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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1673.

Testing of Magnesium Alloy Trench Mortar Base
and Steel Trench Mortar Barrel with Brittle
Lacquer Coatings.

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(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

OTTAWA July 7th, 1944.

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Testing of Magnesium Alloy Trench Mortar Base and Steel Trench Mortar Barrel with Brittle Lacquer Coatings.

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- Abstract -

This report records an effort to determine in a rough qualitative manner the distribution of stresses in a standard steel trench mortar barrel and a magnesium alloy trench mortar base, the latter designed by Major B. D. Irwin of the Department of National Defence (Army), Ottawa. The "brittle lacquer" technique was followed, as the complexity of the design ruled out determination of stress by calculation.

Brittle lacquer technique is ideally suited to the determination of the direction and, in many cases, the extent, of the principal tensile stresses. The locations of the stressed areas are shown in the photographs at the end of the report.

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Origin of Request:

Major B. D. Irwin, of the Department of National Defence (Army), Ottawa, having recently designed a new type of cast magnesium trench mortar base, desired to determine how the base was stressed during firing. Since the design was revolutionary, the calculation of stress under dynamic loading was practically impossible. The maximum stress created could only be guessed at, and its location was unknown.

Use of Brittle Lacquer Coatings in Stress Analysis:

The brittle lacquer technique is ideally suited to the determination of the direction, and in many cases the extent, of the principal tensile stresses. Brittle lacquer coatings are not, as a rule, used for determining compressive stresses in dynamically loaded structures.

The most extensively used brittle lacquer is that known as "Stresscoat", and is manufactured by the Magnaflux Corporation. This company makes a series of brittle lacquers each of which has a different sensitivity when subjected to strain. These lacquers are sprayed upon the part to be studied and are subsequently dried under constant temperature conditions. At the same time as the part is sprayed a calibration strip is similarly sprayed. This strip is then loaded as a beam in a specially designed "calibrator" (see Figure 2) for the same length of time as is the part under test. The loading of this strip is such that the strain set up in it varies along its length. Consequently, there will be a point on the strip wherein the strain is just sufficient to crack the coating. Above this point the coating is cracked; below this point the coating remains whole. When the strip is removed from the calibrator and placed in the specially constructed strain scale (see Figure 3), the actual value of strain at the point at which the cracking finishes is considered the strain sensitivity of this particular type of lacquer. Consequently, in any loaded structure, the amount of strain may be quantitatively determined by noting the areas which just begin to crack. It must be emphasized that the number of cracks or the size of cracks at any one point is not used as a measurement of stress. The only point at which the actual amount of stress can be determined is at the junction of the area which is cracked and the area which still remains whole, since it is known by reference to the calibration strip that the strain at that point is

(Use of Brittle Lacquer Coatings in Stress Analysis, cont'd) -

equal to the strain determined from the calibration strip.

__Preparation of Base and Barrel Prior to Firing:__

In order to employ the most suitable type of lacquer it is usual to select one which, under certain weather conditions, will give the greatest strain sensitivity. In this case, however, it was desired to employ both a sensitive lacquer and one which was fairly insensitive, so that the amount of strain could be reasonably estimated by a bracketing of the strain range. The temperature on the day the base and barrel were sprayed was found to be 73° F. dry bulb and 64° F. wet bulb and it was assumed that the conditions on the following day would be about the same. By examining the lacquer chart provided by the company, it was found that Lacquer 1205 would give the greatest sensitivity for the above weather conditions. It was also determined that 1201 would be a fairly insensitive lacquer. Thus, these were the two selected for the test.

In view of the fact that both the base and barrel were symmetrical through their vertical axis, it was decided to spray Lacquer 1201 on one half and Lacquer 1205 on the other half of both the base and the barrel. The base, the barrel and the calibration strips were cleaned of paint, scale, grease, etc., employing acetone and a special cleaner supplied by the company. They were then sprayed completely with a light coat of aluminium pigmented undercoating lacquer (No. ST-840). This undercoat provides a uniform background and makes it easier to judge the final thickness of the coating.

Half of the base and barrel was masked off and sprayed with Lacquer 1201. At the same time several calibration strips were sprayed with the same lacquer. After giving this coating an opportunity to set, this half was then masked

(Preparation of Base and Barrel Prior to Firing, cont'd) -

and the remaining halves of the barrel and base were sprayed with Lacquer 1205, as were several calibration strips. A coating 0.005 inch in thickness was aimed at, although the coating thickness is not critical. Base, barrel and calibration strips were permitted to dry in a room held at a fairly constant temperature for approximately 18 hours. They were then wrapped carefully in burlap and transported to the Connaught Ranges, where the firing trial was to be held. The wrapping of the lacquered parts is important, in order to prevent any sudden change in temperature. Sudden changes in temperature will cause the coat to craze, i.e., crack in many different directions.

Firing Trial:

The base was placed on soft ground, the barrel set at an angle of 60 degrees. One 3-inch trench mortar bomb with normal charge was fired. At the same time, the calibration strips were loaded in the calibrator in approximately one second. The location of the last pattern on the calibration strip was marked with a scriber, and by placing the strips in the strain scale it was found that Lacquer 1205 had a strain sensitivity of 0.00065 inch per inch and Lacquer 1201 one of 0.001 inch per inch.

A photograph of representative calibration strips is shown in Figure 1.

When any part of the mortar was strained 0.00065 inch per inch, Lacquer 1201 would crack, but not Lacquer 1201. Lacquer 1201 would not begin to crack until the strain reached 0.001 inch per inch. Thus, if the coating on one half of the mortar (at corresponding locations) was cracked and the other half not, the strain is then known to lie between 0.00065 and 0.001 inch per inch.

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Development of Strain Patterns:

Since this base was dynamically loaded by the sudden impact caused by the explosion of the charge, the lacquer coating cracked. Although the cracks were most certainly present they could not be seen with the naked eye. Therefore, to bring out the cracks a penetrant supplied by the manufacturer, called Red Dye Etchant, was painted on the entire surface of the barrel, base and calibration strips. This etchant was permitted to dry for approximately 15 minutes and then another coating was painted on and immediately wiped off with an emulsifier. This left only the Red Dye Etchant remaining in the cracks, the rest of the surface being cleared of etchant. Unfortunately, it is rather difficult to photograph these cracks, and in some cases their direction and location had to be drawn in on the negative.

DISCUSSION OF RESULTS; CONCLUSIONS:

A. - Trench Mortar Barrel

The 1201 lacquer which was sprayed on one half of the trench mortar barrel did not crack, but the 1205 which was sprayed on the other half of the barrel did. Figure VI is a photograph of the half of the trench mortar barrel which was sprayed with Lacquer 1205. On close observation it may be seen that the cracks run in a longitudinal direction, which was to be expected since the tensile stress is always tangential. Since the strain sensitivity of these lacquers is known, it may be concluded, assuming the modulus of elasticity of the steel to be 30 million, that the tangential tensile stress set up in the barrel lies between 0.00065 x 30,000,000 = 19,500 pounds per square inch and 0.001 x 30,000,000 = 30,000 pounds per square inch. By employing two lacquers which have a strain sensitivity fairly close together, the amount of stress set up in the barrel during firing may be ascertained within fairly close limits

(Discussion of Results; Conclusions, cont'd) -

and with a fairly high degree of accuracy. Of course, the most accurate method of determining the amount of strain set up in the barrel is by employing electrical strain gauges in conjunction with dynamic strain recording equipment. These Laboratories will soon be equipped with the recording devices, and it will be possible to measure accurately the stresses over the entire barrel.

B. - Magnesium Trench Mortar Base

As mentioned previously, it was not possible to ascertain the direction and amount of the compressive stresses set up in the mortar base. These, however, may be found by developing a method for statically loading the base. However, the direction of the tensional stresses was easily found and may be seen by referring to Figures 4, 5, 7 and 8. The direction of the principal tensile stresses is at right angles to the cracks. No definite statement can be made as to the actual stress created in firing the charge. It can be said, however, that wherever cracked patterns have appeared in the 1201 lacquer, the tensile stress is over 0.001 x 7,000,000, or 7,000 pounds per square inch (7,000,000 being the modulus of elasticity of magnesium). It may be observed, from Figure 4, that tensile stresses at points C and D were caused by the members E and F loading this beam. A suggested design of this casting would be to eliminate members E, F, G and H, and to shorten members I and J so that they project radially from the centre portion. As a result of this, it would probably be possible to lighten the sections C and D since no stress will be placed upon that portion, the stress being taken up by the corners and the members K, I, L and J, as shown in Figure 9.

Of course, one application of stresscoat and one firing trial tell only a little about the amount of stress, (Magnesium Trench Mortar Base, cont'd) -

but show its distribution. The base should be sprayed and fired, several times. It must rest on a hard surface during firing so that maximum strains expected in service can be estimated.

Since the distribution and direction of the tensile stresses are now known, the distribution and direction of the compressive stresses may be estimated. Electrical strain gauges in conjunction with dynamic strain recording equipment may now be employed to accurately measure the stresses at any position in the mortar base.

Further work will continue on this project. Work to date has been limited by the fact that only one base was available for tests. If more new bases could be received it should be possible to obtain the approximate ~~stress~~ distribution on firing, in a reasonable length of time. Information so obtained should be of value in improving the design.

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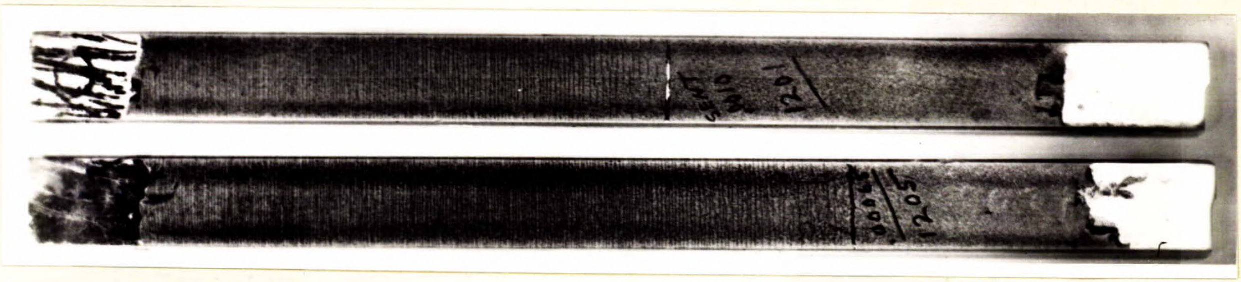
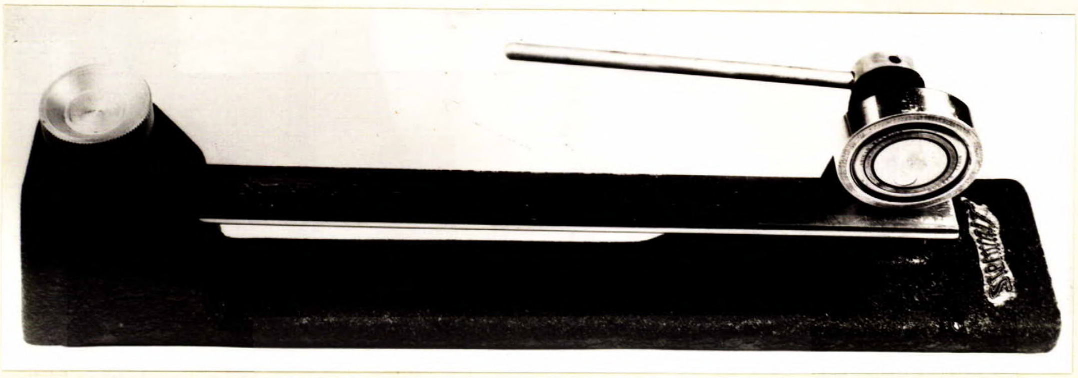
Figure 1.



CALIBRATION STRIPS WHICH HAVE BEEN LOADED
IN CALIBRATOR, SHOWING LOCATION OF CRACKS.

Figure 2.



CALIBRATOR USED TO LOAD CALIBRATION STRIP.

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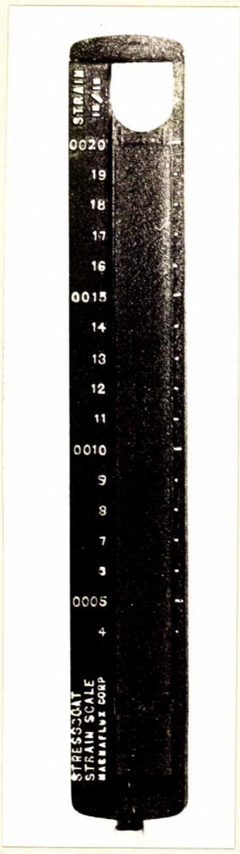
Figure 3.



STRAIN SCALE IN WHICH CALIBRATION STRIPS ARE PLACED AFTER LOADING.

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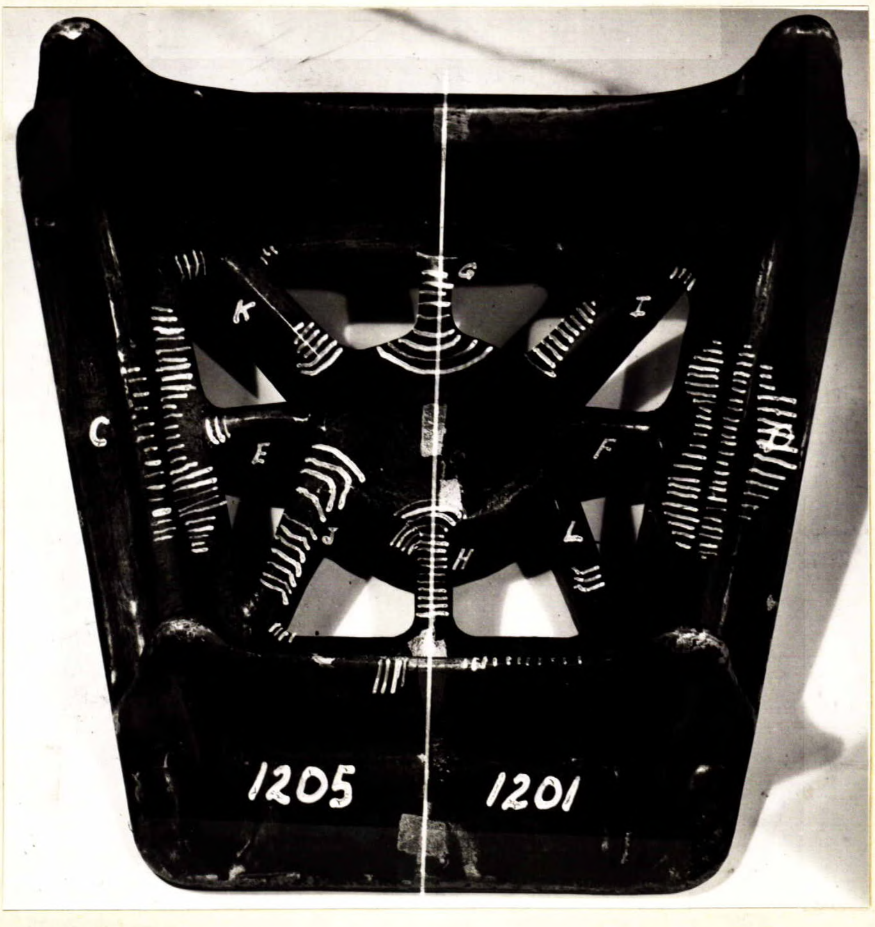
Figure 4.



BOTTOM OF MAGNESIUM ALLOY MORTAR BASE, SHOWING DIRECTION AND LOCATION OF STRESSES.

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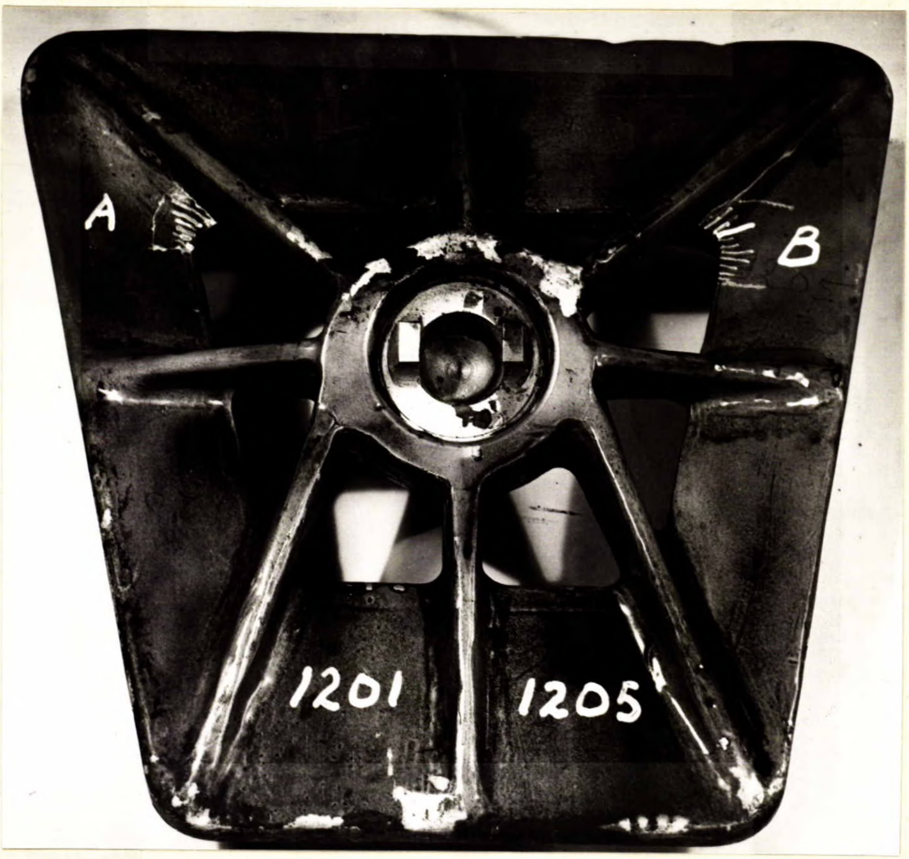
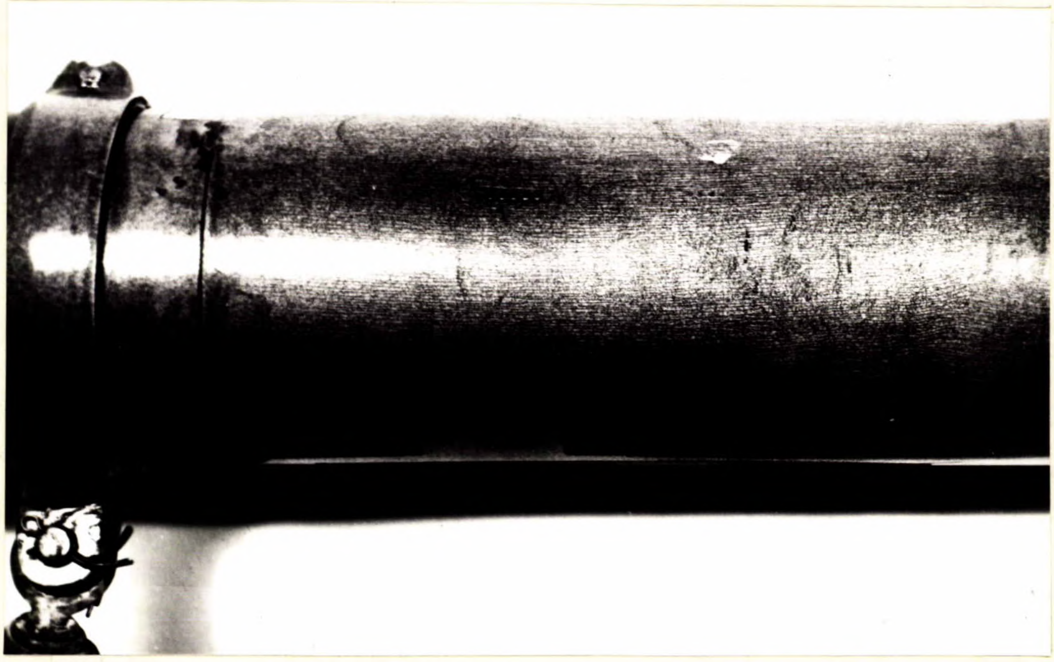
Figure 5.



TOP OF MAGNESIUM ALLOY MORTAR BASE, SHOWING DIRECTION AND LOCATION OF STRESSES.

Figure 6.



TRENCH MORTAR BARREL, SHOWING DIRECTION OF TENSILE STRESSES (AT RIGHT ANGLES TO DIRECTION OF CRACKS).

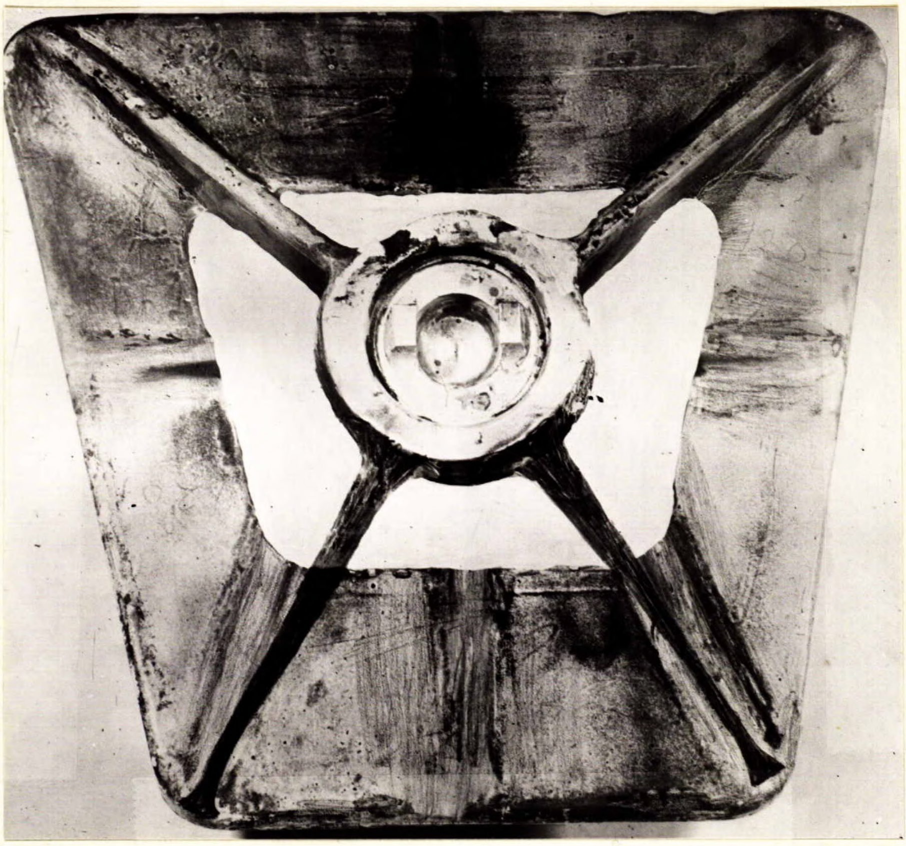
Figure 7.

CLOSEUP AT POSITION "A" ON TOP OF MORTAR BASE.

Figure 8.

CLOSEUP AT POSITION "B" ON TOP OF MORTAR BASE.

Figure 9.



A SUGGESTED DESIGN OF THE MORTAR BASE.

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