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FURTHER INVESTIGATION OF PREHEATING AND POSTHEATING IN SPOT-WELDING 0.040-INCH ALCLAD 24S-T

By W. F. Hess and F. J. Winsor

Rensselaer Polytechnic Institute

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SUMMARY

This report describes additional work in an investigation to determine the effects of preheating and postheating on the quality and the strength of spot welds in aluminum alloys. In this study all welding was performed with an alternating-current machine, using a program timer to sequence the preheat and weld, or the weld and postheat, cycles.

The results of this work showed that in alternating-current spot welding of aluminum alloys the weld time is very important with regard to the quality of welds produced. For a given weld size, too short a weld time, in conjunction with a low electrode force, resulted in the occurrence of internal cracks in the welds. Increasing the weld time eliminated these cracks, although it had relatively little effect on the weld size, provided the current remained constant. The minimum weld time required for the complete elimination of internal cracks is a function of the weld size.

With properly prepared surfaces, preheating produced some improvement in weld quality when the preheat current was sufficiently high in magnitude and of long duration. The employment of intermediate values of preheat current, however, was definitely dangerous. This is believed to be due to a lowering of the sheet-to-sheet resistance which rendered the welding current ineffective in producing welds of adequate size. High values of preheat current tended to eliminate expulsion and surface flashing usually associated with spot-welding untreated Alclad 24S-T.

Postheating of spot welds in 0.040-inch Alclad 24S-T had no effect on the weld strength or quality, unless the magnitude of the postheating current was at least equal to that of the welding current. The passage of high values of postheat current for a long period of time improved both the strength and the quality of the welds, in cases in which the welds exhibited internal cracking without the application of postheating. This improvement in weld strength and quality, however, was no greater than that which could be effected by increasing the weld time and the welding current.

INTRODUCTION

The present report describes the results of the continuation of an investigation to determine the effects of preheating and postheating on the quality of spot welds in aluminum alloys.

The investigation was performed with a conventional alternating-current spot welder using a Thyratron control panel and a program timer. A brief study of the postheating of spot welds in 0.040-inch Alclad 24S-T was made with this equipment in the previous investigation (reference 1). The purpose of the present work was to provide additional knowledge of the effects of postheating on the quality of spot welds in Alclad 24S-T and also to determine the effects of preheating on the weldability of this material.

Previous work with regard to the postheating of spot welds had shown that the passage of current following welding had no effect on the strength or the quality of the welds unless the magnitude of the current was sufficiently high to cause remelting in the weld zone (reference 1). When the current for postheating was high enough and of sufficient duration to cause remelting, the shear strength of the welds increased. This increase in strength, however, was not accompanied by an increase in the percentage of cracked welds. The present work was undertaken to broaden this observation and to compare the quality of postheated welds with those made without postheating.

It is known that the surface condition of aluminum alloys prior to spot welding greatly influences the spot weldability of these materials. With this in mind, another objective of this investigation was to determine the effects of preheating upon the weldability of Alclad 24S-T alloy and upon the quality of the welds produced, both when the material had been treated in the normal manner and when it was untreated prior to welding.

This work was conducted at the Rensselaer Polytechnic Institute under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

EQUIPMENT

This investigation was performed with a Thomson-Gibb, 200-kilovolt-ampere, press-type spot welder using a combination of a General Electric A-125 Thyratron control panel, an F-149 sequence timer, and an F-121 temper control. The power supply to the welding machine was obtained from a 350-kilovolt-ampere, single-phase generator driven by a 4000-volt, three-phase synchronous motor.

For preheating, the current program was obtained by first setting the magnitude and the time of preheat current on the A-125 panel. The time between the end of preheating and welding (4 cycles min.) and the total elapsed time for the program were set on the F-149 sequence timer. The time and the magnitude of the welding current were set on the F-121 temper control. An automatic current compensator which is normally used with this equipment was disconnected for these tests since the short welding times employed did not permit the compensator to act consistently.

The current program for postheating was obtained by first setting the magnitude and the time of welding current on the A-125 panel. The F-149 sequence panel performed the same function as in preheating - namely, to control the interval between welding and postheating and the total elapsed time for the program. The F-121 temper control was used to obtain the proper magnitude and time of flow of postheating current. With this equipment the maximum time available for preheating was 30 cycles and for postheating, 90 cycles.

In order to obtain welds with effectively no preheating, it was necessary to set the controls on the A-125 panel at the lowest possible phase setting and for 1 cycle of time. This condition arose from the impossibility of operating the other control equipment without operating the A-125 panel. The procedure which was adopted eliminated the necessity for relying on a calibration of the phase-control rheostat settings on the A-125 and F-121 panels as a function of welding current. Such would have been required if it had been considered essential to obtain welds with absolutely no preheating, yet with exactly the same welding current as that used for the welds in the preheat series. A calibration of this sort would have been somewhat unreliable since experience showed that, from day to day, different welding currents were obtained at the same rheostat settings.

The foregoing situation did not arise with postheating since it was possible to operate the A-125 panel independently of the temper and sequence controls. Therefore, welds with no postheat could be obtained merely by making the temper and sequence controls inoperative.

PROCEDURE AND RESULTS

Preheating

In this part of the investigation all welds were made with a constant electrode force of 800 pounds, using 4-inch-radius dome-shape electrodes. The current-time program was set to give 30 cycles of preheat with 4 cycles off-time, followed by 4 cycles of welding current. Chemical treatment prior to spot welding for the treated specimens was performed with a solution of hydrofluosilicic acid (3 percent by volume of concentrated acid plus 0.1 percent by weight of Nacconol NR wetting agent) followed by rinsing in cold water and drying in air (reference 2).

The effects of preheating upon the strength and the quality of spot welds in chemically treated 0.040-inch Alclad 24S-T are shown in figure 1. Each curve was obtained by making a series of welds, holding the welding current constant and varying the preheat current. Curves were obtained for various values of welding current, which produced welds of three different sizes. Figure 1 shows that the weld strength decreased with increasing preheat current, reaching a minimum value with a preheat current of 65 to 75 percent of the welding current. With further increases in preheat current the shear strength increased to approximately the original value or, in some cases, to a slightly higher value. This analysis shows that the employment of intermediate values of preheat current was definitely dangerous. An explanation for this is that the preheating lowered the sheet-to-sheet resistance and rendered the welding current ineffective in producing welds of adequate size. From the curves in figure 1 it is apparent that with high values of preheat current (90 percent of the welding current) cracks in the welds were eliminated, and in some cases the strength was improved. The explanation for this is that probably under these conditions the high values of preheating current were sufficient to produce a considerable portion of the total fused zone. By virtue of the long preheat time, the low weld force was effective in eliminating the shrinkage cracks. Then the application of the welding current later caused only actual remelting and some additional fusion. The amount of improvement in weld strength was greater for the small welds than for those of intermediate size. With the large welds (735 lb shear strength) a preheat current resulted in welds of lower strength than those made with 4 cycles of welding current alone. This phase of the investigation led to the conclusion that, with properly prepared surfaces, preheating was effective in improving weld quality when the magnitude of the preheating current was sufficiently high.

Tests were conducted to determine the effects of preheating untreated stock in an effort to improve its weldability. Alclad 24S-T sheet as received from the mill is covered with a natural oxide film, and the sheet-to-sheet contact resistance of this material is invariably high and inconsistent. This oxide film results in the production of welds of poor appearance and considerably reduces the electrode-tip life. In order to improve the weldability of such material, one of several methods of surface preparation prior to spot welding is employed. The object of the surface preparation is to produce a low, consistent contact resistance.

It was considered a possibility that the passage of current of insufficient magnitude to melt the faying surfaces might render the initial high, inconsistent surface resistance less effective in determining weld quality. This was the purpose in studying the preheating of untreated Alclad 24S-T material.

The strength-current characteristic presented in figure 2 shows the results of this study This curve reveals no improvement in weld quality from the standpoint of elimination of cracks, porosity, and expulsion until the preheat-current magnitude reached approximately 80 percent of the value of the welding current. A preheat current of this value was sufficient to cause some melting at the faying surfaces, yet was not completely effective in eliminating expulsion. It was thought that a further increase in the magnitude of the preheating current would have increased the expulsion rather than eliminated it. This tendency was observed in two of the welds made with a preheat current which was 80 percent of the welding current, slight surface flashing having occurred during the passage of the preheat current. These results indicated that the application of a preheating cycle for the purpose of improving the spot weldability of untreated Alclad 24S-T would be somewhat critical. This condition may be explained by the fact that the preheat current would have to be of sufficient magnitude to lower the initial contact resistance in order to avoid expulsion during welding yet must not be so high as to cause expulsion itself. A preheat-current magnitude ranging from 70 to 75 percent of the welding current should produce the desired results.

Postheating

A constant electrode force of 800 pounds, in conjunction with 4-inch-radius dome-shape electrodes, was also employed for this phase of the investigation. The chemical method of surface preparation prior to spot welding was identical to that used for the studies of preheating.

The initial work in this study of postheating was performed with a current-time program producing a 4-cycle weld, a 4-cycle off-time, and a 90-cycle postheat The results of this work are graphically presented in figure 3. The curves show the effect of variations in the magnitude of postheating current for four different sizes of weld. From these curves it is apparent that the intermediate values of postheat current had erratic effects on the weld strength, in some cases causing a decrease in strength and in others an increase compared with the values obtained with no postheat. These intermediate values of postheat current also were not observed to improve the weld quality. With postheat currents higher in magnitude than the welding currents, improvement in weld strength and quality was noted in all cases. The improvement in strength was due to remelting of the welds with the consequent production of larger fused zones. The great duration of the postheat current permitted the weld and the surrounding metal to remain in a plastic condition long enough for the 800-pound electrode force to be effective in removing shrinkage cracks.

Since the results of the preceding tests indicated that the soaking effect of the long postheat improved the weld quality, it was decided to investigate the effects of postheating spot welds made with a longer weld time. The current-time program was such as to produce a 10-cycle weld, a 4-cycle off-time, and a 15-cycle postheat. The magnitude of the welding current was 23,200 amperes, with an electrode force of 800 pounds, and this produced, without postheating, sound welds having an average shear strength of 543 pounds. The application of the postheat, varying in magnitude from 4600 to 25,000 amperes, did not affect the weld quality, which was already excellent because of the longer weld time. On the basis of three welds made at each value of postheat current, the postheating reduced the average weld strength by 10 to 15 percent. Series of 10 welds each made with and without postheating, however, for strength-consistency analysis showed an improvement in strength of 4 percent due to postheating with 17,600 amperes. The coefficient of variation (reference 3) for postheated welds was 6.2 percent as compared with a value of 7.3 percent for the welds made without postheat. This indicates a slight improvement in consistency by postheating.

The results of these tests on the effects of postheating spot welds in Alclad 24S-T indicate that, under certain conditions, weld quality and strength may be improved by the application of postheating. This improvement is effected in cracked welds made with too short a weld time by high magnitudes of postheating current of long duration which produce remelting and a slow cooling rate in the fused zone. Postheating of spot welds which are internally sound as a result of a long weld time has little or no beneficial effect on the strength, but may slightly improve the strength consistency.

Alternating-Current Welding without Preheat or Postheat

Since the study of postheating had demonstrated that the selection of the weld time had a pronounced effect on the practicability of employing postheating in alternating-current spot welding, it was decided to investigate this variable further. The first step was to produce welds at various magnitudes of current, using an extremely long weld time, that is, 90 cycles. This procedure was adopted in order to determine whether such conditions could produce results comparable with those obtained in welding followed by high magnitudes of postheat current for a long period of time.

The results of this work are graphically presented in figure 4. From the symbols on this curve it is to be noted that all the welds were radiographically sound. Also, a very high value of current resulted in strengths equal to those of highest value produced by postheating. These results definitely indicated that weld quality could be improved by using a longer weld time and that it was possible to produce very large sound welds in this material even with a relatively low value of electrode force if the weld time were sufficiently long. Increasing the weld time is a much simpler method of improving weld quality than is the application of a postheat following a short-time weld.

In an effort to obtain some quantitative information on the effect of the weld time on the weld quality for a weld of given size, tests were made with a constant value of welding current (23,200 amperes) and with weld times ranging from 4 to 30 cycles. With a weld time of 4 cycles the average shear strength of the welds was 460 pounds, and all the welds showed internal cracks under radiographic examination. With a weld time of 5 cycles, the average shear strength had increased to 533 pounds; yet only two out of eight welds showed internal cracks. Increasing the weld time to 10 cycles completely eliminated the internal cracking in welds having an average strength of 517 pounds. Further increase in the weld time, from 10 to 30 cycles, had no appreciable effect on the weld strength, and all the welds were sound.

These tests indicated that a weld time of 10 cycles with an electrode force of 800 pounds was sufficient to produce crack-free welds averaging slightly greater then 500 pounds in shear strength. The previous tests showed that sound welds approaching 800 pounds in shear strength could be produced with a weld time of 90 cycles. Such a long weld time was, without doubt, unnecessary for the elimination of cracks in these large welds, but the minimum value would be expected to be somewhat greater than for smaller welds.

The practical significance of the work on postheating with regard to improving weld quality in alternating-current welds is that, before attempting to use complicated equipment for postheating, it would be better to investigate thoroughly, yet within reasonable limits, the effects of both electrode force and weld time on weld quality. The fact that there is a possibility of improving weld quality merely by increasing the weld time should also, in many cases, obviate the necessity for employing a forging pressure in alternating-current spot welding.

CONCLUSIONS

As a result of the investigation to determine the effects of preheating and postheating on the quality and the strength of spot welds in aluminum alloys, the following conclusions may be drawn:

1. In alternating-current spot welding of aluminum alloys the weld time is very important with regard to the quality of weld produced.

2. For a given weld size, too short a weld time, in conjunction with a low electrode force, resulted in the occurrence of internal cracks in the welds. Increasing the weld time eliminated these cracks. The minimum weld time required for complete elimination of internal cracks probably is a function of the weld size.

3. With properly prepared surfaces, preheating produced some improvement in weld quality when the preheat current was sufficiently high in magnitude and of long duration. The employment of intermediate values of preheat current was definitely dangerous. This was believed to be due to a lowering of the sheet-to-sheet resistance which rendered the welding current ineffective in producing welds of adequate size.

4. High values of preheat current tended to eliminate expulsion and surface flashing usually associated with spot-welding untreated Alclad 24S-T. The application of preheating for improving spot weldability, however, may be quite critical. Too low a value of preheat current may either fail to eliminate expulsion or seriously reduce the weld strength. Too high a value of preheat current may, of itself, cause expulsion rather than eliminate it.

5. Postheating currents of lower magnitude than the welding current had no effect on the weld size or quality.

6. Postheating currents higher in magnitude than the welding current and of long duration improved both weld shear strength and quality, in cases for which the welds exhibited internal cracking without the application of postheating.

7. The improvement in weld strength and quality effected by postheating was no greater than that which could be brought about merely by increasing the weld time and the welding current.

8. From the standpoint of producing welds of excellent quality in Alclad 24S-T, the weld time is one of the most important variables in the alternating-current spot-welding process. By exercising proper control over this variable it was possible to produce large welds of excellent quality in 0.040-inch Alclad 24S-T with a relatively low electrode force for welding and without the application of forging.

Welding Laboratory
Rensselaer Polytechnic Institute
Troy, N. Y., June 25, 1946

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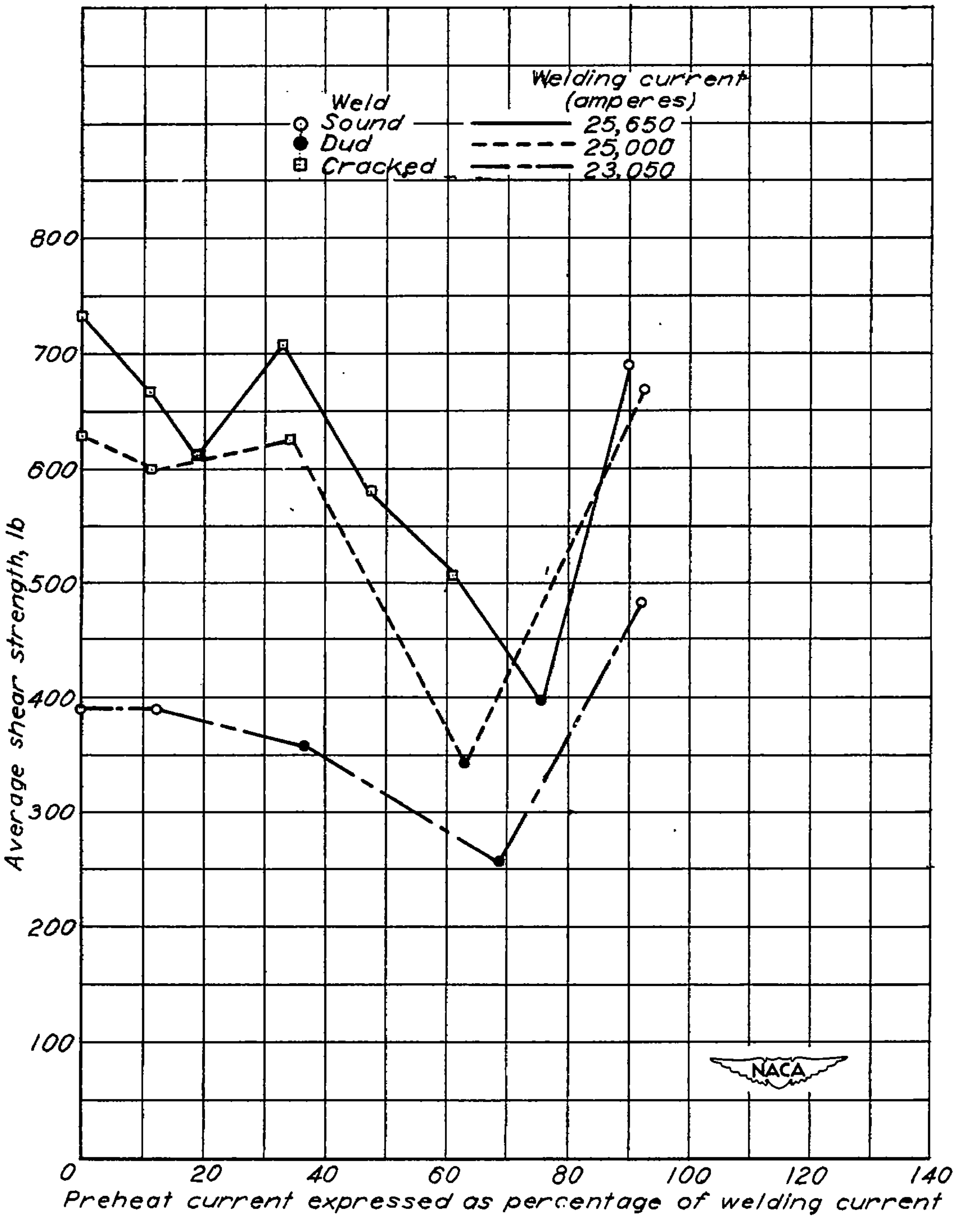

Figure 1.- Effects of preheating chemically treated 0.040-inch Alclad 24S-T. Electrode-dome-tip radius, 4 inches; electrode force, 800 pounds; preheat time, 30 cycles; off-time, 4 cycles; weld time, 4 cycles.

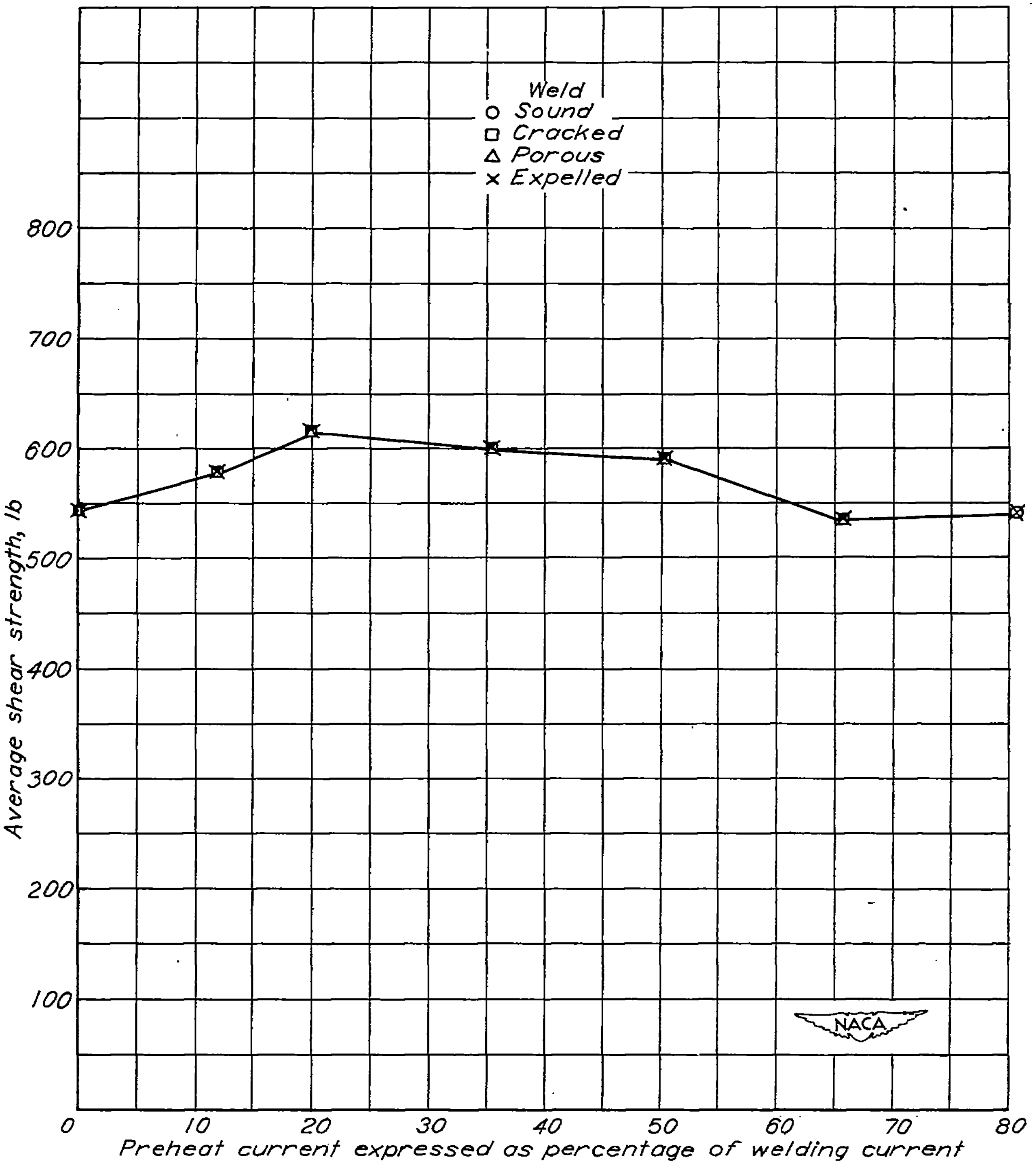

Figure 2.- Effects of preheating untreated 0.040-inch Alclad 24S-T. Electrode-dome-tip radius, 4 inches; electrode force, 800 pounds; welding current, 24,100 amperes; preheat time, 30 cycles; off-time, 4 cycles; weld time, 4 cycles.

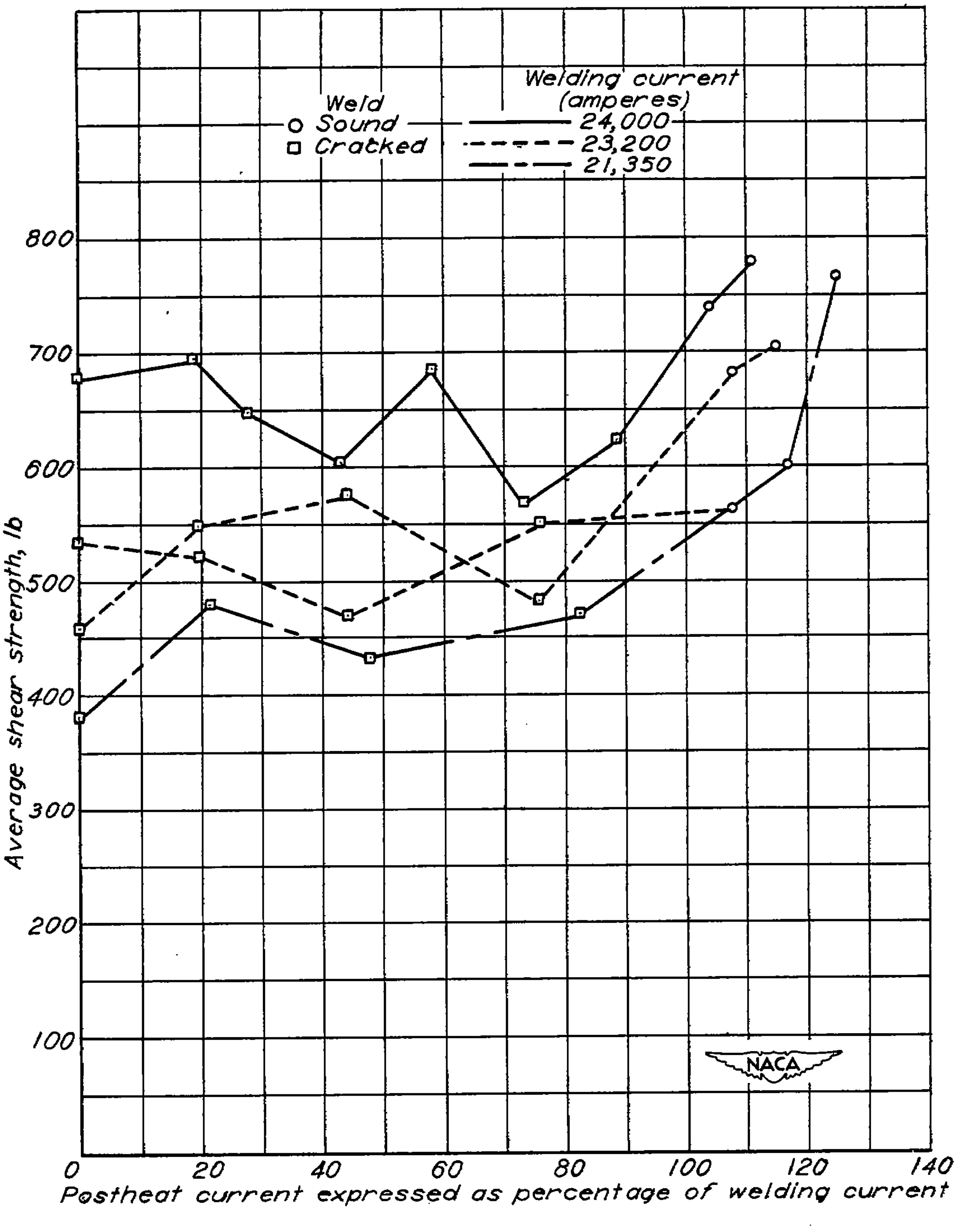

Figure 3.- Effects of postheating chemically treated 0.040-inch Alclad 24S-T. Electrode-dome-tip radius, 4 inches; electrode force, 800 pounds; weld time, 4 cycles; off-time, 4 cycles; postheat time, 90 cycles.

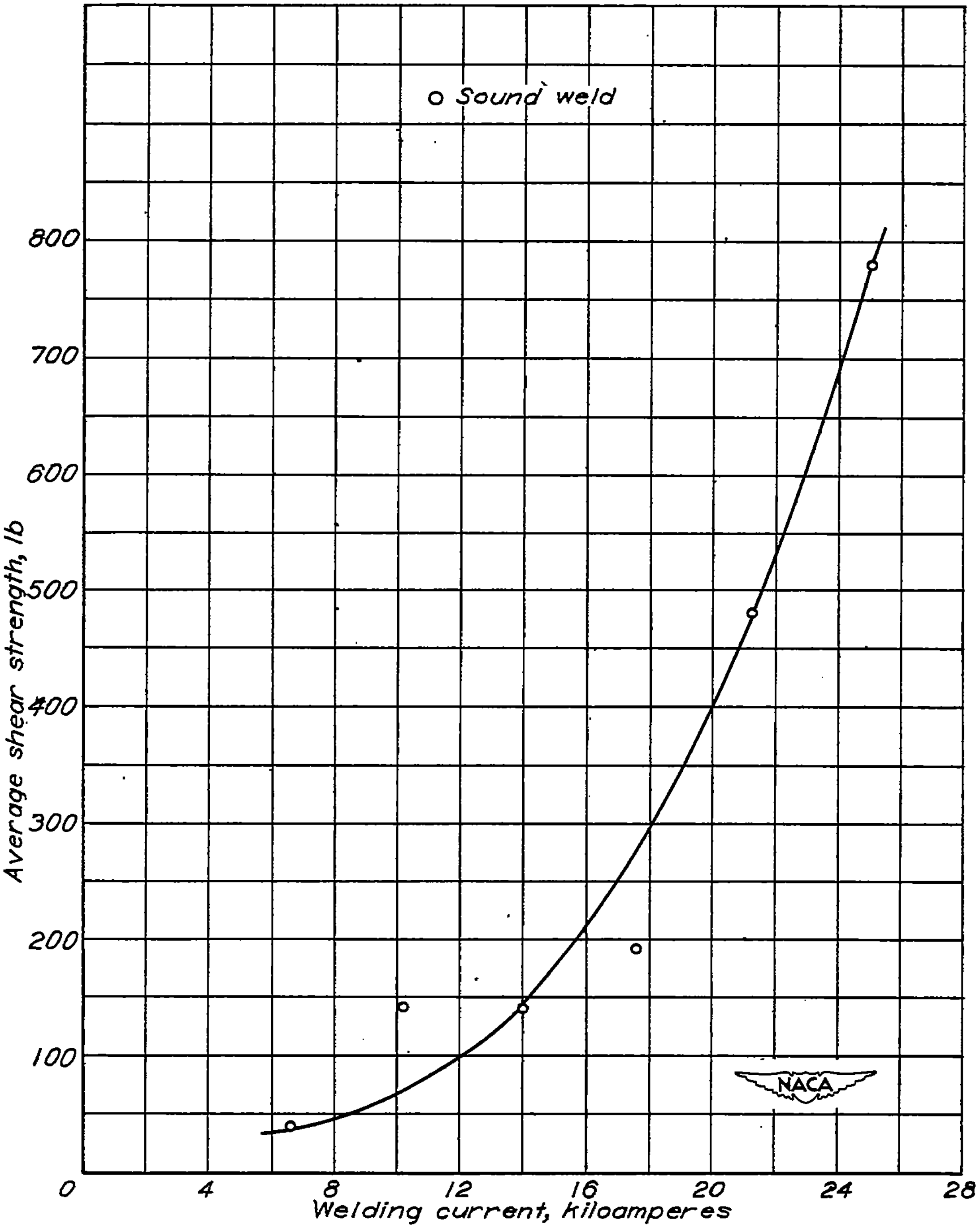

Figure 4.- Strength-current characteristics for alternating-current spot welds in chemically treated 0.040-inch Alclad 24S-T. Electrode-dome-tip radius, 4 inches; electrode force, 800 pounds; weld time, 90 cycles.