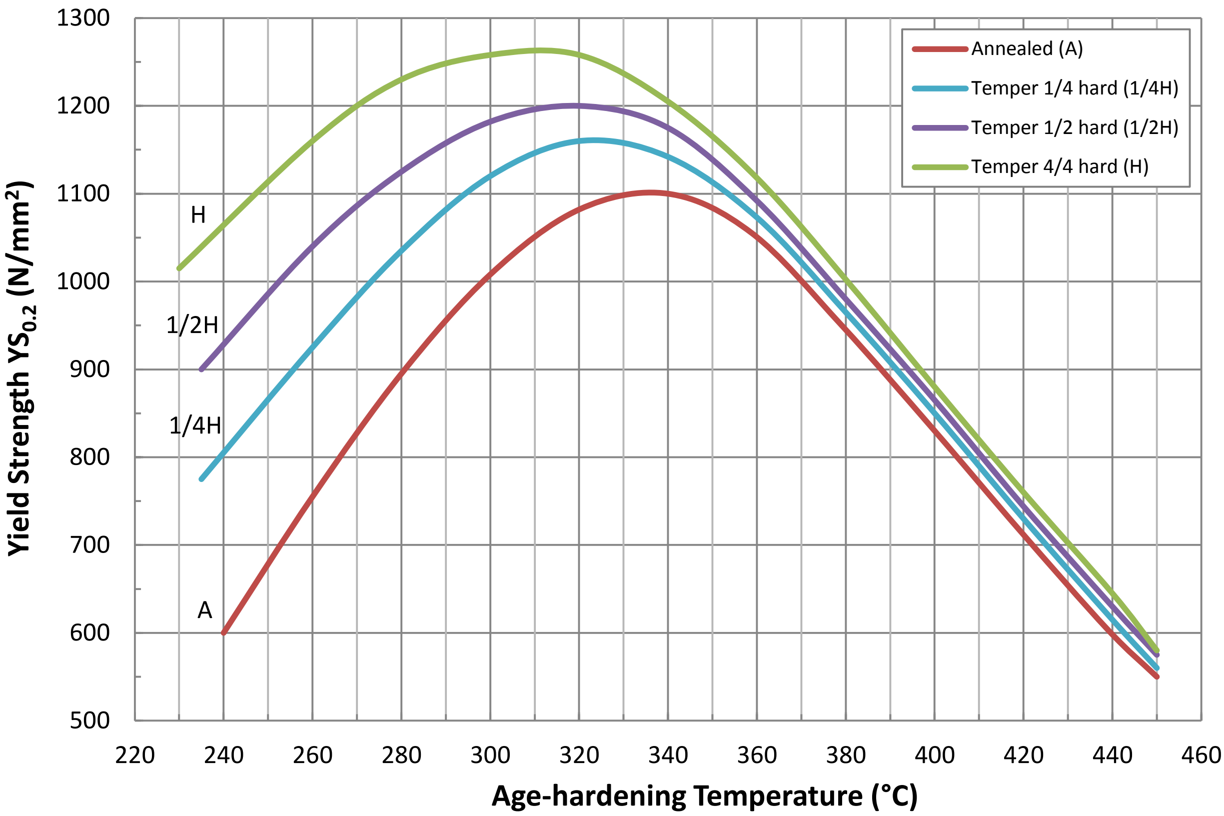


Ultimate Tensile Strength (UTS)

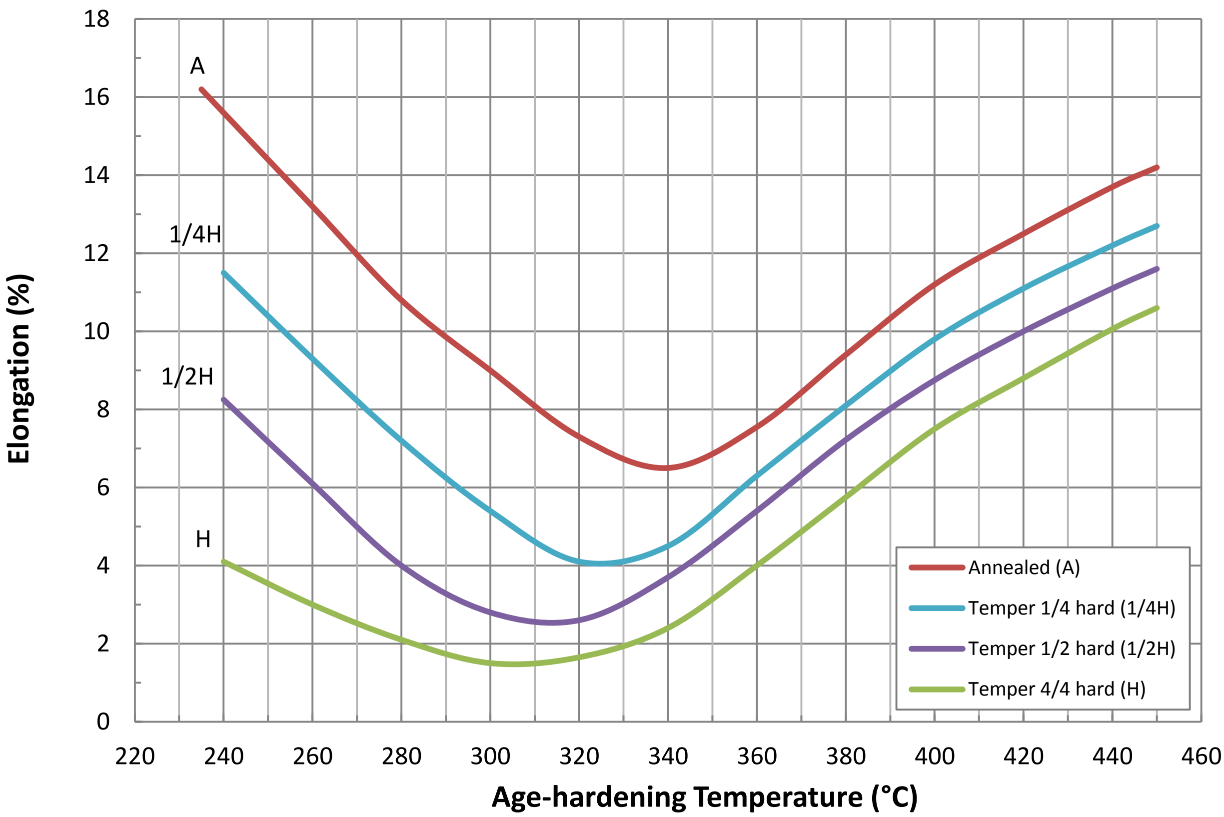


B25 and B33/25 ALLOYS
effects of 3-hour precipitation treatment according to condition

0.2% Yield Strength ($YS_{0.2}$)

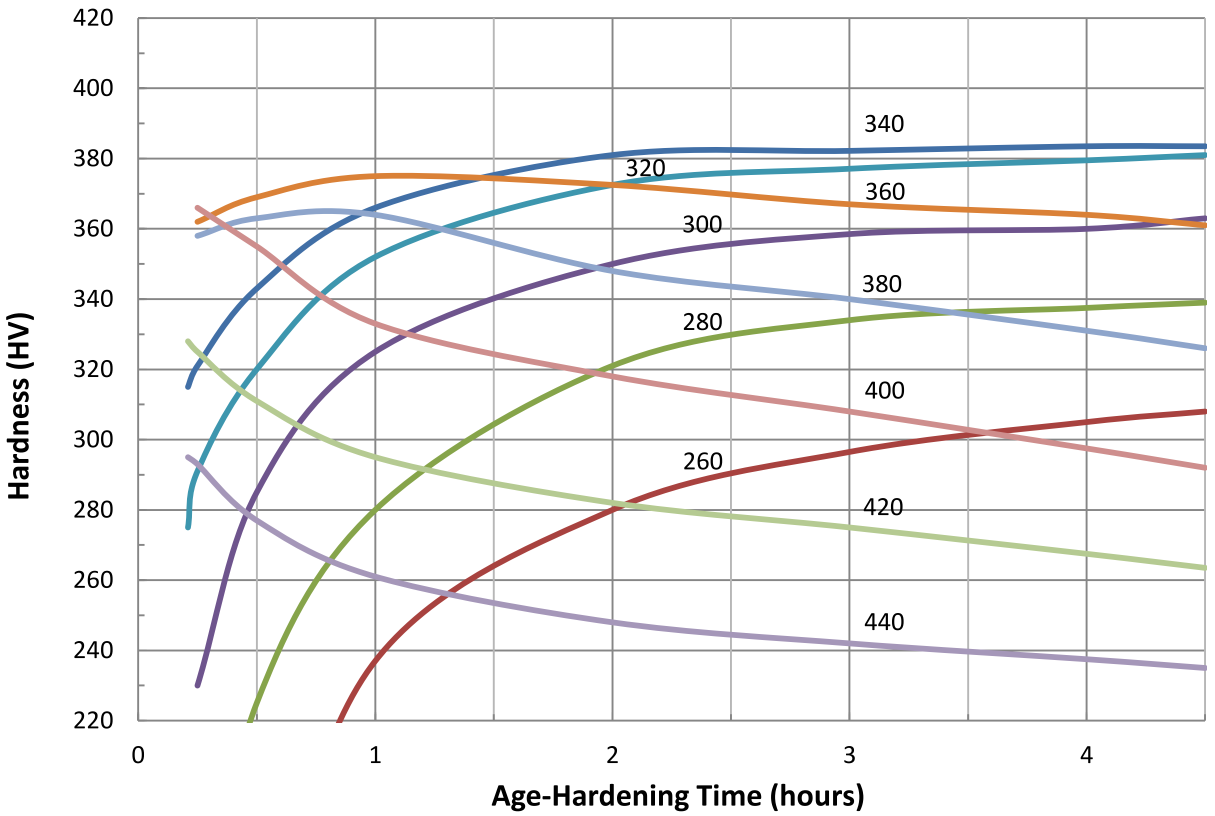


Elongation in % (L_0 50mm)

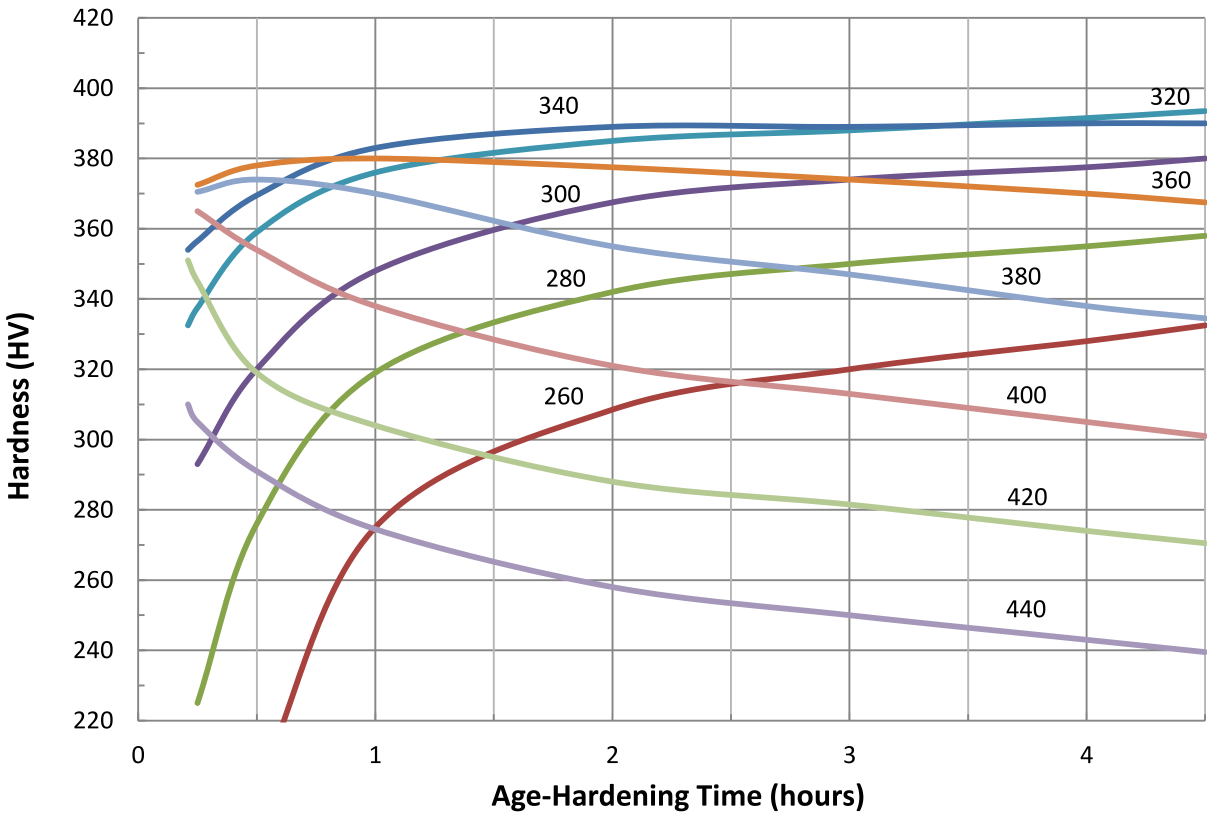


VICKERS HARDNESS – B25 and B33/25 ALLOYS
effects of precipitation treatment temperature and time

Temper Annealed (A) - Age-Hardened

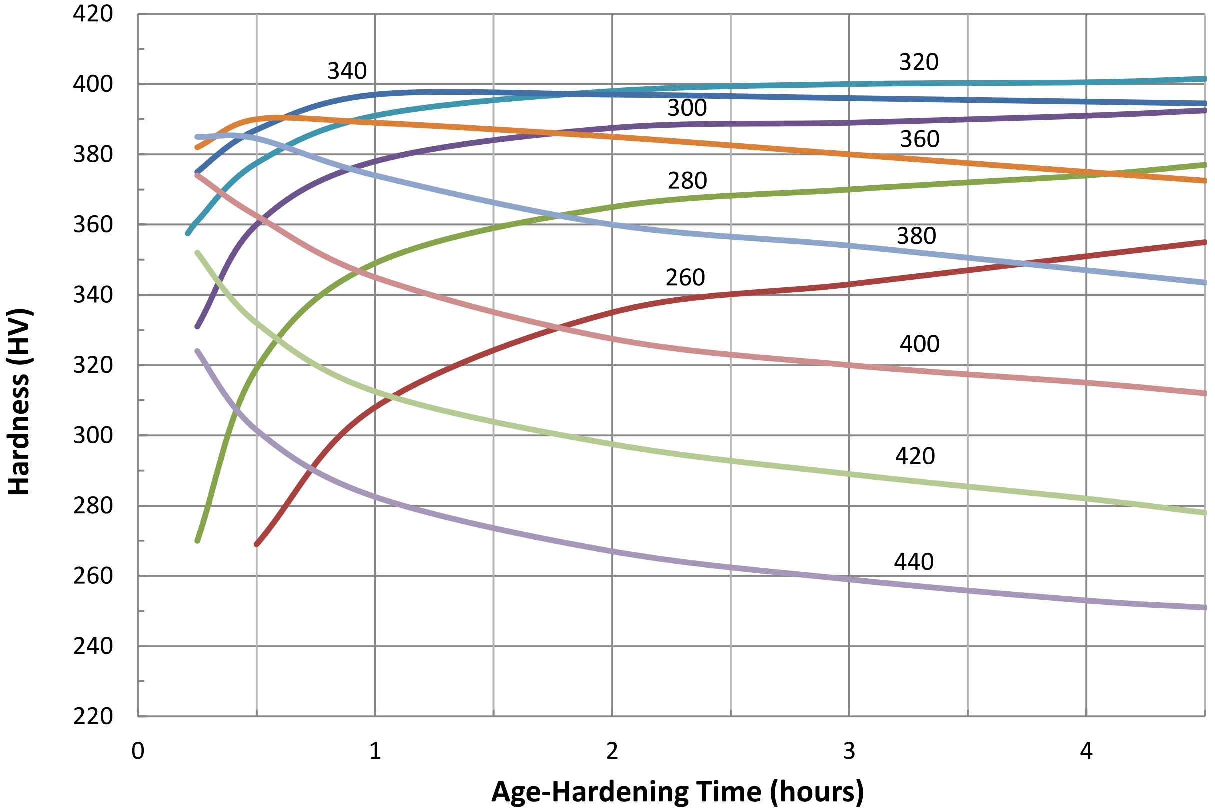


Temper Quarter Hard (1/4 H) - Age-Hardened

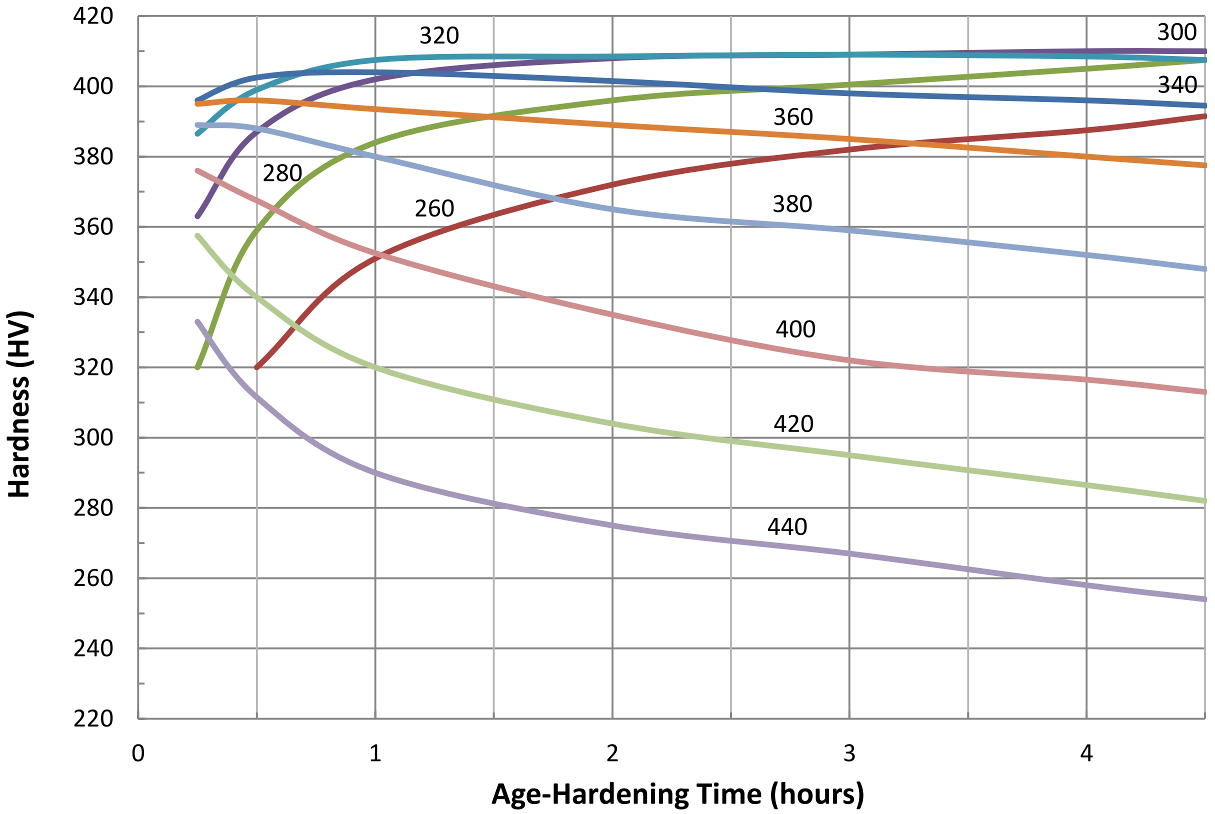


VICKERS HARDNESS – B25 and B33/25 ALLOYS
effects of precipitation treatment temperature and time

Temper Half Hard (1/2 H) - Age-Hardened

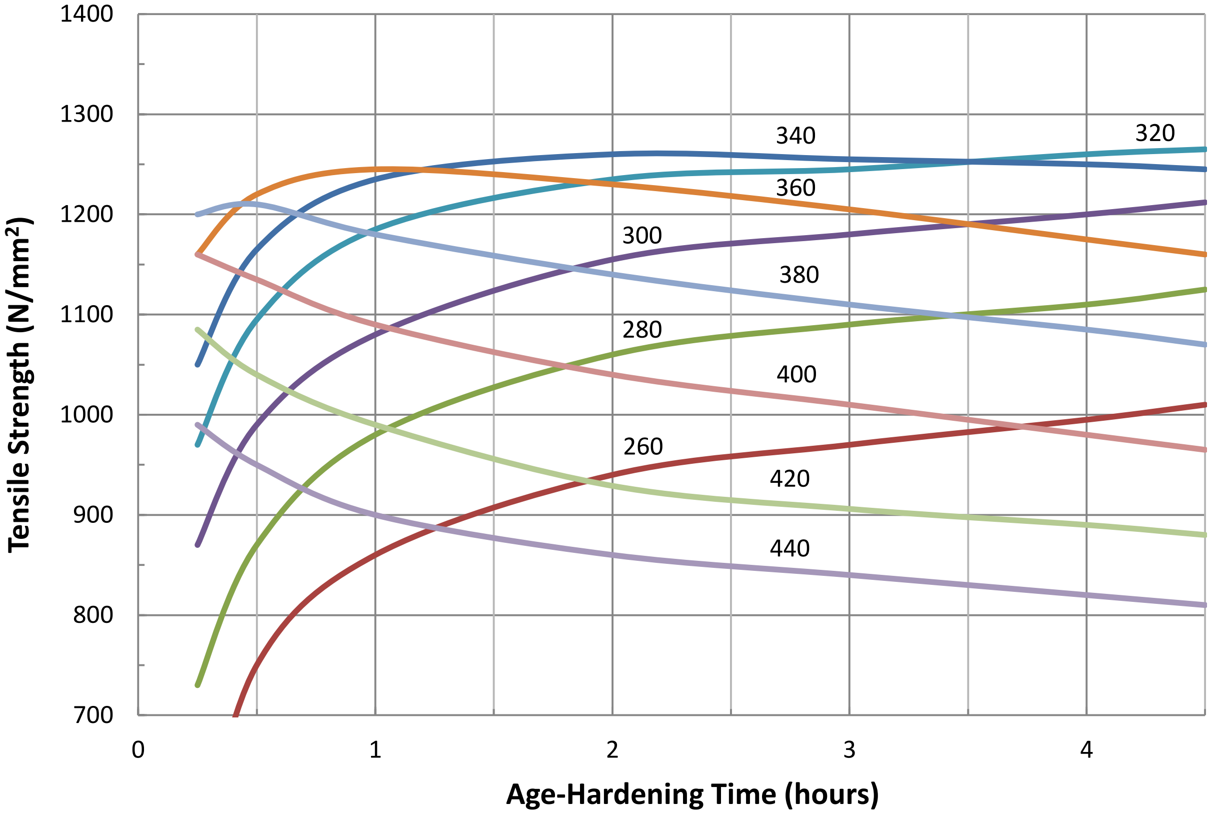


Temper Full Hard (H) - Age-Hardened



ULTIMATE TENSILE STRENGTH (UTS) – B25 and B33/25 ALLOYS
effects of precipitation treatment temperature and time

Temper Annealed (A) - Age-Hardened



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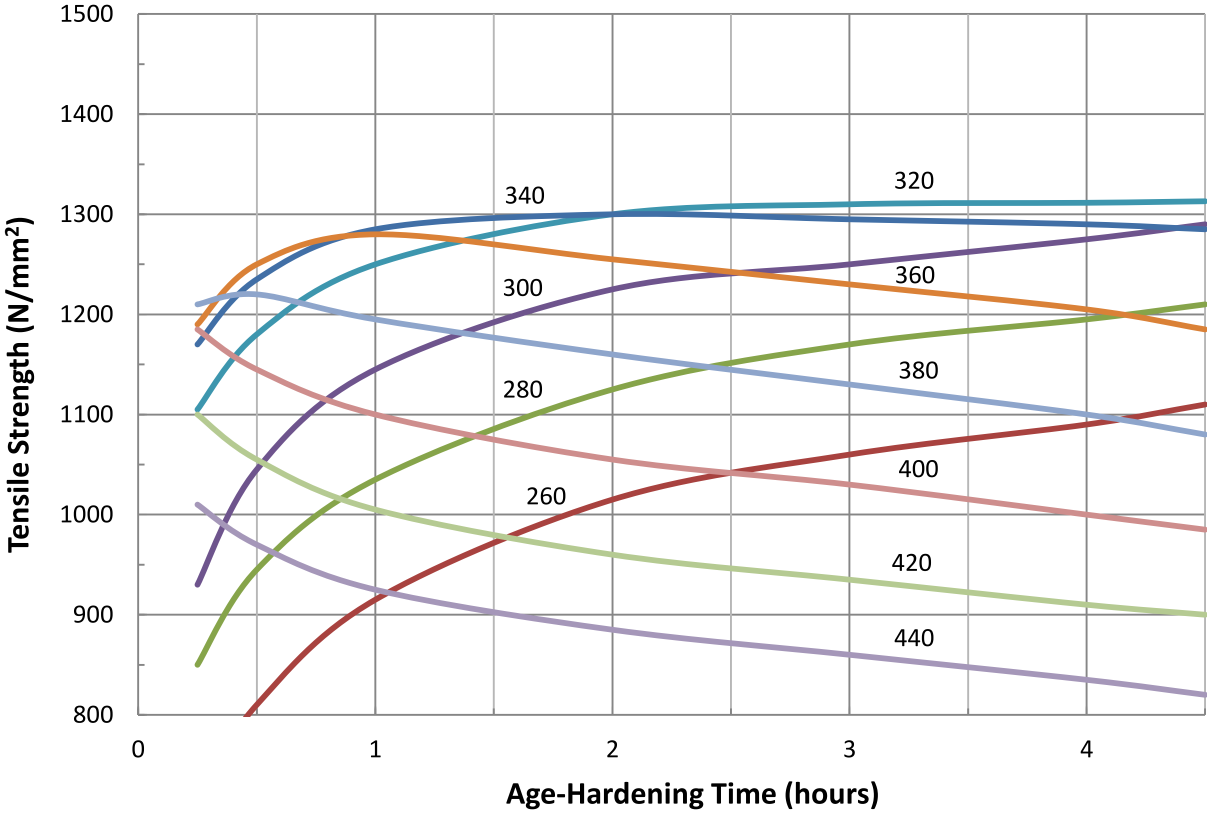

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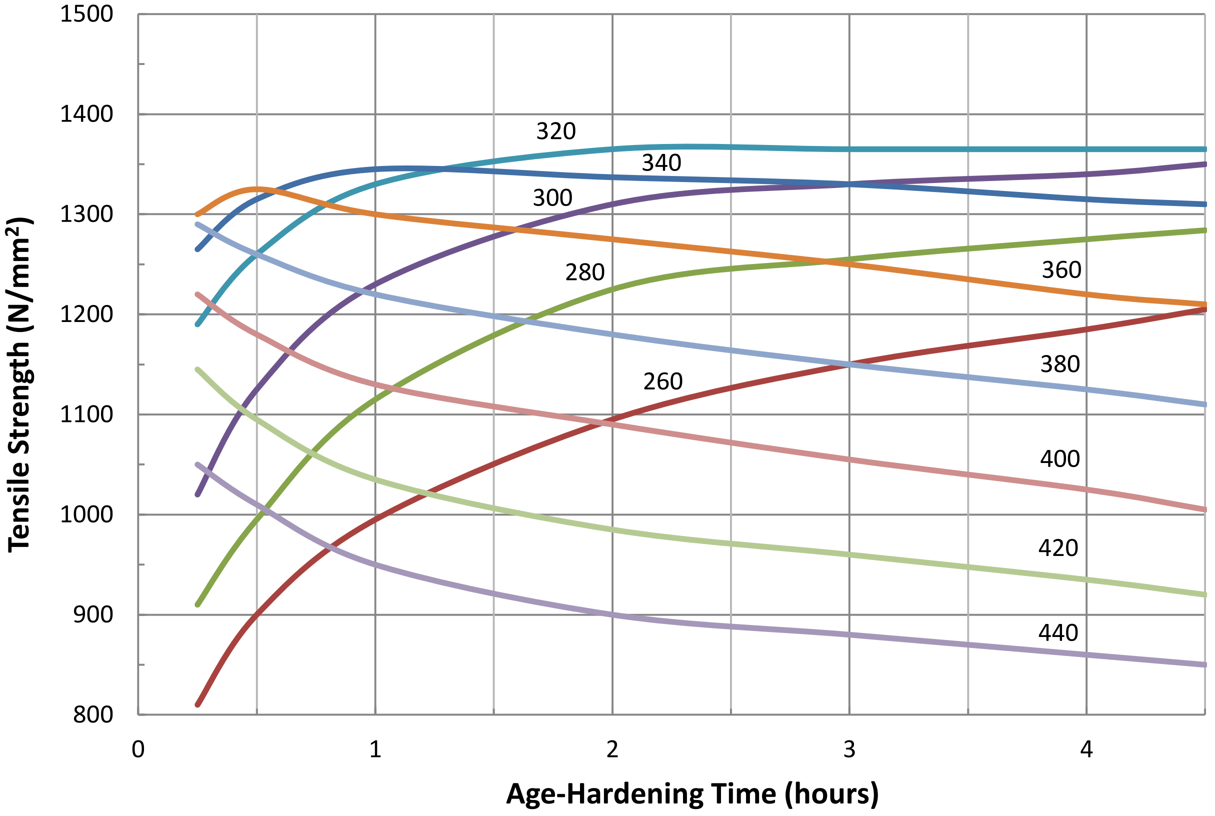
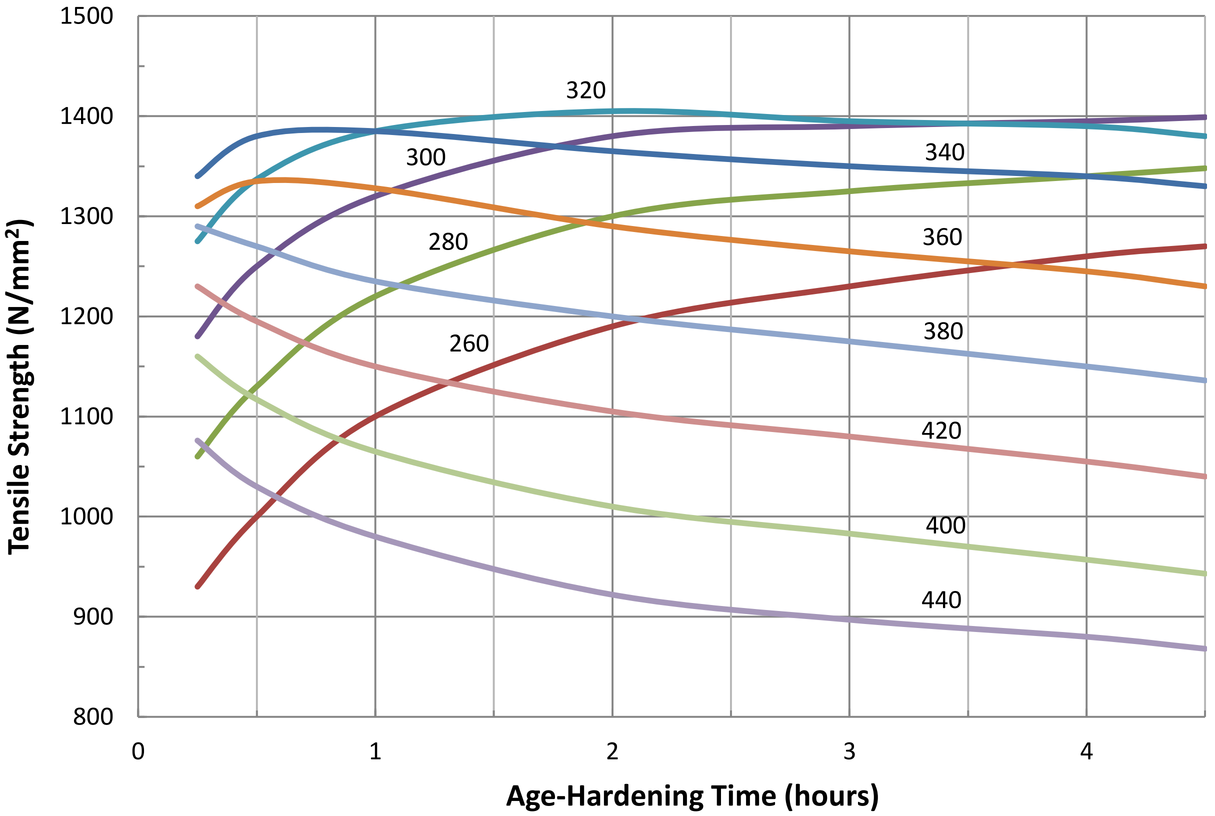
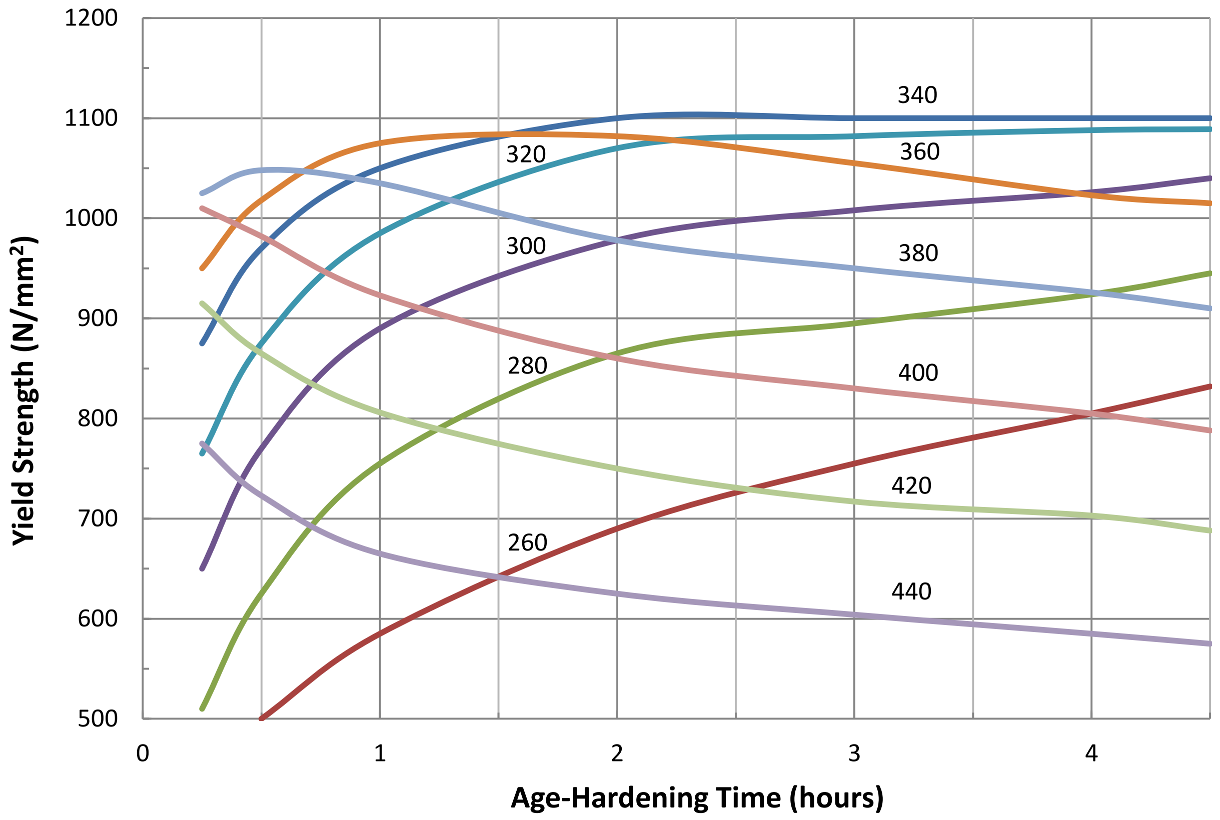


Temper Full Hard (H) - Age-Hardened

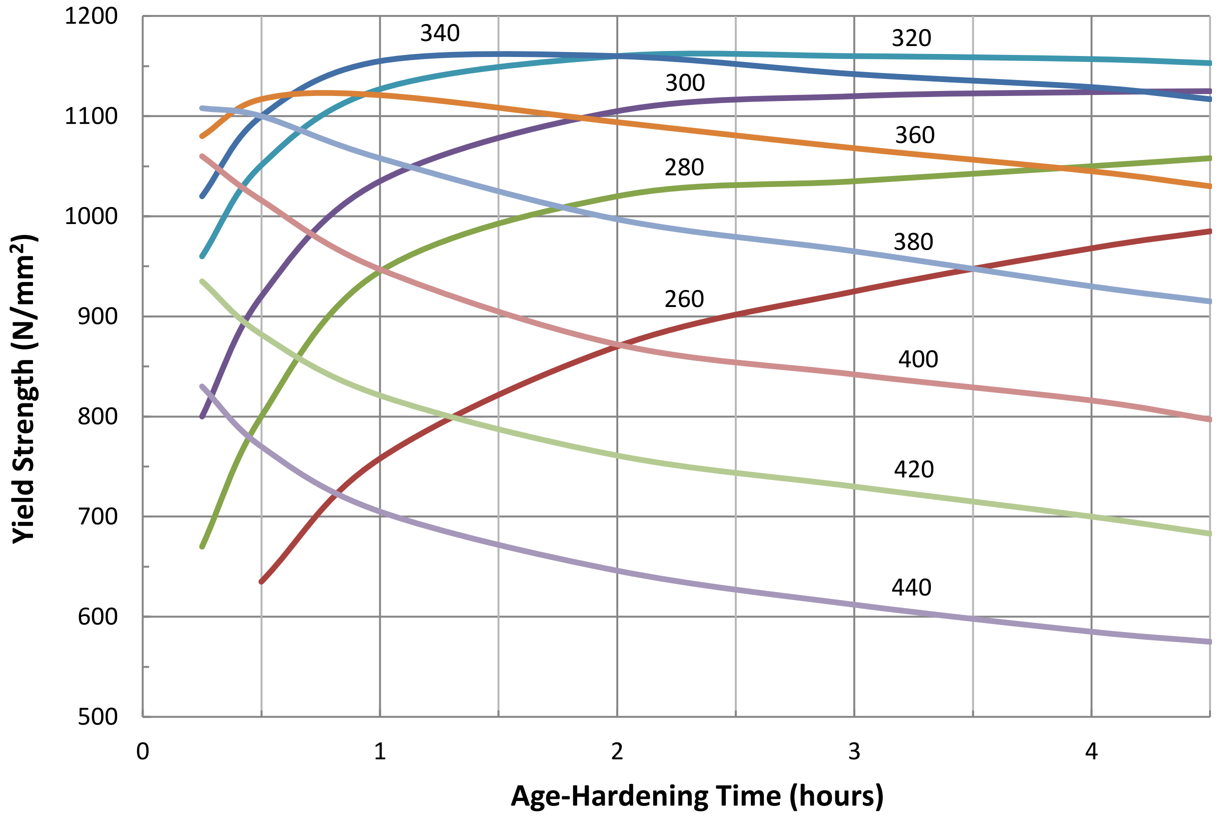


0.2% YIELD STRENGTH ($YS_{0.2}$) – B25 and B33/25 ALLOYS
effects of precipitation treatment temperature and time

Temper Annealed (A) - Age-Hardened



Temper Quarter Hard (1/4 H) - Age-Hardened



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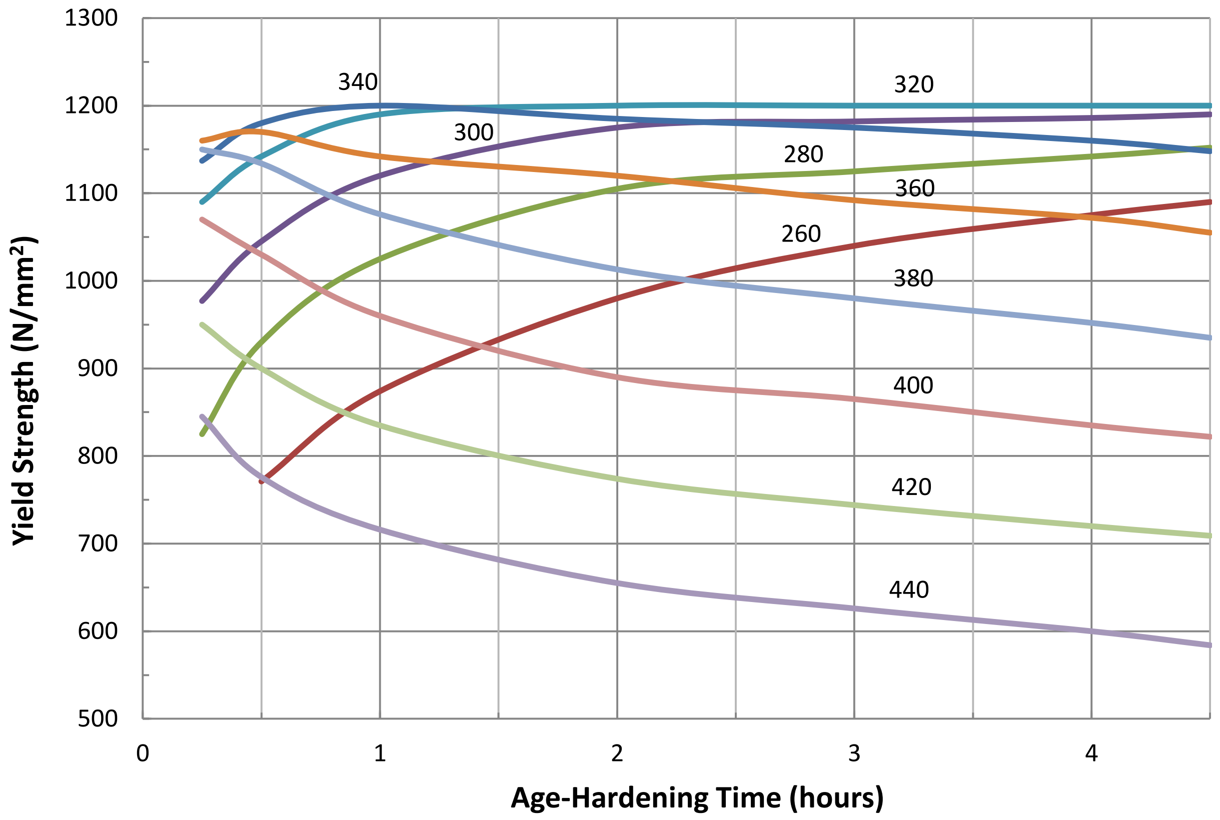
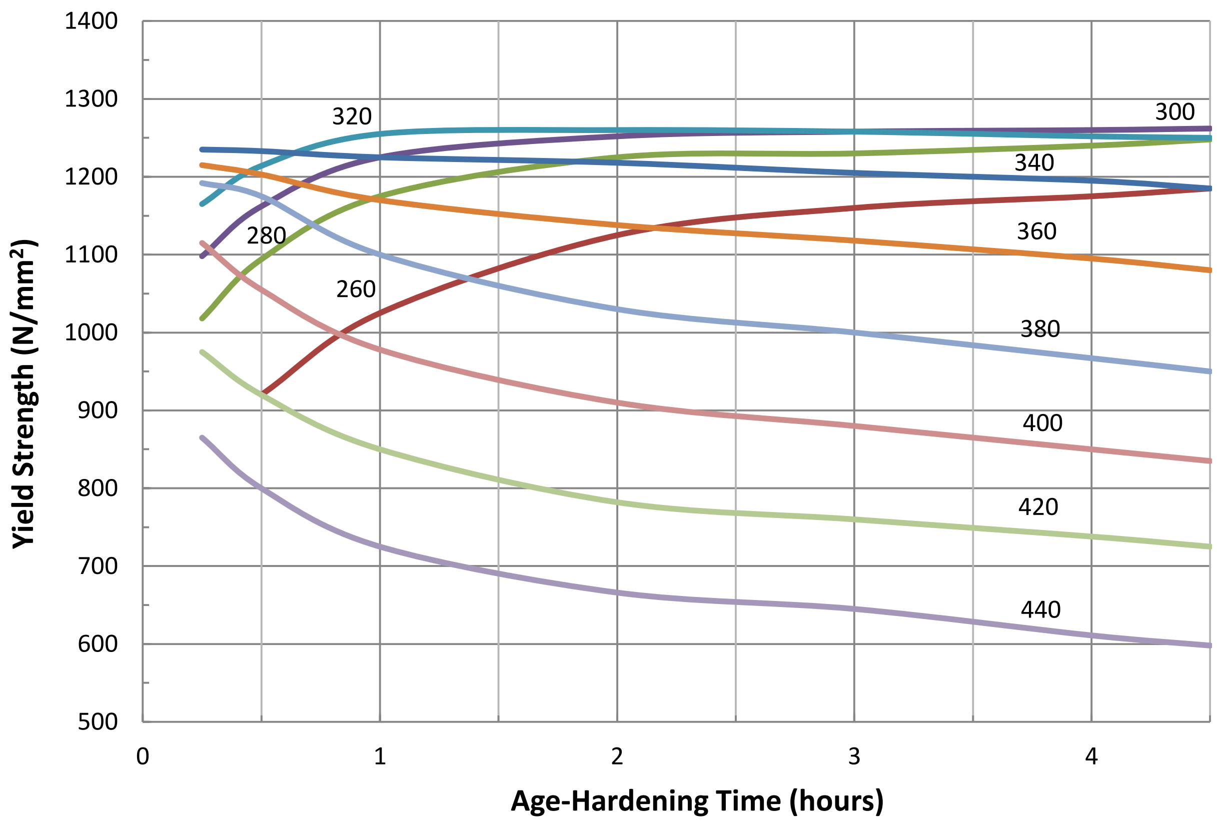
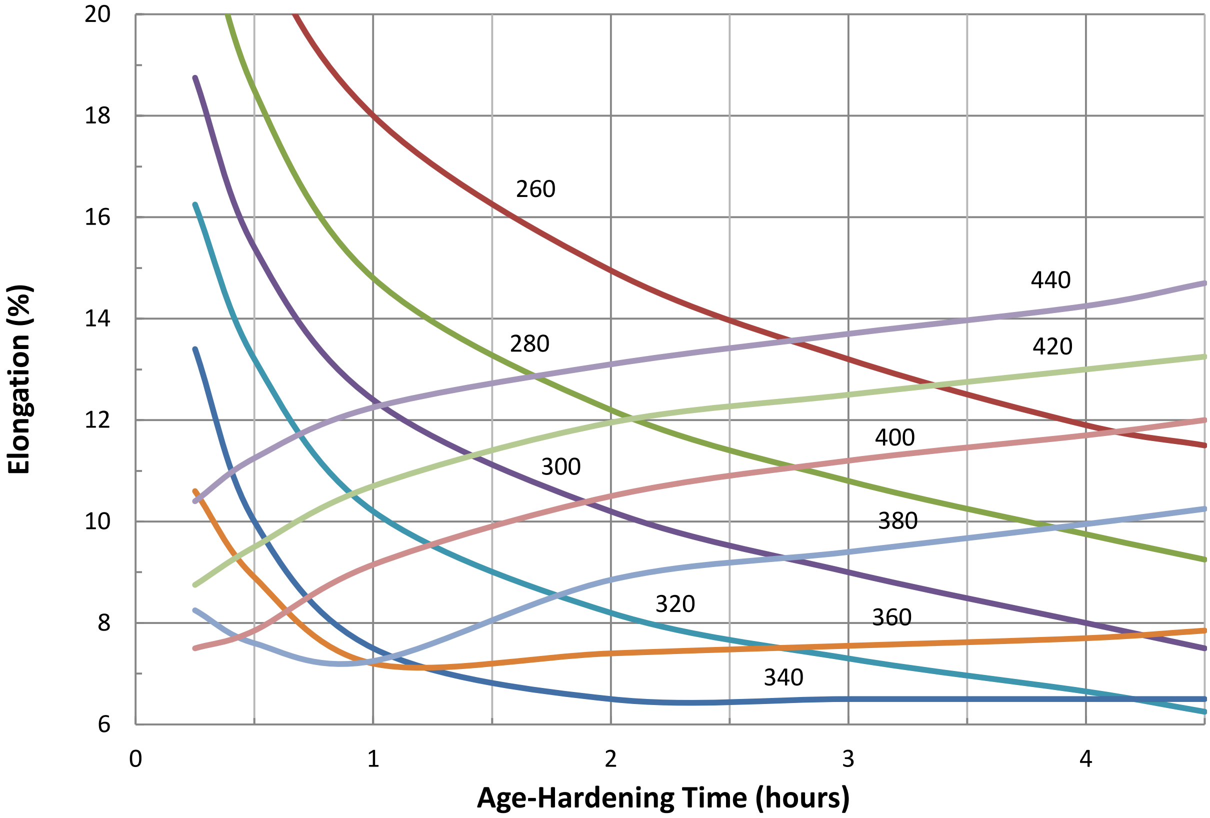


Temper Full Hard (H) - Age-Hardened



ELONGATION – B25 and B33/25 ALLOYS
effects of precipitation treatment temperature and time

Temper Annealed (A) - Age-Hardened



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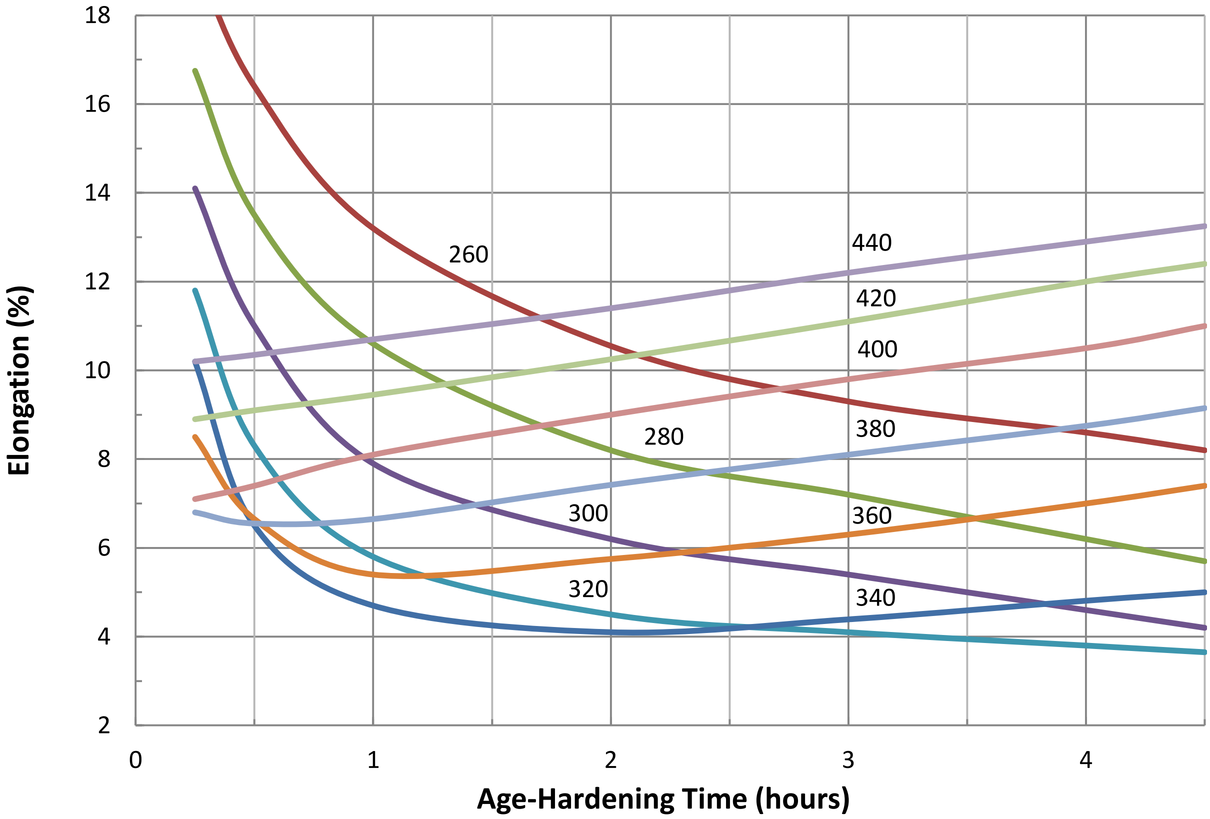

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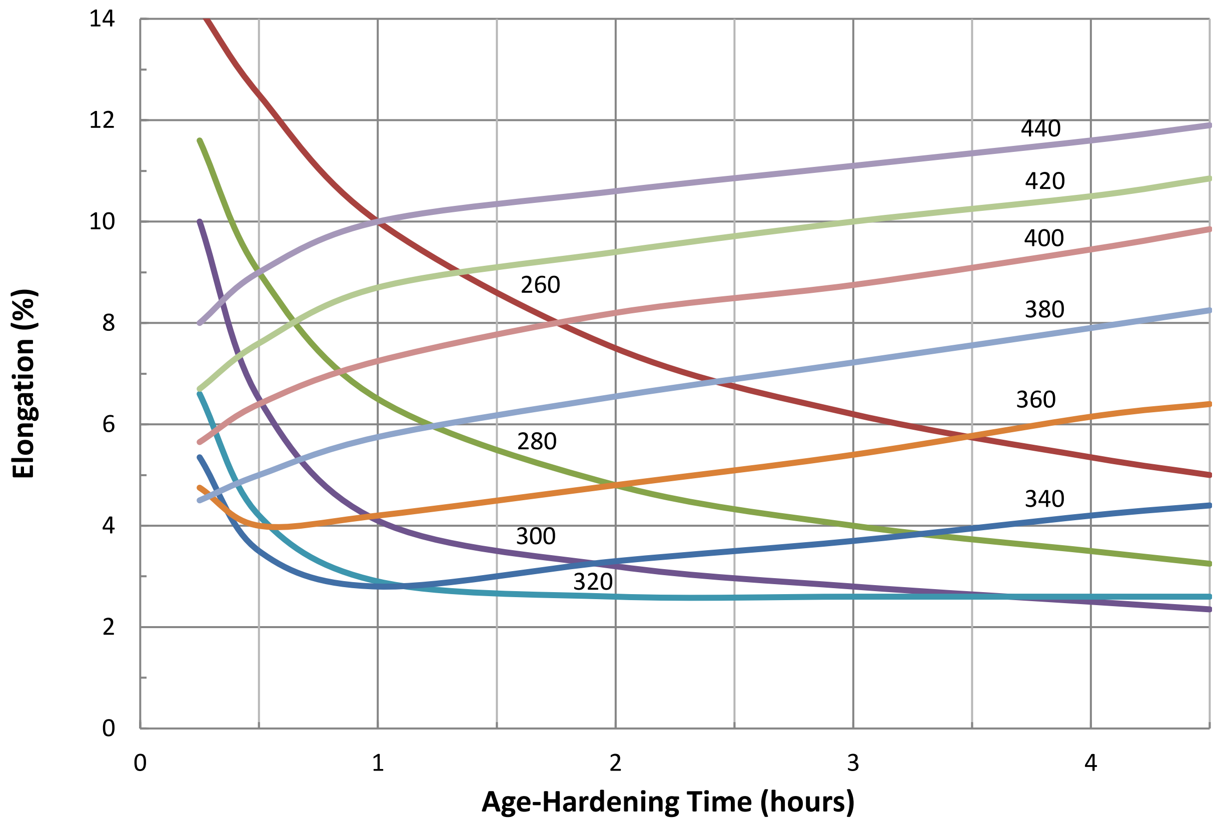

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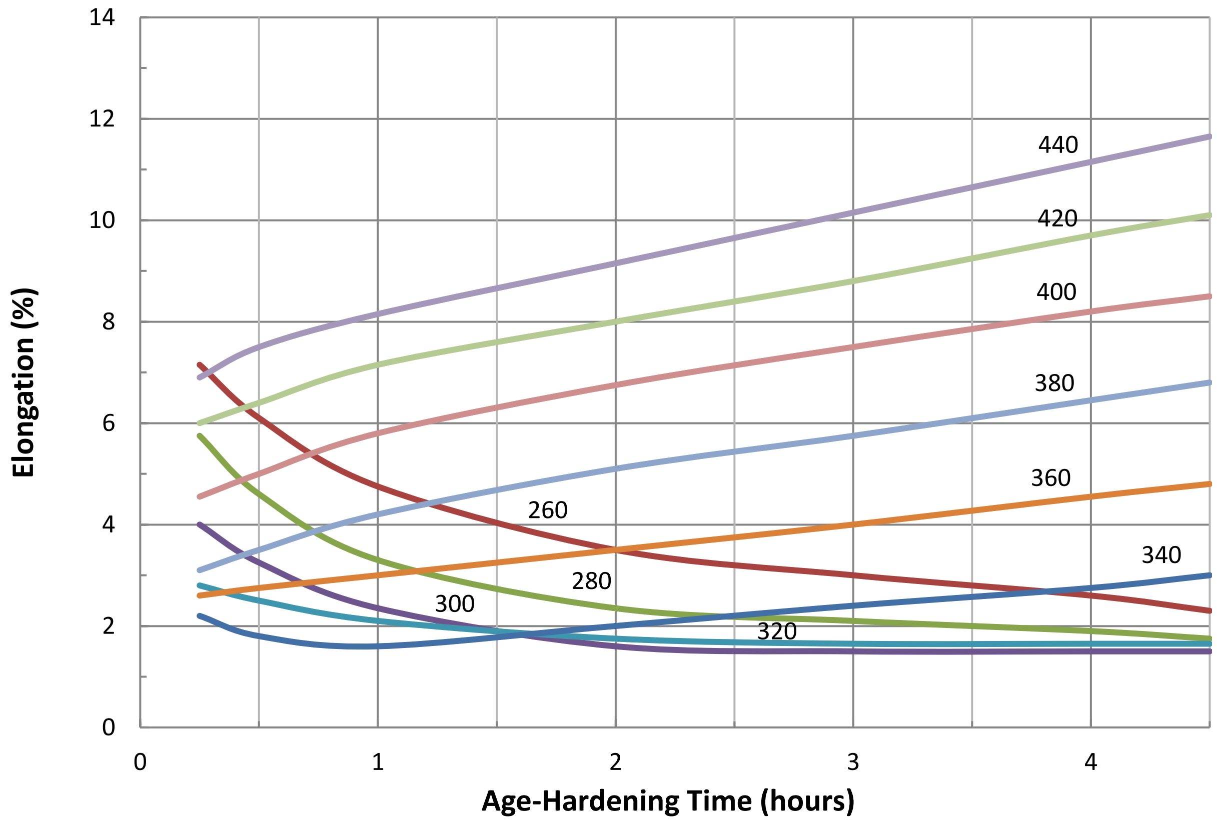

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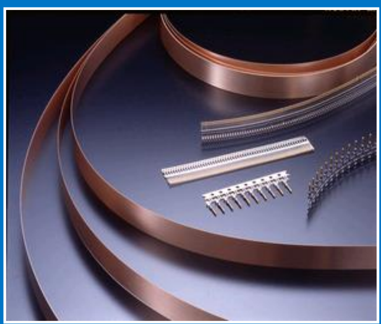

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