Annealing of Aluminum Conductors

The minimum tensile strength of aluminum and copper wires is specified by ASTM or IEC standards. This is the stress at which the wire breaks. At temperatures above 75oC, the tensile strength decreases with time. The tensile strength of galvanized, aluminum-clad, or copper-clad steel wires is not affected by temperatures below 300oC. Thus extended exposure of conductors made up largely of aluminum or copper wires to temperatures above 75°C can eventually lead to tensile failures during high ice and/or wind loading events.

The following figure shows the reduction in tensile strength with time and temperature for 0.081 inch diameter hard drawn copper wire. There are 8760 hours in a year, so the diagram clearly shows that sustained operation at 65°C yields no measureable reduction of tensile strength, sustained operation at 100°C yields a 10% reduction in 600 hours (25 days), and that only 40 hours at 125°C reduces the wire tensile strength by 10%.

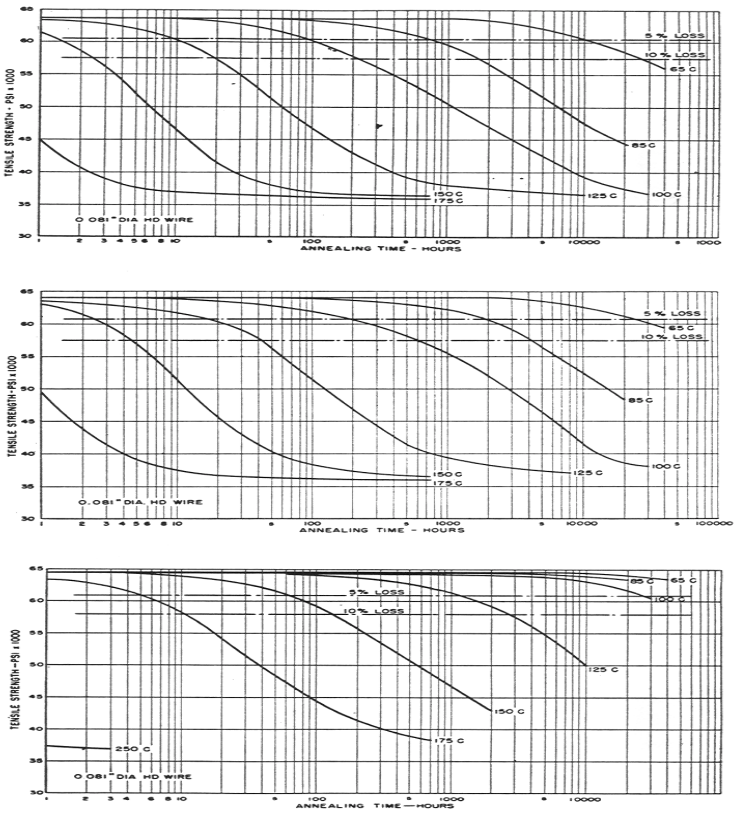

Figure 2 (top). Effect of heat and time—no tension

Brand *C*—hard-drawn wire

Figure 3 (center). Effect of heat and time—no tension

Brand *B*—hard-drawn wire

Figure 4 (bottom). Effect of heat and time—no tension

Brand *AHT*—hard-drawn wire

for the three brands at the lower operating temperatures (65, 85, 100, 125 degrees centigrade).

Comparing these data with those published previously, it would appear that previously available commercial copper wire anneals at a lower temperature than indicated by Seelye and Malmstrom,[20] Olmstead[24] and George;[25] also that extrapolating the data of Pilling and Halliwell[29] to temperatures below 100 degrees centigrade is not permissible.

Figure 6 shows a comparison between the authors' data and that of Seelye and Malmstrom (Figure 2)[20] for the time required at different temperatures for a 5 per cent loss in strength for hard-drawn wire. Fortunately, there appears to be some temperature at which no annealing will occur. If this be true, the data for 60 and 47.5 degrees centigrade shown by Olmstead (Figure 7)[24] appear questionable for representative commercial copper, and certainly so for Hy-Therm copper.

EFFECT OF HEAT AND TIME—WITH TENSION

Duplicate samples were heated at 150 degrees centigrade while held under tension equal to 25 per cent of the original breaking strength of the wires. This corresponds to normal working tension in overhead-line operation.

Figure 7 shows the effect of tension on the 150 degrees centigrade annealing

Table III. Temperature/Time Relation

For Five Per Cent Loss in Initial Strength

Annealing Temperature, Degrees Centigrade	Annealing Time for 5 Per Cent Loss in Strength Hard-Drawn Copper Wire Brand *AHT*, Hours	Brand *B*, Hours	Brand *C*, Hours
65	(a)	24,000	10,500
85	(a)	1,950	770
100	24,000	200	95
125	1,100	15	9.5
150	63	2.3	1.4

(a) Indeterminate to date; 1.4 per cent loss in strength occurs in 40,000 hours at 65 degrees centigrade and 21,000 hours at 85 degrees centigrade.

Figure 0-1 - Annealing of 0.081 inch diameter Hard Drawn Copper Wire

The following figure shows similar tensile strength reduction data for 1350-H19 "EC" hard drawn aluminum wire. In general, tensile strength reduction of aluminum wires at

temperatures of less than 90°C is considered negligible. At 100°C, the tensile strength of the wire is reduced by 10% after 5000 hours and at 125°C, the tensile strength is reduced 10% after 250 hours.

When compared to copper, aluminum appears to anneal somewhat more slowly though the difference is probably not important in transmission line applications. The source of the copper wire data also noted a significant amount of variation in the annealing rates for wire obtained from different manufacturers.

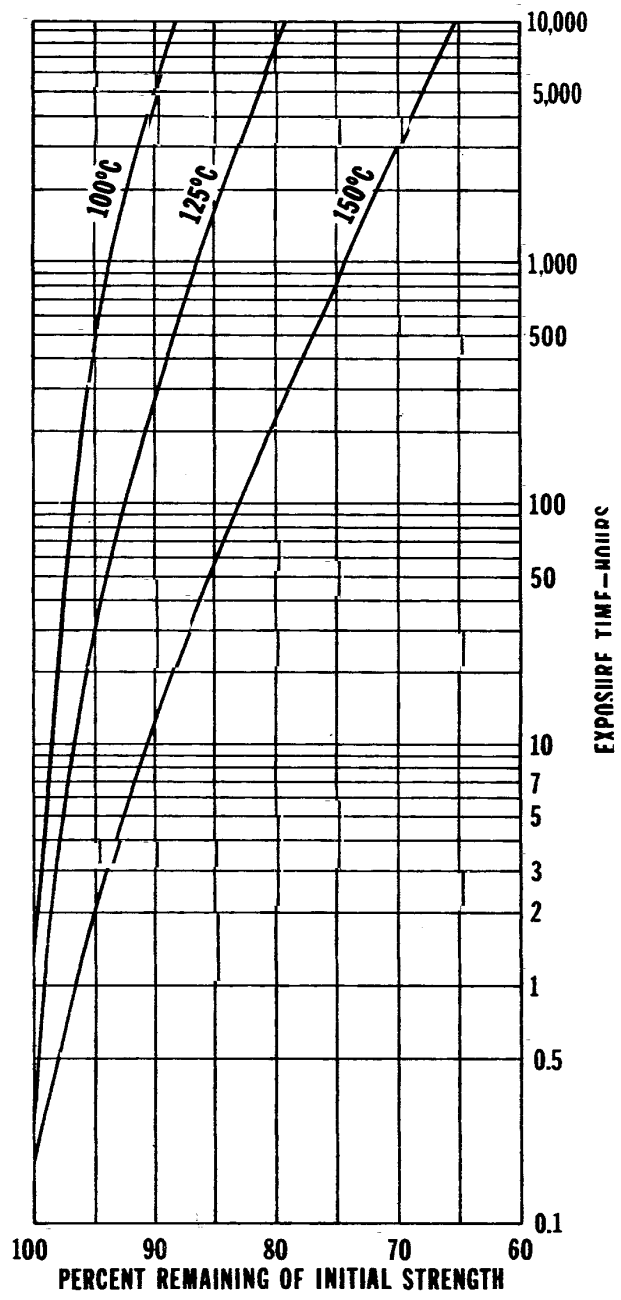

Figure 0-2 - Annealing of 1350-H19 Hard Drawn Aluminum Wire