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Improvement of Copper Alloy Springs. I
Effects of Various Third Elements Added to Plain 60/40 Brass*

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Synopsis

For the purpose of improving the spring properties of plain 60/40 brass, iron, aluminium, manganese, nickel, cadmium and tin were added to the alloy, and the alloys of Cu-Mn-Ni and Cu-Fe series were also examined. The conclusion obtained was as follows: (1) Among those elements, iron, manganese, aluminium, and tin were considered to be favorable to the purpose, and a satisfactory result might be obtained by increasing each content, unless injuring other practical processing. (2) The alloys of Cu-Mn-Ni series might be expected as the high heat-resistant spring material. (3) The alloys of Cu-Fe series also could be hopeful of spring materials, provided that those were suitably heat-treated during the manufacturing processes.

I. Introduction

As the excellent spring materials of copper alloys used for communications and measuring apparata, nickel silver, phosphor bronze, and beryllium bronze are generally known, but those alloys contain nickel, tin or beryllium and show some difficulties in the formability. For instance, the spring materials used for the socket of a vacuum tube should have a wide range of elasticity and a high degree of formability. The former will be satisfied, of course, by improving the spring characteristics as observed in phosphor bronze or nickel silver, but the latter will be disturbed by directionalities of rolled sheets as observed especially in phosphor bronze. For the spring material, a series of brass has also been used in general. The alloy shows several favorable characters, for instance, easier producibility or lower cost, compared with others, but it also involves several defects for a higher class material, that is, though the alloy contains 40 per cent of zinc and is cold-rolled heavily (about 75 per cent) (1), the absolute value of spring properties is inferior to those of the materials described above, and the formability will be hidden by heavy cold-working. The absolute values of residual deflection in a static spring test of the alloy are greater than those of other copper alloys shown above, even though the treatment of ready-to-finish annealing may be done at the best temperature of 400°C (2). In addition to this, the most unfavorable defect of the alloy will be to show the so-called "secular change", which is the phenomenon

* The 858 th report of the Research Institute for Iron, Steel and Other Metals. Read at the Annual Meetings of Japan Institute of Metals at Sapporo and Tokyo, Sep. 1950 and Apr. 1953.

(1) H. Tsuda and E. Tamura, Rep. Furukawa Elect. Co., No. 6 (1950), 36.

(2) K. Murakawa, Rep. Inst. Sci. Tech., **3** (1949), 10; 82.

of deterioration of the spring properties with time, even after the best treatment for spring properties (both cold-working and low-temperature annealing). The tendency will occur more intensely with increasing content of zinc. Low heat-resistivity and low contact-conductivity may also be considered as defects.

Therefore, the present investigation was carried out first to improve the spring properties of the brass, and then was extended to the other copper alloys, in view of their high heat-resistivity.

II. Experimental procedures

1. Specimen

A series of 60/40 brass was investigated by adding various third elements, namely, iron, aluminium, manganese, nickel, cadmium and tin. Those were added as much as they can show the same ratio of the phases of α and β on the base of the 60/40 brass containing 1 per cent of iron. As the alloys of high heat-resistivity, the Cu-Mn-Ni and the Cu-Fe alloys were also examined. The nominal composition of the former was 10 per cent of manganese and 10 per cent of nickel, and 15 per cent of manganese and 19 per cent of nickel. The latter contained about 4 per cent of iron, which was the limited amount within the range of solid solution.

Those alloys were melted by a coke furnace, excepting the Cu-Mn-Ni alloys which were melted by a high frequency electric furnace. The amount of each charge was about 2.5 kg, which was cast into an iron mould ($20\times90\times150$ mm^3). The ingot was homogenized at 700~800°C for 24 hrs after scalping, and then hot-rolled at 700°C. A series of brass was cold-rolled from 5 to 2 mm in thickness with intermediate annealing at 600°C for 30 min and was finally cold-rolled to 0.5 mm by the reduction of 75 per cent after ready-to-finish annealing at 400°C for 1 hr. On the other hand, the alloys of Cu-Mn-Ni series were hot-rolled to 2 mm, and were divided into two groups; one was furnace-cooled ("FC"), and the other was quenched into water ("WQ") after annealed at 700°C for 1 hr. Both were then cold-rolled to 0.5 mm. A series of Cu-Fe alloys was hot-rolled down to 4 mm in thickness, and divided into two groups; one was furnace-cooled after kept at 800°C for 1 hr, and then cold-rolled to 0.5 mm, during which the treatments of low-temperature annealing at 250°C for 30 min were inserted, the total reduction being 87.5 per cent ("CFF"). The other was tempered at 550°C for 1 hr after quenching into water at 950°C, and then cold-rolled to 0.5 mm ("CFT").

The specimens were cut in parallel and transverse to rolling direction of the sheet into the standard size, 10 mm in width and 150~160 mm in length, and were subjected to low-temperature annealing, if necessary.

2. Measurement

The spring test was carried out by Furukawa spring fatigue testing machine shown in Fig. 1 in the following way[(3)]: spring properties were compared with one another by measuring the residual deflections caused by repeated bending applied to the fixed end of cantilever, 50 mm in length. For instance, the spring limit

(3) Y. Konishi, T. Kashibuchi and E. Tamura, Rep. Furukawa Elect. Co., No. 1 (1947), 32.

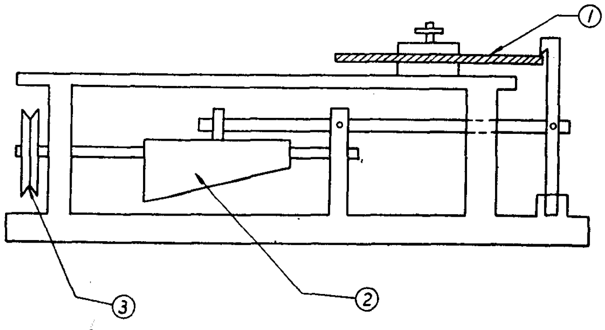

Fig. 1. Scheme of bending fatigue tester for plate form springs.

could be determined by measuring the maximum surface stress, at which the residual deflection was exactly 0.1mm after 50 repetitions. The bending test of 2,000 cycles under the loads near the spring limit was carried out, and the residual deflection was observed. The rate of repetition was about 300 cycles per minute. Further, the Vickers hardness was messured at the load of 10 kg.

III. Experimental results and considerations

1. A series of special brass

A series of special brass containing individually a small amount of Fe, Al, Mn, Ni, Cd or Sn was examined, and the results are shown in Figs. 2 ~ 8 with the compositions of Zn and the third elements. The three curves denoted by 35, 40 and 45 show the residual deflection measured under the maximum surface stresses of 35, 40 and 45 kg/mm², respectively. In the figures, the hardness changes caused by the low-temperature annealing were also shown.

In the case of the rolled condition, the specimen "S" showed a comparatively superior property, and "M", "N" and "D" followed this. The others, "B", "F" and "A", were not so good as those shown above. Otherwise, after low-temperature annealing for 1 hr, the minimum points were observed more than twice on each residual deflection-temperature curve. The changes could correspond to those of hardness values showing maxima. The minimum values of deflection and the temperatures at which the deflection showed the minimum values were slightly different with

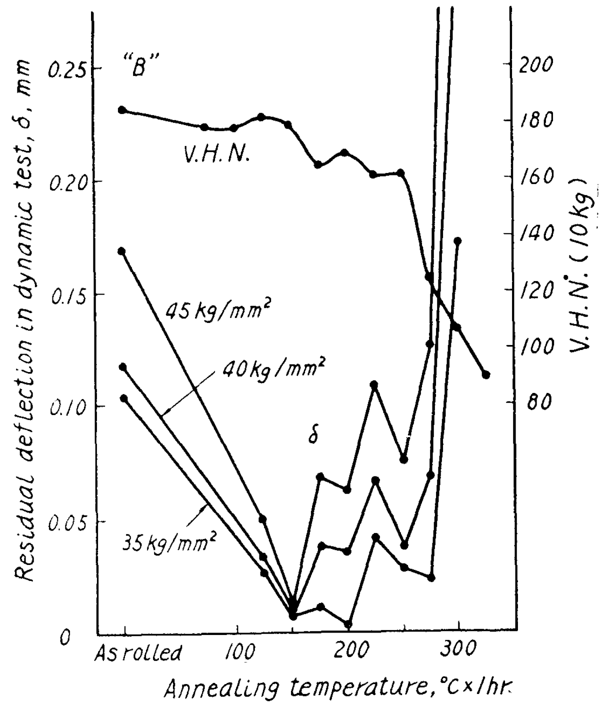

Fig. 2. Results of spring and hardness test of specimen "B" (Zn 42.2%)

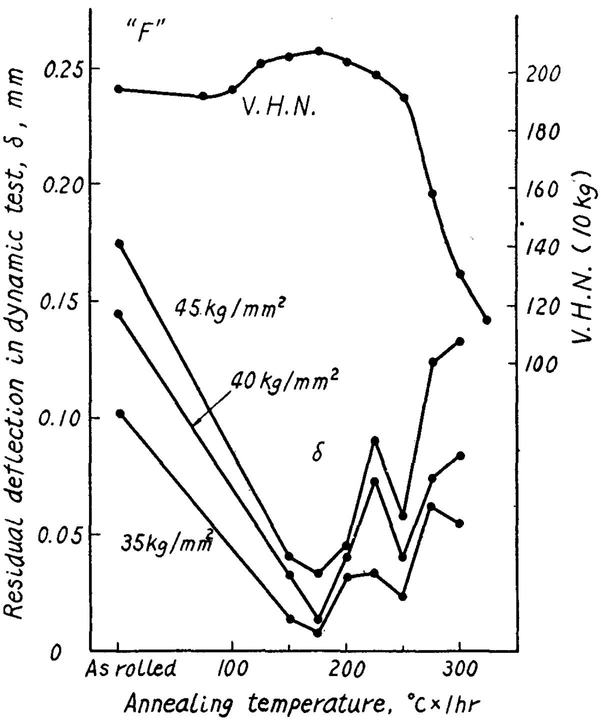

Fig. 3. Results of spring and hardness test of specimen "F" (Zn 42.1%, Fe 0.86%)

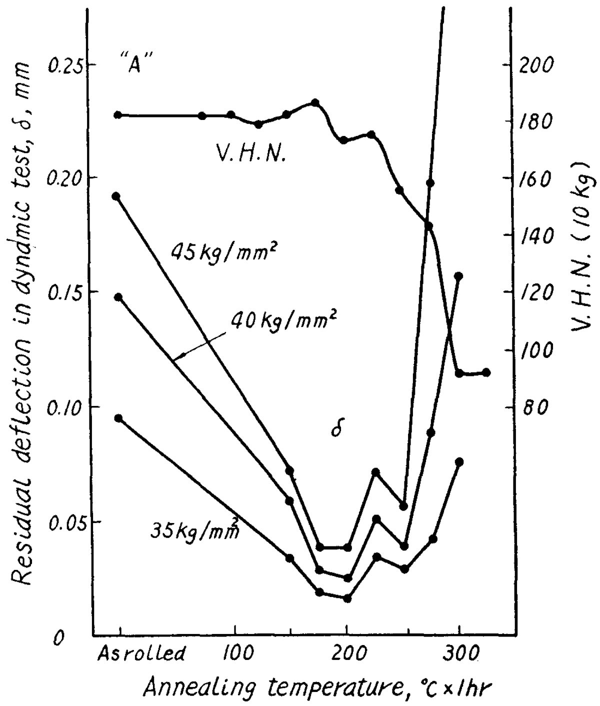

Fig. 4. Results of spring and hardness test of specimen "A" (Zn 42.2%, Al 0.28%)

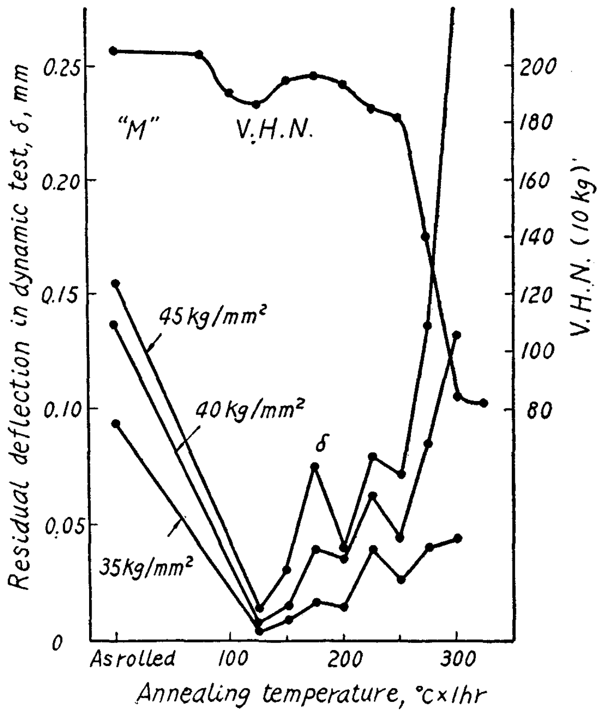

Fig. 5. Results of spring and hardness test of specimen "M" (Zn 41.0%, Mn 0.98%)

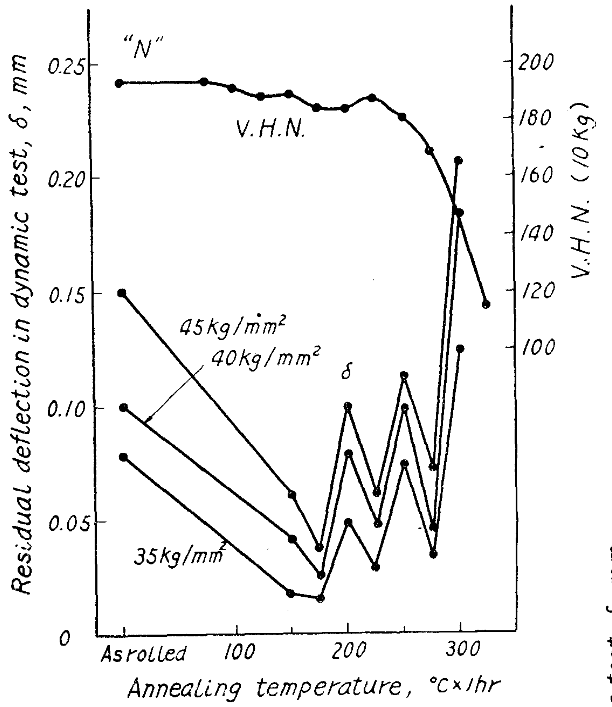

Fig. 6. Results of spring and hardness test of specimen "N" (Zn 40.9%, Ni 1.56%)

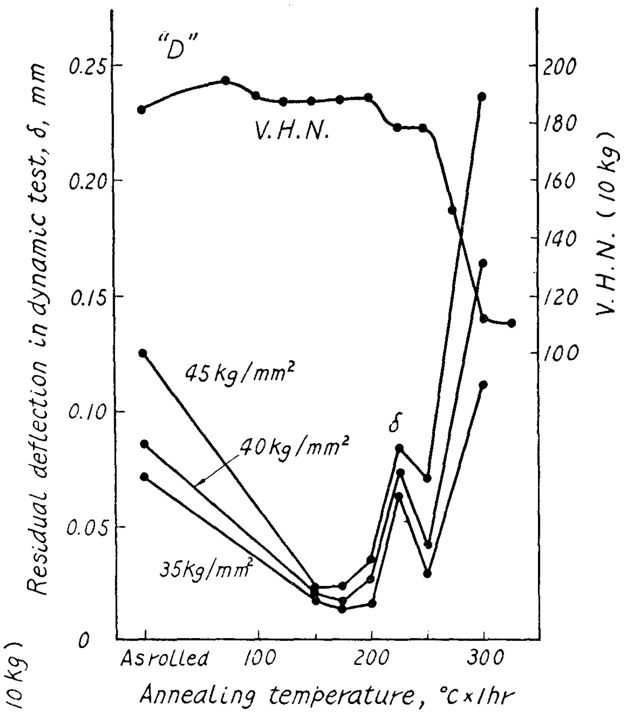

Fig. 7. Results of spring and hardness test of specimen "D" (Zn 40.9%, Cd 1.56%)

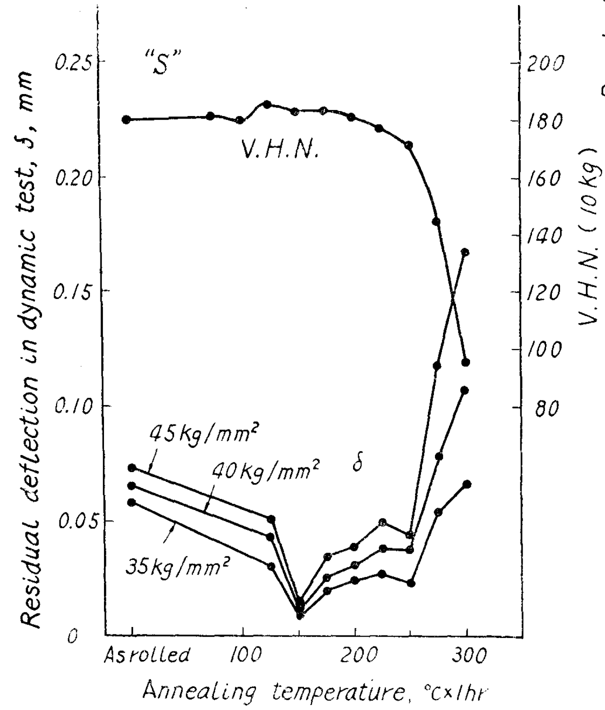

Fig. 8. Results of spring and hardness test of specimen "S" (Zn 40.6%, Sn 0.60%)

different alloys, but very small was the difference between those values under different loads for each temperature. Though the smaller the values, the better the spring properties (for instance, "M", "S", "B" etc.), it would be more favorable that the range of temperature at which the deflection showed minimum was wider, because some difficulties might be introduced into those heat-treatments in practice. Therefore, from the figures, "F", "M", "A", "S" and "D" would be more favorable than "B" or "N". Furthermore, from the point of heat-resistivity, "F", "M", "A" and "S" could be considered as more improved spring materials than plain brass, "B". If the content of the third elements was increased, a further improvement would be expected. At room temperature "F" and "A" had smaller values of specific electrical resistivity than others, excepting "B", and those might be significant for the purpose of electrical uses. (abridged in the figures)

2. A series of Cu-Mn-Ni alloys

The alloys (MN10) containing 9.6 per cent of manganese and 11.6 per cent of nickel and (MN17) containing 14.6 per cent of manganese and 19.0 per cent of nickel were heat-treated in two ways, that is, quenched into water at 750°C and then cold-rolled 75 per cent (WQ); furnace-cooled at 750°C and then cold-rolled 75 per cent (FC). The results are shown rspectively in Figs. 9, 10, 11 and 12. From a metallographic consideration, some improvements in the mechanical properties of Cu-Mn-Ni alloys could be expected by quenching and tempering on the base of its pseudo-binary system(4),(5). Therefore, within the range of low contents of manganese and nickel, the alloy was examined in the spring properties, especially from the point of heat-resistivity. Results showed that "MN10" was good, when annealed at 350°C, and that the deflection due to several loads was comparatively stabilized. The alloy showed a superior property in the rolled condition, compared with the cases of brass and the others, and its deflection increased temporarily at 200°C, which resembled the type of quenched and tempered Cu–Be alloy. Therefore, the most suita-

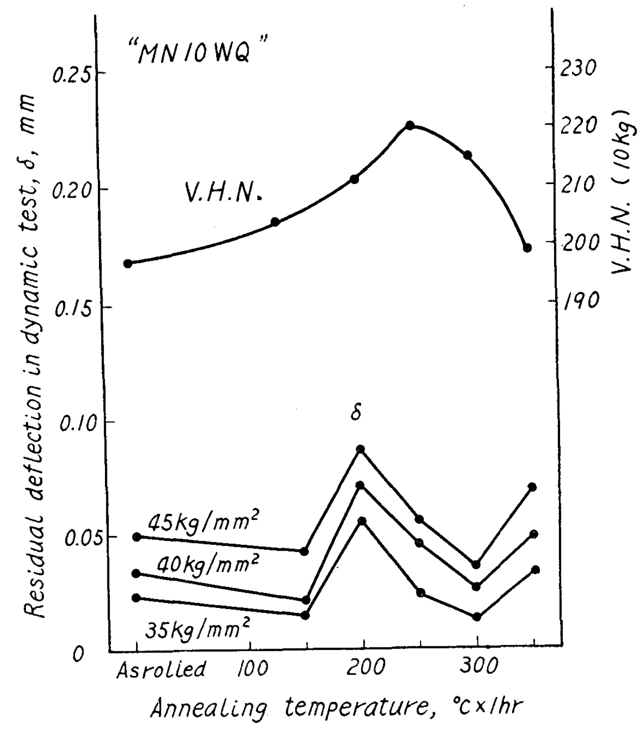

Fig. 9. Results of spring and hardness test of specimen "MN10WQ" (Mn 9.6%, Ni 11.6%), Water-quenched at 750°, then cold-rolled 75%

(4) C. H. Samans, C. C. Brayton, H. L. Drake and L. Litchfield, Trans. A. S. M., Preprint No. 31 (1948), 23.

(5) P. Mabb, Metallurgia, **41** (1950), 243.

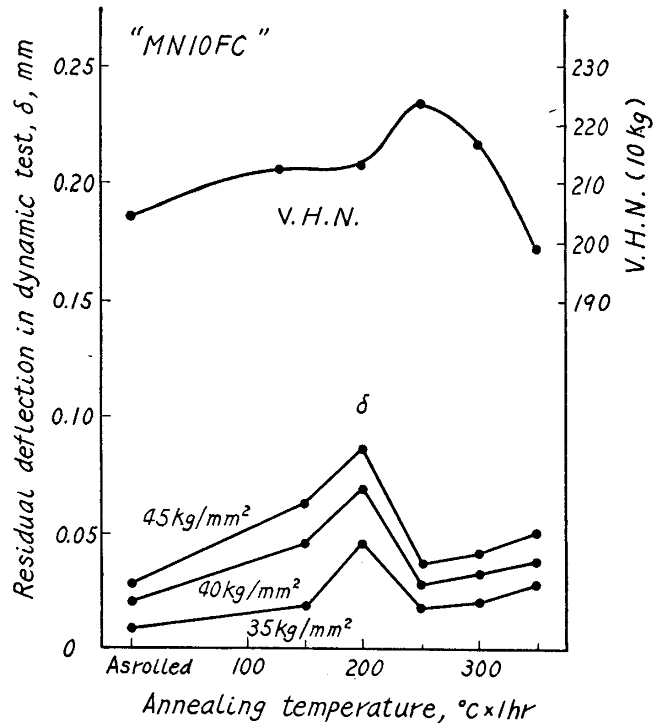

Fig. 10. Results of spring and hardness test of specimen 'MN10FC" (Mn 9.6%, Ni 11.6%), Furnace-cooled from 750°, then cold-rolled 75%

ble low-temperature annealing should be carried out at 275 or 300°C, which would also be shown from the change in hardness. The difference due to two types of heat-treatment seemed to be negligible. In the case of "MN17", the temperature dependence of the residual deflection was similar to that of an alloy of solid solution type, and the minimum points of deflection were observed at 250°C in "WQ", and at 150 and 300°C in "FC". The latter showed comparatively high values of hardness, and the temperature range of small deflection was wider and more stabilized than the former. Those might be due to the difference in the heat-treatment. Those did not result

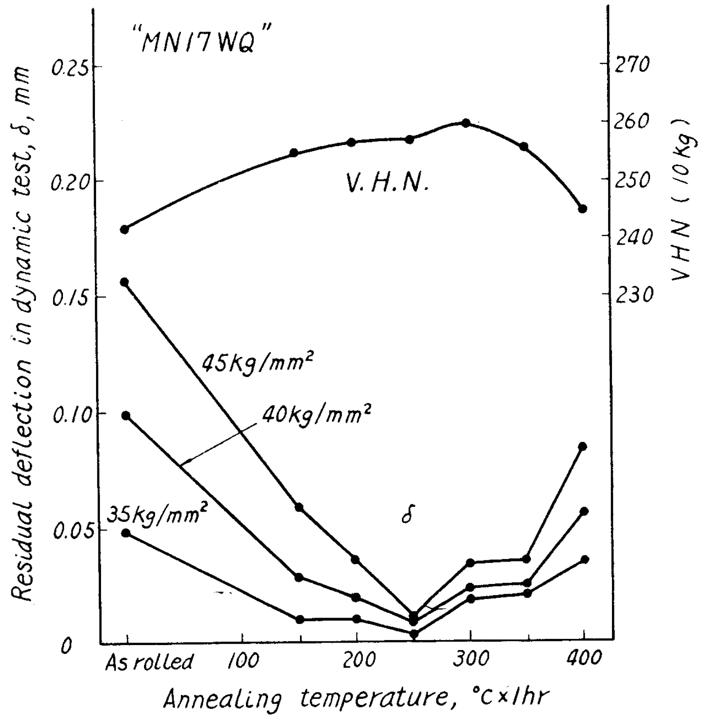

Fig. 11. Results of spring and hardness test of specimen "MN17WQ" (Mn 14.6%, Ni 19.0%), Water-quenched at 750°, then cold-rolled 75%

in so remarkable improvements as expected, due perhaps to their compositions deviating slightly from the line of the pseudo-binary system. However, the series could be expected as a favorable heat resistant material, if the problems of the resource of component were not considered economically.

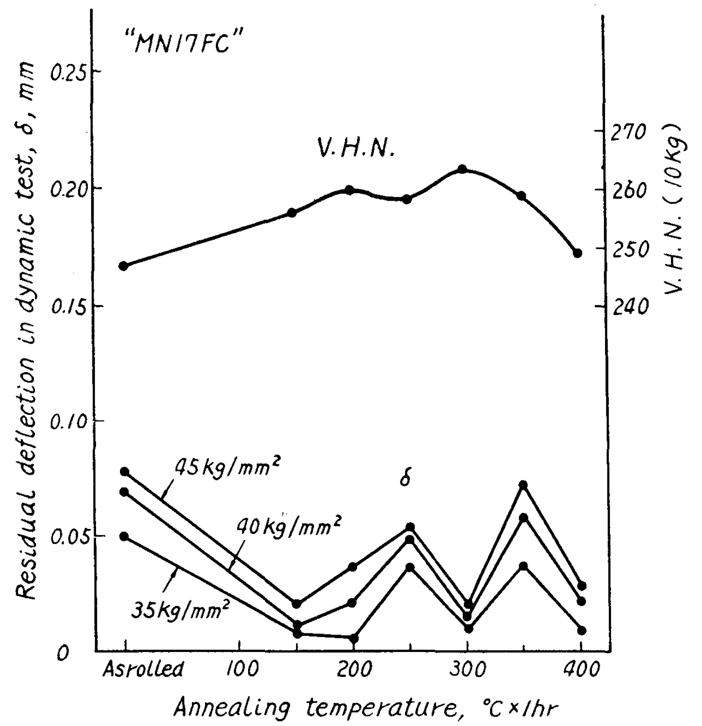

Fig. 12. Results of spring and hardness test of specimen "MN17FC" (Mn14.6%, Ni 19.0%), Furnace-cooled from 750°, then cold-olled 75%

3. A series of Cu-Fe alloys

Fig. 13 shows the results of the alloy containing 4.21 per cent of iron. The residual deflections under the load of 35 kg/mm² were compared with those of the above alloys. The hardness was comparatively low, and, as expected, the absolute values of residual deflection were considerably large. Those might, however, be improved by increasing the iron content. It would be interesting that "CFF" showed a minimum deflection of about 0.15 mm at 200°C. On the other hand, though "CFT" showed a minimum deflection at 150°C, the amount was larger than that of "CFF" at 200°C. Whithin the range from 200 to 350°C, "CFF" was superior to "CFT", but above the range "CFT" was contrarily more stabilized than "CFF" up to the higher temperature (600°C). The behaviors of both were, below 350°C, remarkably different from those observed in general heat-treatable alloys, that is, the precipitation of iron from the super-saturated solid solution of copper-side would be different from that of general case, as mentioned by others(6). Therefore, it would be more effective for the precipitation of iron and for the stabilization of the phase to cool the alloy continuously through each temperature range than the case of quenching and tempering. From the point of view mentioned above, "CFF"

(6) C. S. Smith and E. W. Palmer, J. Metals, **1** (1950), 1486.

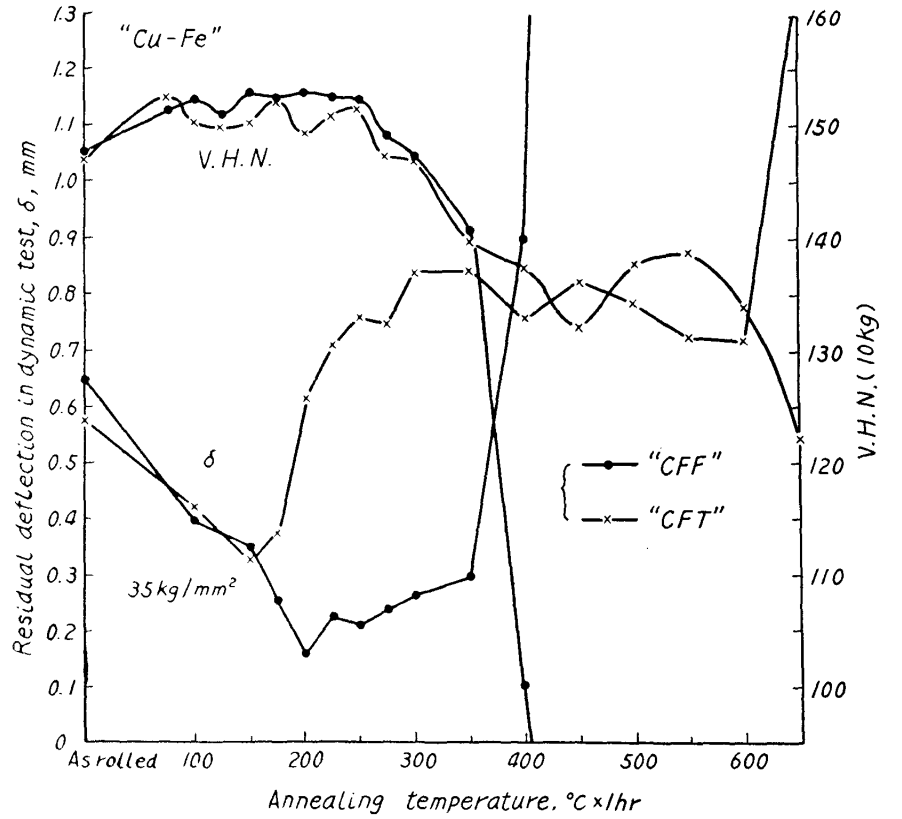

Fig. 13. Results of spring and hardness test of Cu-Fe alloys (Fe 4.21%)

would be more favorable than "CFT". In addition to this, the low-temperature annealings inserted during each cold-working process would increase the degree of reduction, and would make the temperature, at which iron precipitated critically, lower and more effective. In the case of "CFT", the effects were considered as those divided "CFF" into two processes, and the process of precipitation hardening of iron would be expected rather at higher temperature. Therefore, if the precipitation of iron from the super-saturated copper side solid-solution of Cu-Fe alloys was used, such a heat-treatment as "CFF" should be necessary for the purpose. Thus, the series might be expected to be used as a spring material only at the iron content above 4 per cent.

Summary

(1) A series of 60/40 brass was examined to improve the spring property by adding various third alloying elements. Among those elements, iron, manganese, aluminium and tin were comparatively favorable for the purpose. In practice, a further improvement might be expected by increasing their amounts within the range in which the formability of the alloys would not be deteriorated.

(2) A series of Cu-Mn-Ni alloys would be hopeful of the spring materials of high heat-resistivity.

(3) A series of Cu-Fe alloys showed considerably good spring properties, when heat-treated properly, and might be expected as a favorable spring material.