N 73 27866

NASA TM X-68257

NASA TECHNICAL MEMORANDUM

NASA TM X-68257

THE RESTORATION OF OBLITERATED STAMPED SERIAL NUMBERS BY ULTRASONICALLY INDUCED CAVITATION IN WATER

by Stanley G. Young
Lewis Research Center
Cleveland, Ohio

TECHNICAL PAPER proposed for presentation at
Twenty-ninth Semiannual Seminar of the
California Association of Criminalists
Palo Alto, California, October 17-19, 1973

ABSTRACT

Seventeen out of 21 obliterated stamped serial numbers on test specimens of copper, brass, steel, and aluminum were successfully restored. Cavitation induced in water by a piezoelectric transducer was the mechanism used. Primarily, smeared metal was removed from the number grooves by the force of the cavitation, however, numbers were also restored at depths at or below the level of the stamped grooves. The feasibility of this technique as a low cost tool for crime laboratories has been clearly demonstrated. The technique is applicable to a variety of materials, and no previous surface or chemical treatments are necessary.

E-7534

THE RESTORATION OF OBLITERATED STAMPED SERIAL NUMBERS BY ULTRASONICALLY INDUCED CAVITATION IN WATER

by Stanley G. Young

Lewis Research Center

SUMMARY

The identification characters, SRI 8368, were stamped on specimens of copper, brass, steel, and aluminum, and then partially obliterated by grinding at the Stanford Research Institute. These specimens were then submitted to the NASA Lewis Research Center for studies of the effects of a new restoration technique. The restoration mechanism was cavitation in water induced by the ultrasonic vibration of a piezoelectric transducer. All the stamped numbers and letters were completely or partially restored on specimens of copper, brass, and steel. Two out of five of the original numbers were restored on aluminum. (The aluminum specimen was originally used for optimizing variables in the restoration process. These variables were separation distance between specimen and vibrator, vibrator power, amplitude, and test time. Temperature and frequency were held constant.) On the copper specimen smeared metal was removed from the number grooves by cavitation. On brass all the numbers appeared in the form of a light-reflecting haze that was slightly brighter than the cavitation damaged background. This was unexpected because the measured depth of grinding was deepest in this specimen - about the same as the depth of the stamped numbers. In steel smeared metal was removed from the number grooves; however, one deeply ground number was restored in a manner similar to the numbers on the brass specimen. In aluminum, letters outside the region being attacked by concentrated cavitation were restored, but not those within the region, indicating that the first attempts of number restoration on this specimen were too severe. After standardized conditions were established, seven new numbers were

stamped on the aluminum, obliterated by grinding, and restored by this technique. Again, smeared metal was removed from the number grooves.

The important conclusion herein, is that the feasibility of this restoration technique has been clearly demonstrated. The method is recommended for use in crime laboratories as a relatively low cost technique that can restore serial numbers on most materials with the minimum of preliminary surface preparation.

INTRODUCTION

Serial numbers on stolen property or guns are often removed by filing or grinding. On recovered property, it is necessary to restore the numbers sufficiently so that they may be read or photographed before they can serve as evidence. In recent years, aluminum and metals other than iron and steel have been increasingly used for vehicles, tools, firearms, etc. (ref. 1). A number of restoration methods exist for each of these types of metals, but they involve chemical (ref. 2), magnetic, dye penetrant, or heat treatment methods. Also, each method is usually unique for the type of metal being examined, and many of these methods allow the numbers to show up only temporarily, with great skill being required to gain the needed photographic evidence. Furthermore, the specimen usually requires a series of mechanical and chemical treatments such as grinding, polishing, and etching, before the numbers can be seen. These treatments all run the risk of losing any residual traces of the numbers due to the restoration technique itself.

A new low cost method has been proposed (ref. 3) which appears to have universal application for serial number restoration on all materials; and which requires no prior surface treatment before the restoration process begins. The technique is based upon the method of ultrasonic etching of metal, accomplished at the NASA Lewis Research Center, reported in Tech Brief 71-10099 (ref. 4). The apparatus, variables, and results of ultrasonic etching, in which cavitation is the etching mechanism, are described in reference 5. Briefly, a magnetostrictive transducer is used to generate ultrasonic vibrations, which are transmitted through a layer of water to the metal specimen. Cavitation bubbles in the ultrasonically excited water produce preferential etching of metal phases or grain boundaries, depending on the relative material properties. This effect was examined in the previous work on a microscopic basis, but had not been studied on a macroscopic basis at magnifications low enough to include stamped serial numbers.

The objective of this work was, therefore, to investigate the utility of the ultrasonic etching technique as a valid, low cost laboratory tool for crime laboratories, capable of restoring obliterated serial numbers on a variety of metallic materials with minimum surface preparation.

This paper reports the results of ultrasonically induced cavitation applied to obliterated serial numbers on copper, brass, steel, and aluminum. The samples were first stamped with letters and numbers, and then the identification numbers were totally or partially obliterated by grinding at the Stanford Research Institute. The effect of cavitation test variables such as temperature, specimen-vibrator separation distance, and ultrasonic power, amplitude and frequency are discussed and optimum test conditions are established where possible.

MATERIALS, APPARATUS, AND PROCEDURE

Materials

Specimens of 99.9 percent copper (Rockwell hardness RB-39), yellow brass (RB-63), low carbon steel (RB-93), and 99.8 percent aluminum (RB-66) were stamped by the Stanford Research Institute (SRI) with the numbers and letters shown in the photomacrograph of figure 1. Each specimen was stamped with the letters and numbers S, R, I, 8, 3, 6, and 8; and an additional specimen number was also stamped on each. The top specimen in figure 1 is copper (1), then brass (2), next steel (3); and aluminum (4) is at the bottom. Some of the numbers and letters were ground off using a grinding wheel, in a manner typical of unauthorized serial number removal on stolen property. The specimens were submitted to NASA by SRI in the condition shown in figure 2. The numbers and letters S, R, 8, 3, 6, and 8 were ground off the copper; 8, 3, 6, and 8 were ground off the brass; S, R, 8, 6, and 8 were ground off the steel; and S, R, 8, 6, and 8 from the aluminum - a total of 21 obliterated numbers and letters.

Apparatus

A schematic drawing of the apparatus used for the serial number restoration process is shown in figure 3. It consists of a piezoelectric transducer assembly driven by a power supply, which converts 60 Hz electrical energy to 20 000 Hz electric energy. Cavitation bubbles are induced in water at the tip of the transducer and the force of the collapsing bubbles is directed to the specimen immersed in the water directly below the vibration head. The bubbles attack weaker portions of the specimen and, in this instance, removed smeared metal from the grooves of the stamped serial numbers on copper, steel, and aluminum. The apparatus shown here was purchased for a total cost of approximately $1500. A positioning table or holder of some type should be added to any standard laboratory set up. A magnetostrictive transducer was used in the work of reference 3 instead of the piezoelectric type used in the present study. The piezoelectric transducer used here was more efficient, gave a higher vibration amplitude, and was less expensive.

Test Conditions

The aluminum specimen was used to determine the effect of separation distance and ultrasonic power on the damage pattern. These two conditions were varied on the as-received specimen and also on the specimen after it was polished. Short bursts of cavitation attack (from 1 to 30 sec) were applied with separation distances varying from 0.5 to 1 mm and power varying from one-third to full. The conditions giving the most uniform haze were observed to be 1 mm at full power (150 W to the transducer). The damage patterns resulting from these optimized test conditions are the haze areas mostly on the left half of the specimen, shown in figure 4. These conditions were held constant for all of the other materials. The vibration frequency was 20 000 Hz and amplitude was about 0.1 mm. Tap water was used as the cavitation media. The temperature was held to approximately 20° C ($\pm 2^{\circ}$ C). A detailed study of test conditions and the resulting amounts and types of damage can be found in reference 5.

Procedure

The as-received specimens were examined very closely by low power binocular microscope; and visible traces of the numbers or letters were recorded. Low magnification (×1 to ×2) photomacrographs were made of each specimen and ×10 to ×20 photomacrographs were made of individual portions of the specimens before ultrasonic treatment. The specimens were then placed in the water bath, temperature was adjusted and the transducer was operated for various time increments. After each increment, the specimens were removed, visually examined and photographed using various methods of lighting. Some specimens were examined by scanning electron microscope at approximately ×30 and higher to record depth effects and mechanisms of material removal.

RESULTS AND DISCUSSION

The photomacrographs of the specimens of copper, brass, steel, and aluminum are shown at various magnifications in figures 5 to 18.

Copper

Figure 5 shows ×1 photomacrographs of the copper specimen. Observations of this specimen before the restoration process indicated that grinding was not too deep; however, all letters and numbers except the I had been obliterated beyond immediate visual recognition. In very short times (3 to 5 min) some of the numbers were recognizable and in 20 minutes all the obliterated numbers and letters were restored enough to be recognized. The numbers and letters are more easily seen in figure 6 at ×2 and figure 7 at ×6. Various methods of oblique lighting helped to highlight the numbers and letters.

In figure 7 the number 3 that was restored after 5 minutes is starting to be obliterated by the cavitation attack (see the pitted region on the 20-minute photomacrograph of fig. 7). For this reason care must be taken to start the restoration process in very small time increments at first, so as not to destroy the numbers and letters restored in the early phases of the test. On this specimen and on some of the other materials, penciled circles were drawn around suspected locations of numbers, and these show up on some of the 0 minute photomacrographs (white circles on fig. 7 - 0 min). These pencil markings were automatically removed during the first few seconds of cavitation attack.

In order to clearly show the mechanism of material removal, Scanning Electron Microscope (SEM) photomicrographs were made of the number 8 shown on the lower right of the photomacrographs of figure 7. These photomicrographs are shown in figure 8. At 3 minutes most of the smeared metal was still in the grooves; however, cavitation had partially loosened some of the metal, so that the outline of the 8 was discernible from the surrounding metal. At 5 minutes, large chunks of the metal were removed and at 10 minutes nearly all the smeared metal was removed. At 20 minutes, the remaining metal was removed; but areas where metal was removed earlier were starting to show severe pitting from the cavitation attack.

Brass

Photomacrographs of the brass specimen at ×1 are shown in figure 9. The numbers 8, 3, 6, and 8 were removed. This specimen was ground more deeply than the others - approximately to the bottom of the stamped notches. The measured depth of grinding was as deep as 0.40 mm while the stamped letters and numbers averaged depths of only approximately 0.37 mm. It was therefore surprising when numbers reappeared in this specimen. From the ×1 photomacrographs at longer times in figure 9 and the ×5 photomacrographs in figure 10, all the numbers have been completely restored and show up in the form of a light haze on a darker background. Under low power binocular observations, the regions of the numbers appeared more reflective in spots than the cavitation damaged background, but higher magnification microscope examinations did not detect observable differences between the two types of surfaces. Further work would be needed to discover the exact mechanism of restoration in this case. But it probably involved differences in attack due to work hardening at the notches of the stamped letters and numbers. Nevertheless, this work indicates that restoration by the ultrasonic technique can be successful even though the numbers have been removed to depths at, or slightly below, the bottom of the stamped numbers.

Steel

In steel the letters and numbers S, R, 8, 3, 6, and 8 were originally removed. The ground surface was quite irregular. The restoration process in steel was a combination of the mechanisms of number restoration in copper and brass. Some numbers were restored by smeared metal removal, while another number, which had been ground more deeply, was restored by the appearance of a light haze. Figure 11 shows ×1 photomacrographs of the steel specimen at times out to 120 minutes. Most of the numbers and letters are readable. At 0 minutes, the circles and numbers shown are pencil indications of areas of interest. These markings, as mentioned before, were quickly removed by the cavitation at the start of testing.

Many different types of lighting were used to try to show up the letters and numbers. Figure 12 shows the restored letters and numbers S, R, 8, and 3 at times from 0 to 70 minutes. The letters and numbers are highlighted by oblique light to show up light on a darker background. In figure 13, at the same magnification, the letters are dark on a lighter background. This was caused by using a sharper oblique lighting angle and rotation of the specimen to allow light reflection from the original grinding marks. Both methods, however, show up the letters quite clearly. Smeared metal was removed from the grooves of the stamped numbers and letters.

Figure 14 shows the partially restored numbers 6 and 8 at ×8, at times to 70 minutes. Because these numbers were not clearly visible, when all other numbers were obvious, much longer test times were allowed over this specific region of the specimen. Figure 15 shows the results on the steel specimen at the end of the test. Attack was discontinued on the region of the S, R, 8, and 3 after 120 minutes, but the test was continued to 220 minutes over the region containing the 6 and 8. From the bottom photomacrograph of figure 15 at ×6, the 6 can now be seen almost in entirety as a light haze. The 8 is still only partially visible, but better than before.

A SEM study was made on the number 3 of the steel specimen and the photomicrographs from this study are shown in figure 16. Magnification range is from ×30 to ×9000. At the high magnification, the steel has a very jagged, torn appearance as a result of the cavitation attack, indicating that even in steel, cavitation is starting to attack the surface of the restored number after long test times.

Aluminum

In the aluminum specimen the S, R, 8, 6, and 8 had been removed. This was the only material for which all of the original obliterated numbers were not at least partially restored. Several reasons may account for this lack of number restoration. First, the aluminum was used as a preliminary test specimen to determine effects of test variables on cavitation damage results. Second, the aluminum base metal may have been attacked as easily as the smeared aluminum. Initial attack was too severe, and slight differences between smeared metal and base metal were masked. The letters S and R however, were restored, but they were just outside of the region of high intensity cavitation attack. Photographs describing restoration methods and results for the aluminum specimen are shown in figure 17. Figures 17(a) and (b) show ×1 photomacrographs of the aluminum at 1 and 5 minutes. Separation distances ranged from 0.5 to 3 mm. At 5 minutes the S and part of the R are visible and, if the viewer has a good imagination, he can see part of the last 8, although this was not counted as part of the successful restoration. Once optimum conditions had been established, new numbers and letters were stamped on the aluminum specimen and ground off by NASA. Six of the seven numbers and letters were entirely restored by the mechanism of smeared metal being removed from the grooves by cavitation (see fig. 18). The N which had been ground most deeply was partially restored. It is believed that the regions beneath the stamped numbers of this originally hard aluminum were not affected by the stamping as were those areas of the brass and steel.

In general, the method described in this paper, of restoring obliterated serial numbers without initial metallographic grinding or polishing, has been very successful. Further work would be useful to more completely understand the potential and applicability of this method to serial number restoration, particularly in determining the effective depth of restoration.

SUMMARY OF RESULTS

The identification characters, SRI 8368 plus a specimen number (1, 2, 3, or 4), were stamped on copper, brass, steel, and aluminum and then partially obliterated by grinding at the Stanford Research Institute. The obliterated serial numbers and letters were completely or partially restored at the NASA Lewis Research Center by cavitation induced by ultrasonic vibration in water. Seventeen out of 21 obliterated numbers or letters were permanently restored.

1. On copper, all the obliterated letters and numbers S, R, 8, 3, 6, and 8 were restored. Smeared metal was removed from the letter and number grooves by the cavitation.

2. On brass, the obliterated numbers 8, 3, 6, and 8, after cavitation exposure, all appeared in the form of a light haze, which was observed in flat light more easily than in oblique light. This result was unexpected because the grinding was deepest in this specimen. (Measured depth of grinding was about the same as the depth of the stamped numbers.) An ability to detect disturbed metal below the stamped numbers and letters is indicated here.

3. On steel, the letters and numbers S, R, 8, and 3 were completely restored and the 6 and 8 were partially restored. As in the case of copper, smeared metal removed from the grooves was the primary mechanism. After longer exposure times the partially restored number 6 was observed in the same manner as were the numbers on the brass specimen.

4. The restoration process on aluminum was a partial success. The original letters S and R were restored but numbers 8, 6, and 8 were not. This material was the first tested, and was used to establish optimum test conditions for the other materials. It is believed that the

initial cavitation conditions used for this material were too severe, and that the residual differences between the grooves and smeared metal were rapidly removed by the cavitation before photographic records were made. Later, new numbers and letters were stamped on the aluminum, obliterated by grinding, and restored using the previously established optimum test conditions.

CONCLUDING REMARKS

The high degree of success achieved in the restoration of stamped numbers and letters demonstrates the feasibility of this technique as a useful crime laboratory tool. This restoration technique has major advantages over chemical or magnetic methods because no prior surface treatment, such as grinding and polishing, is necessary, and it appears to be applicable to a variety of materials. Also, while only temporary restoration is possible with many of the other methods, this method provides permanent restoration of the numbers.

The metals, with the exception of brass, were not ground too deeply. Thus, this method was found to be a type of very high intensity "ultrasonic cleaning" method which removed smeared metal from the grooves of stamped letters and numbers, leaving the stamped surfaces relatively undamaged. However, another mechanism may be operating when the grinding is deeper. The brass specimen and part of the steel specimen were ground to depths approximately equal to the depth of the original stamped numbers. Yet, after cavitation attack, the numbers appeared quite clearly as a lighter haze on the darker background. Low magnification showed brighter surfaces in the number regions than observed in the surrounding material. It appeared that the deformed metal beneath the numbers was damaged in a manner different from the surrounding metal. The difference in damage was probably due to work hardening at the notches of the stamped letters and numbers. Further study of the effect of the restoration technique at depths below the number is recommended.

This serial number restoration technique appears to work on a diversity of materials, and it is dependent on differences in the materials due to the mechanical deformation involved in the stamping process. Therefore, it is suggested that stamping be considered in preference to other methods of applying numbers during the manufacturing process. The numbers would then be more permanent because it is extremely difficult to remove all residual traces of them.

REFERENCES

1. Chisum, W. J.: A Catalytic Process for Restoration of Serial Numbers on Aluminum. J. Forensic Soc., vol. 6, no. 2, Apr. 1966, p. 86.
2. Mathews, J. Howard: Firearms Identification: The Laboratory Examination of Small Arms. Rifling Characteristics in Handguns and Notes on Automatic Pistols. Vol. 1. C. C. Thomas, 1962.
3. Chisum, W. Jerry; and Parker, Brian: Potential Application Report, Problem SRI/C-30, Obliterated Serial Number Restoration, Apr. 27, 1972.
4. Young, S. G.: Ultrasonic Metal Etching for Metallographic Analysis. NASA Tech Brief 71-10099, 1971.
5. Young, Stanley G.: Etching of Metallographic Specimens by Cavitation. Proceedings of the Third Annual Technical Meeting of the International Metallographic Society, 1971, pp. 167-185.

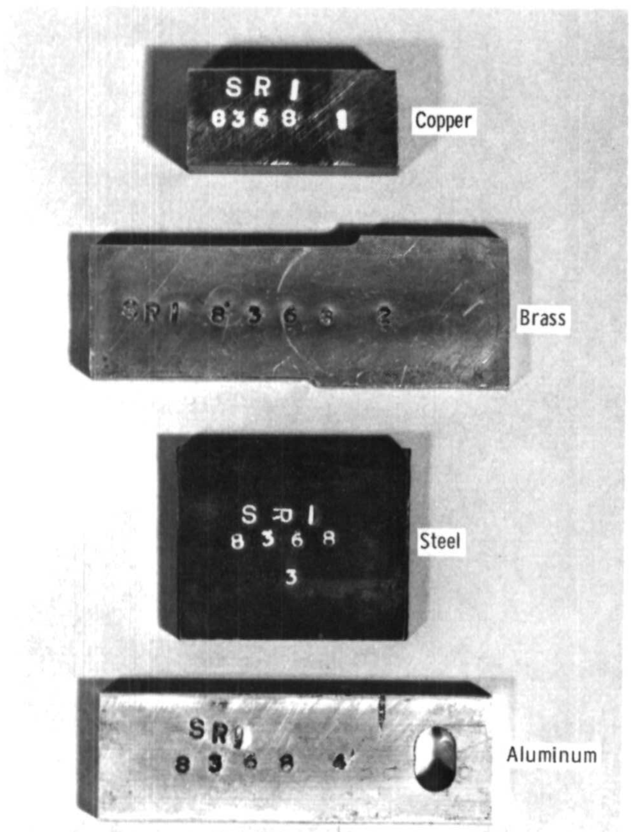


Figure 1. - Photograph of specimens of copper, brass, steel, and aluminum with serial numbers stamped by the Stanford Research Institute.

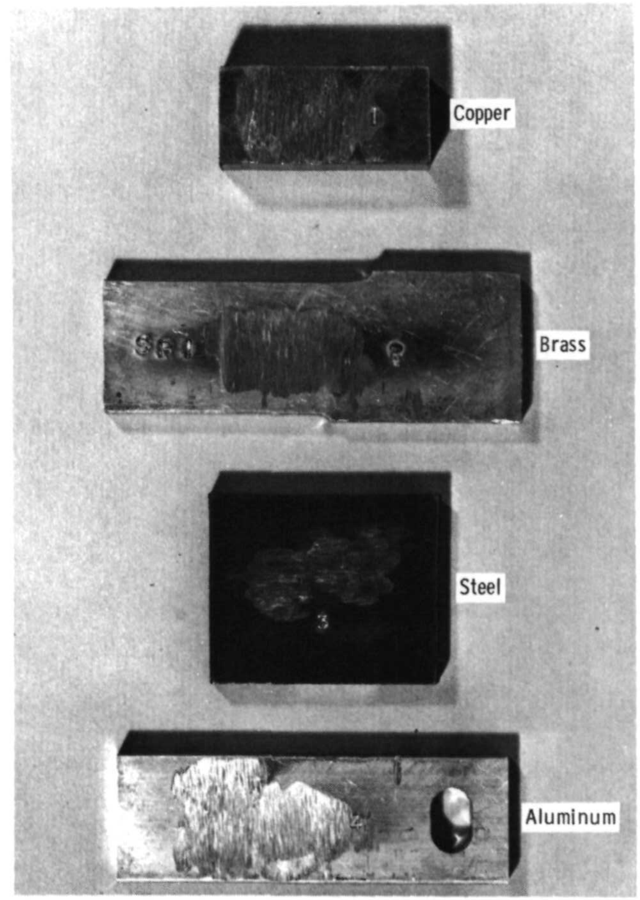


Figure 2. - Photograph of specimens of copper, brass, steel, and aluminum with serial numbers ground off by the Stanford Research Institute (as furnished to NASA.)

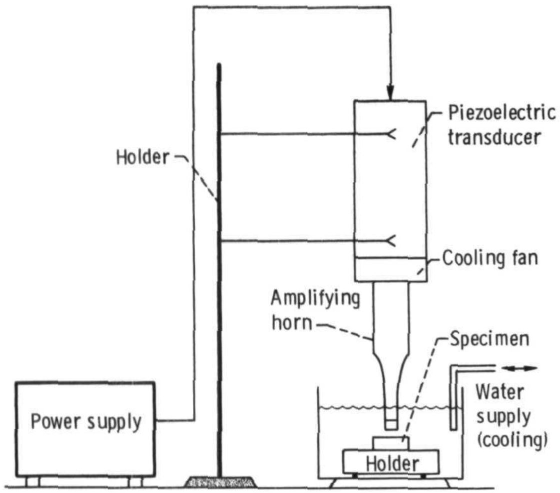


Figure 3. - Schematic diagram of test apparatus used to restore serial numbers by ultrasonically induced cavitation.

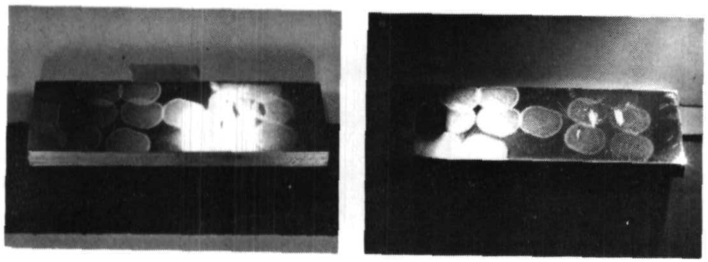


Figure 4. - Polished specimen showing cavitation damage haze patterns caused by exposures from 1 to 30 seconds at varying separation distances (two photos of same specimen at different light angles).

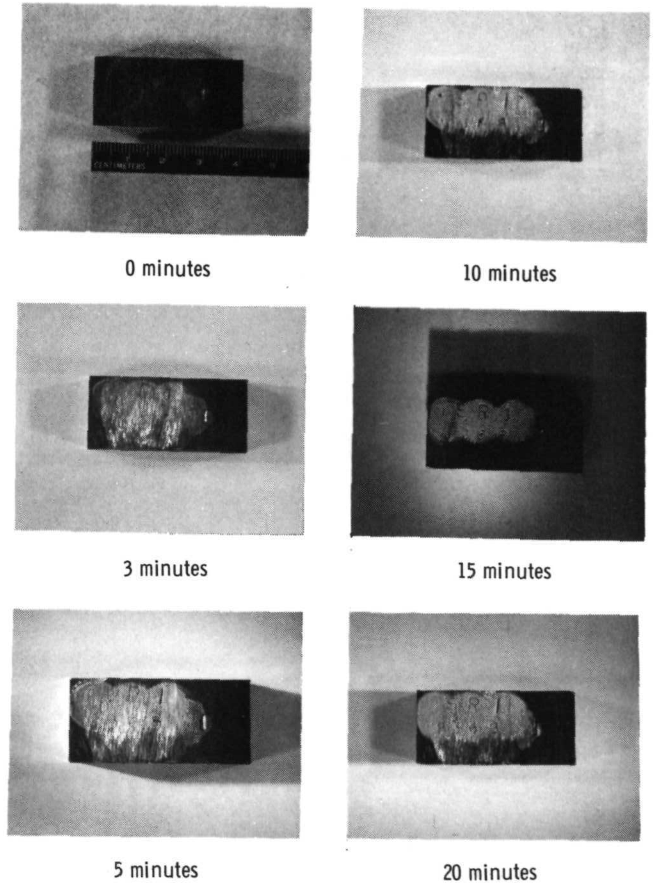
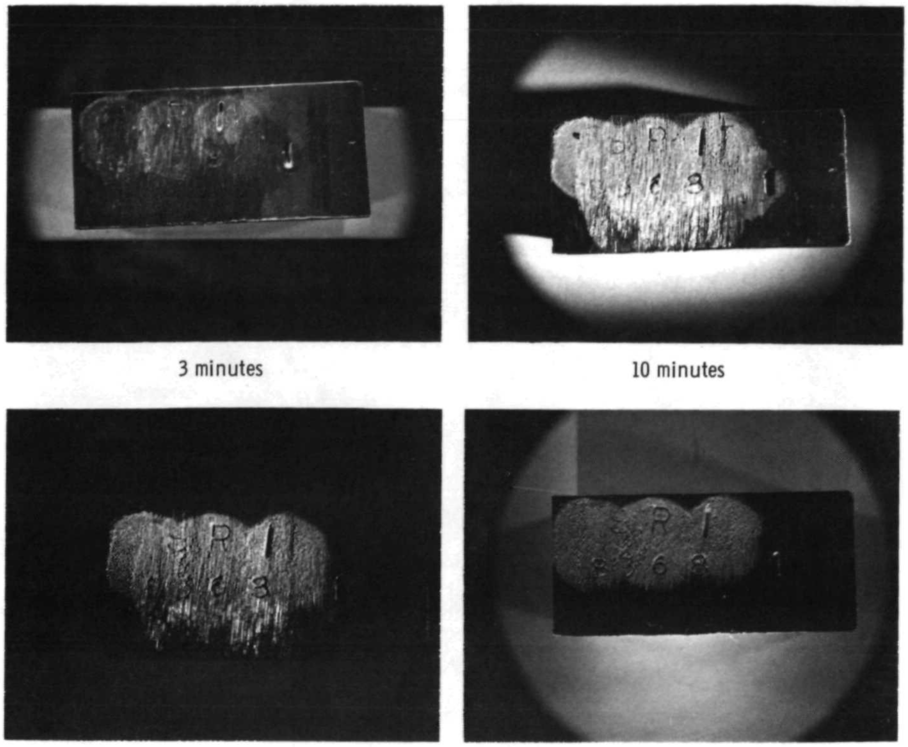


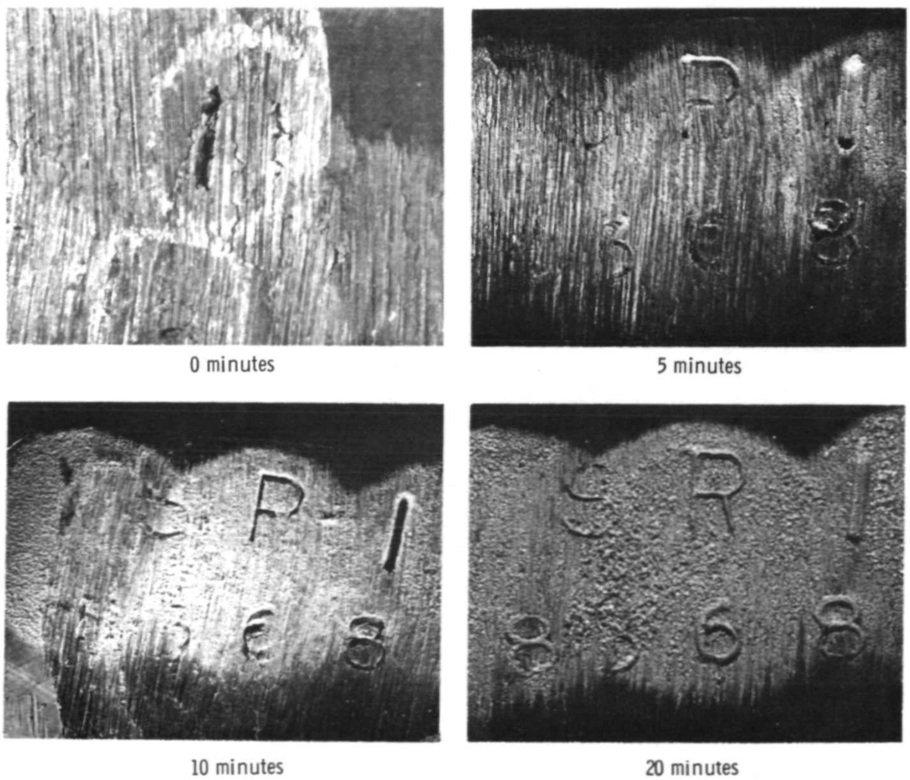
Figure 5. - Photomacrographs of copper specimen subjected to cavitation, showing serial number restoration at various exposure times - X1.



3 minutes 10 minutes

15 minutes 20 minutes

Figure 6. - Photomacrographs of copper specimen subjected to cavitation, showing the restored letters and numbers at various exposure times (high intensity oblique lighting - X2).



0 minutes 5 minutes

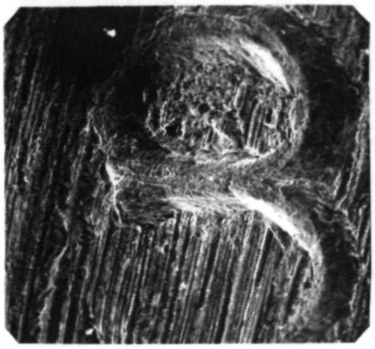
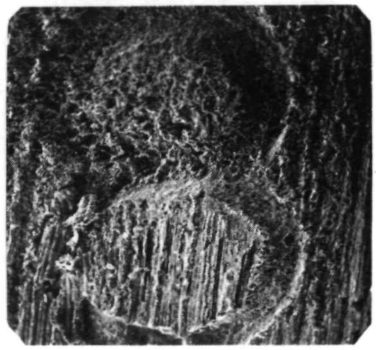
10 minutes 20 minutes

Figure 7. - Photomacrographs of copper specimen subjected to cavitation, showing the restored letters and numbers at various exposure times. - X6.

E-7534


3 minutes

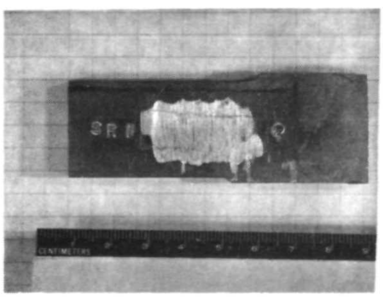
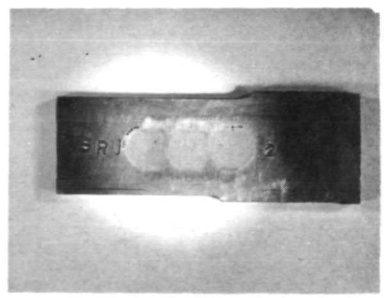
5 minutes

10 minutes

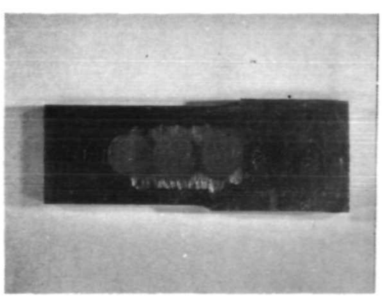
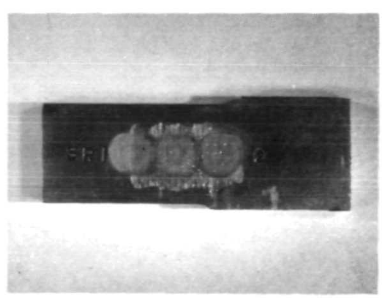
20 minutes

Figure 8. - Scanning electron photomicrographs of number 8 on copper specimen in the process of being restored. Smeared metal being removed from the grooves - X30.

0 minutes

60 minutes

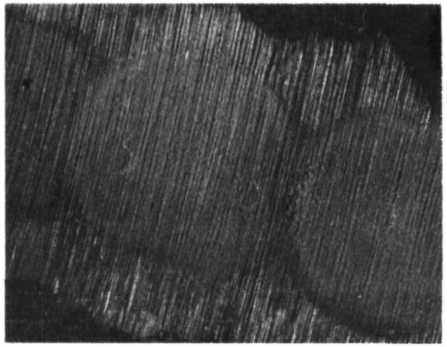



70 minutes

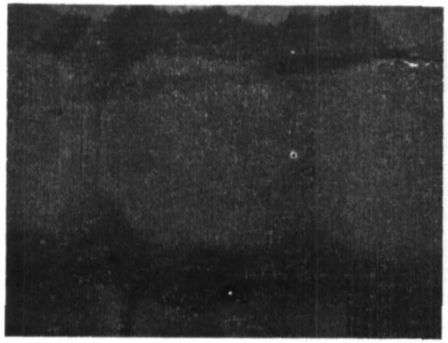
80 minutes

Figure 9. - Photomacrographs of brass specimen subjected to cavitation, showing serial number restoration at various exposure times - X1.

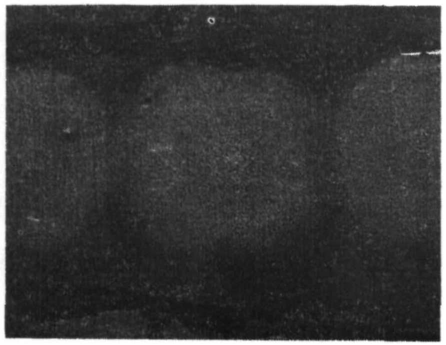
0 minutes



50 minutes

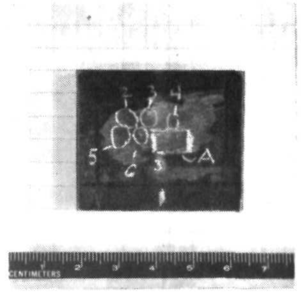


70 minutes

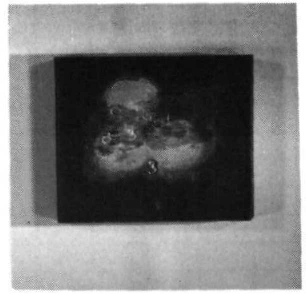


80 minutes

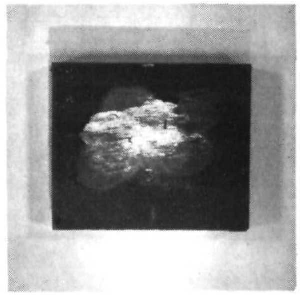
Figure 10. - Photomacrographs of brass specimen subjected to cavitation, showing serial number restoration at various exposure times - X5.



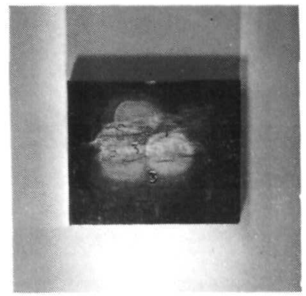
0 minutes



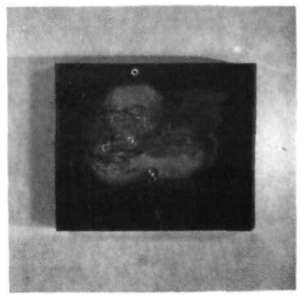
70 minutes



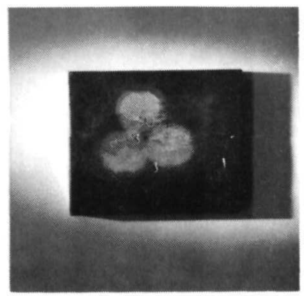
20 minutes



100 minutes

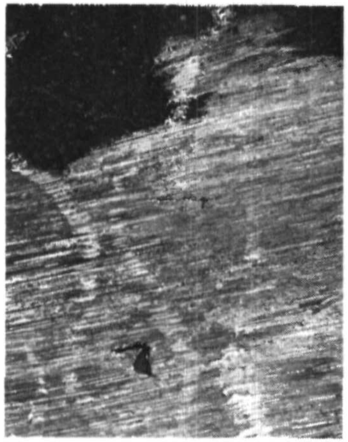


50 minutes

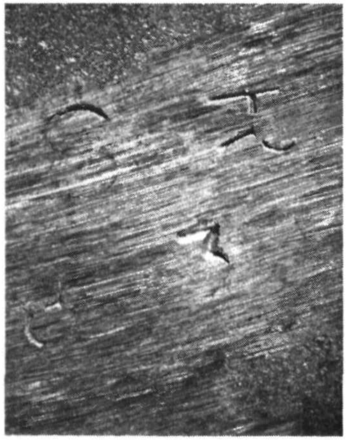


120 minutes

Figure 11. - Photomacrographs of steel specimen subjected to cavitation, showing serial number restoration at various exposure times - X1.

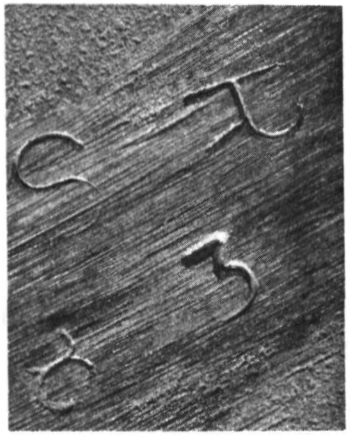


0 minutes



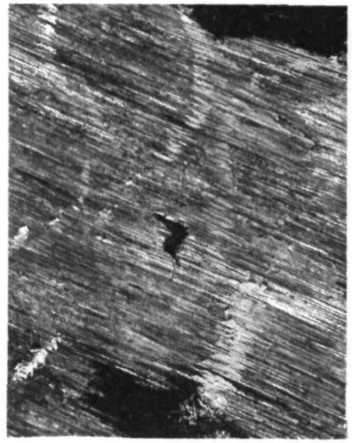
20 minutes

30 minutes



70 minutes

Figure 12. - Photomacrographs of steel specimen subjected to cavitation, showing the restored letters and numbers - S, R, 8, and 3, at various exposure times (letters highlighted on dark background by oblique light - X8).



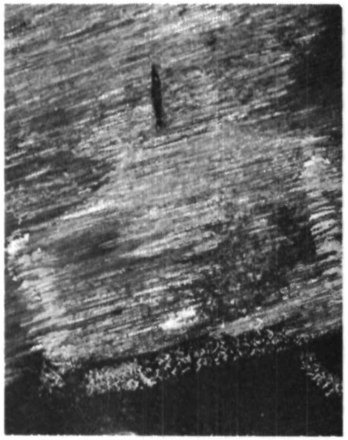
0 minutes

20 minutes

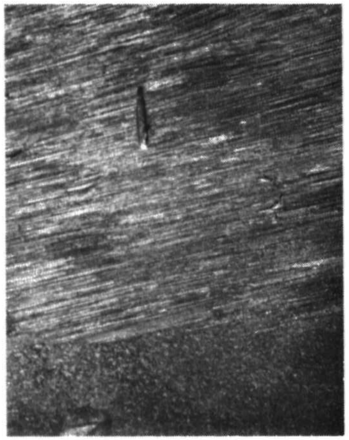
30 minutes

70 minutes

Figure 13. - Photomacrographs of steel specimen subjected to cavitation showing the restored letters S and R, and the number 3, at various exposure times (letters dark on light background - X8).



0 minutes

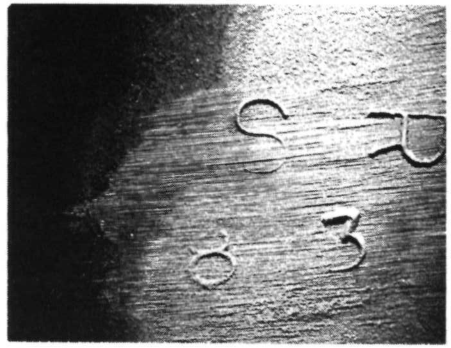


20 minutes

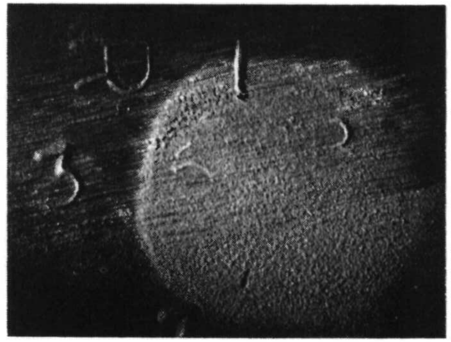
30 minutes

70 minutes

Figure 14. - Photomacrographs of portions of steel specimen subjected to cavitation, showing the partially restored numbers 6 and 8, at various exposure times - X8.

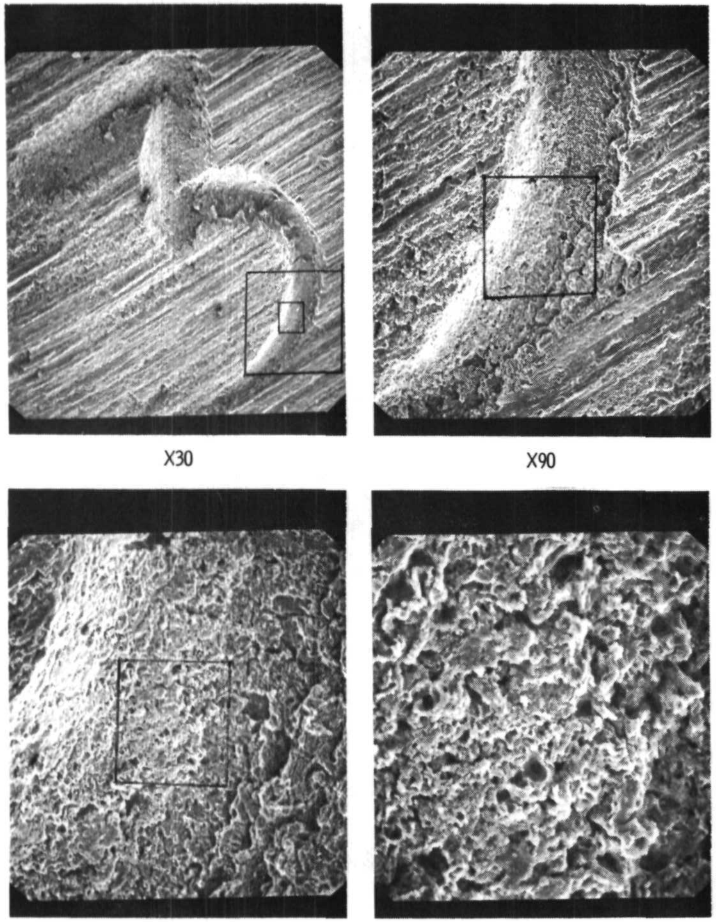


120 minutes



220 minutes

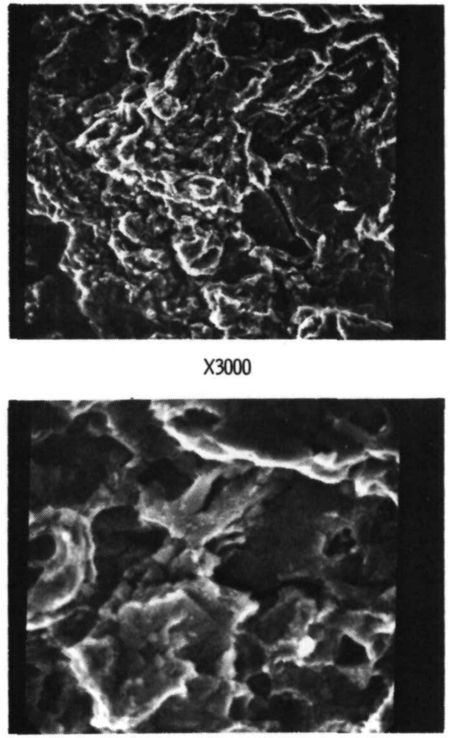
Figure 15. - Photomacrographs of restored letters and numbers on steel specimen at end of experiment - X6.



X30 X90

X300 X900

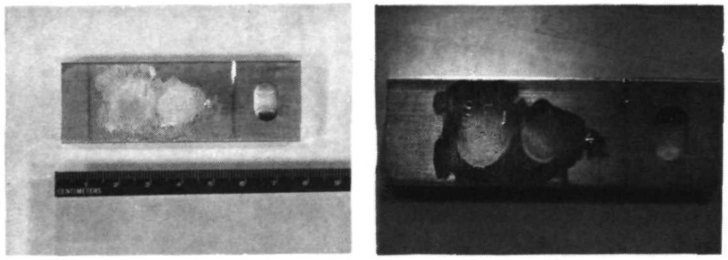
Figure 16. - Scanning electron microscope photomicrographs of restored number 3 on steel at various magnifications after 120 min. exposure to cavitation.



X3000

X9000

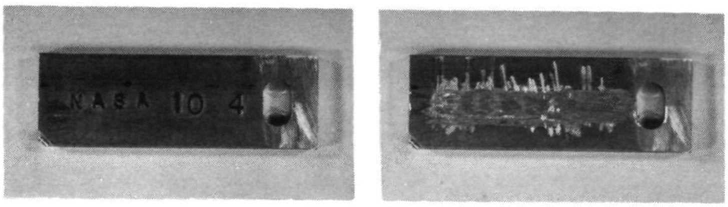
Figure 16. - Concluded.



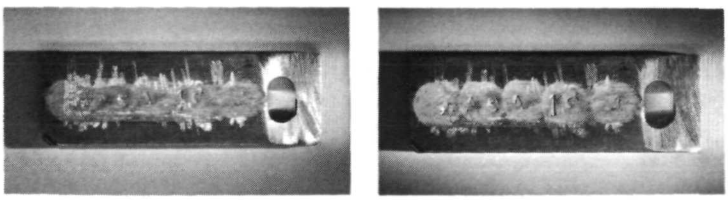
(a) 1 minute cavitation - uniform light. (b) 5 minutes cavitation - oblique light.

Figure 17. - Photographs of aluminum specimen showing results of initial attempt to restore letters and numbers.

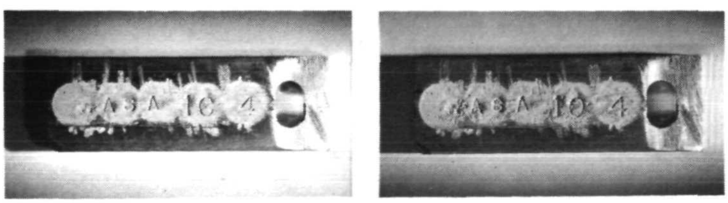
E-7534



As-stamped Identification obliterated



3 minutes cavitation 5 minutes



10 minutes 20 minutes

Figure 18. - Results of serial number restoration by cavitation on aluminum specimen. (Identification stamped and obliterated by NASA).

NASA-Lewis-Com'l