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DEPARTMENT OF MINES AND RESOURCES

BUREAU OF MINES

CANADA

Ottawa, June 5, 1946.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2060.

Stress Analysis with Brittle Lacquer,
Performed on a Cast Magnesium Piano Plate. - Part I.

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(Copy No. 18.)

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Abstract.

The qualitative distribution of the stresses which are produced in a cast magnesium piano plate by tuning the strings up to the pitch normally used by piano manufacturers, was determined by the application of "Stresscoat," a brittle lacquer made by the Magnaflux Corporation.

The piano plate was fixed to a wooden resonance box and loaded twice by tightening the strings up to the normal pitch. The accessible surface parts of the plate were sprayed under load with Stresscoat No. 1200 for the first examination, and with Stresscoat No. 1204 for the second examination. After drying the stresscoat and relaxing the strings, the stress pattern was obtained in those places which had been under compression while the strings were up to pitch.

The areas loaded in compression in excess of the characteristic load of the stresscoat applied, have developed the stress patterns shown in photographs. The results of the examination are discussed.

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

O T T A W A June 5, 1946.

REPORT

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2060.

Stress Analysis with Brittle Lacquer, Performed on a Cast Magnesium Piano Plate. - Part I.

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Origin of Request:

In a letter (File No. D/18/2/1 - Piano Plate) dated February 22, 1946, Mr. W. Z. Jarmicki, design engineer of Dominion Magnesium Limited, 67 Yonge Street, Toronto, Ontario, requested that a stress analysis be performed upon a cast magnesium piano plate which he was submitting.

As received, the plate was attached to a wooden piano back made by Mason & Risch Limited, 642 King Street W., Toronto, and had been tuned to a true pitch by Orme Limited, 175 Sparks Street, Ottawa.

Introduction:

The application of brittle coatings for stress analysis constitutes a very convenient method, supplying in a short time useful general information about the characteristics of actual stress distribution.

This method is applied especially to complicated structures in which it is very difficult to calculate the distribution and magnitude of stresses. A cast piano plate is a good example of this type of structure.

The stresscoat technique is used to determine the direction of maximum strain, since the lines of fracture of the lacquer are perpendicular to these strains. The stress pattern starts to appear at a certain characteristic strain, different for different lacquers; this may be used to obtain information concerning the magnitude of stresses involved.

The structure under investigation is sprayed with a brittle lacquer under rigidly controlled conditions of temperature and humidity and allowed to dry. The structure is then loaded, and characteristic stress patterns may appear in places loaded in tension. Places loaded in compression do not show these patterns.

In the present investigation, a different technique was used. First, the piano plate was loaded (that is, tuned up to pitch) and then sprayed with the stresscoat. Then, after drying, the strings were released, and the lacquer being now thus exposed to tension cracked in those parts of the plate which had been under compression. This technique was applied in this case for two reasons: first, it is easier to unload (release) the tuned strings in a short time than to tune them; secondly, the majority of accessible places were loaded in compression, the tension side of the magnesium plate being fixed to the wooden resonance box and therefore less accessible

(Introduction, cont'd) -

to direct observation.

Technique Applied:

Two stresscoats were applied, Nos. 1200 and 1204. The characteristic strain at which the stress pattern starts to form may be determined in two ways, namely:

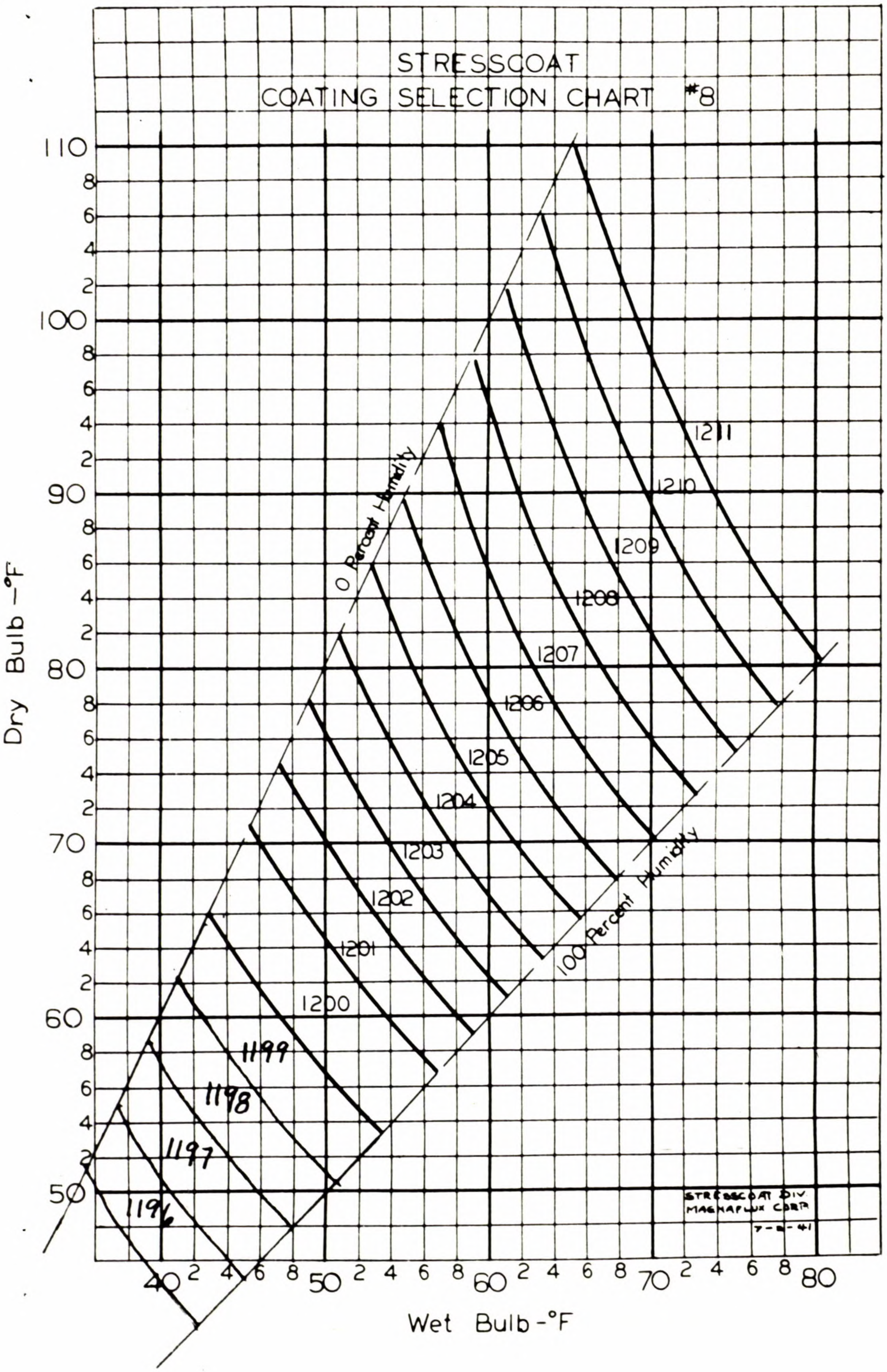
A. By using calibration strips loaded as cantilever beams and graduated along the strip length. In the present case, the procedure was to coat the bottom surface of the calibration strip with the stresscoat, loading the strip before drying (bottom of the strip under compression), and releasing at the same time as the strings on the piano plate were released. The spraying, loading, drying and releasing of load, both of piano plate and calibration strips, were done at the same time and under approximately the same atmospheric conditions.

B. By using Chart No. 8 (see Figure 1) supplied by the Stresscoat Division of the Magnaflux Corporation, if the loading, spraying and drying are carried out under the same atmospheric conditions. For any combination of wet and dry bulb readings, this chart gives the number of the stresscoat which will have a sensitivity of 700 to 800 micro-inches per inch. When a more sensitive coating is desired, that is, one in which strain patterns start to form at a lower value of strain, the next higher number of stresscoat should be used. Conversely, lower numbers will be less sensitive. The variation in sensitivity is approximately 100 micro-inches per inch per coating number. Thus, knowing the stresscoat number and the atmospheric conditions, the strain sensitivity can be determined from the chart.*

(Figure 1 follows on Page 4.)
(Text is resumed on Page 5.)

* The technique is described in full in the Operating Instructions for Stresscoat, issued by the Magnaflux Corporation, Chicago, Ill.

Figure 1.


STRESSCOAT
COATING SELECTION CHART #8
Dry Bulb - °F
Wet Bulb - °F
0 Percent Humidity
100 Percent Humidity
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
110
100
90
80
70
60
50
40
STRESSCOAT DIV.
MAGNAFLUX CORP.
7-2-41

(Technique Applied, cont'd) -

To increase the visibility of the stress patterns, the red dye-etchant was used after the pattern was formed.

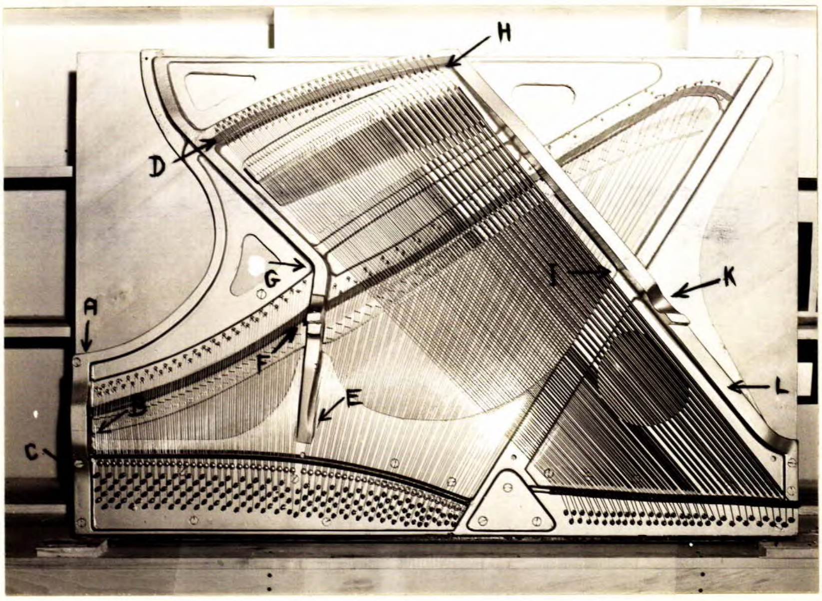
Before each application of stresscoat, the surface of the magnesium piano plate was cleaned by "thinners" ST-1 and ST-2. Aluminium-pigmented undercoating lacquer ST-840 was applied to the plate and calibration strips, in order to obtain a uniform background to facilitate the observation of stress patterns.

The drying and the unloading of the plate and calibration strips were carried out in a room maintained at a constant temperature.

Description of the Magnesium Piano Plate:

A view of the piano plate is shown in Figure 2. The plate had been cast in a green sand mould and afterwards sand-blasted. Machining and mounting on a wooden frame 3 inches thick was done by Mason & Risch, Limited, of Toronto.

Figure 2.



VIEW OF MAGNESIUM PIANO PLATE.

2060

(Description of the Magnesium Piano Plate, cont'd) -

The casting was made from Magnesium Alloy AZ80X, of the chemical composition given below:

		Per Cent
Aluminium	-	7.6-8.5
Zinc	-	0.2-0.6
Manganese	-	0.2 minimum.
Magnesium	-	Remainder.

No heat treatment was applied; the material was used in the "as cast" condition.

The mechanical properties are given in Table I.

TABLE I. - Properties of Domal Magnesium Alloy AZ80X, As Cast.

Tensile Strength, p.s.i. Ultimate: Typical	Tensile Strength, p.s.i. Ultimate: Minimum	Tensile Strength, p.s.i. Yield 0.2% Proof Stress: Typical	Tensile Strength, p.s.i. Yield 0.2% Proof Stress: Minimum	Elongation, per cent in 2 inches: Typical	Elongation, per cent in 2 inches: Minimum	Compressive Strength, p.s.i.: Ultimate	Compressive Strength, p.s.i.: Yield	Brinell Hardness (50-kg. load, 10-mm. ball)
28,000	23,000	14,000	10,000	5.0	3.0	48,000	11,500	52

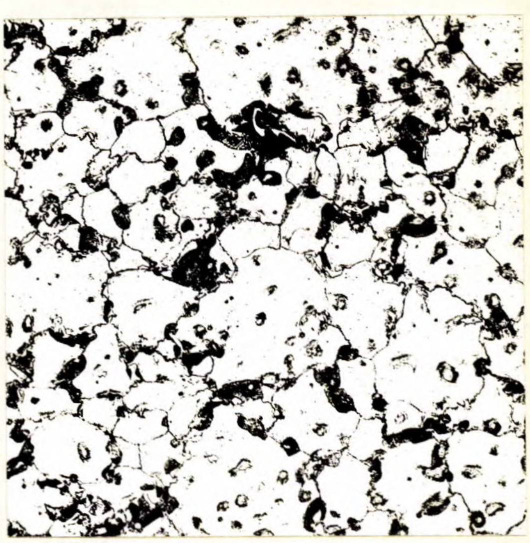
Metallographic Examination:

Metallographic examination (see Figures 3 and 4) of samples cut from the piano plate showed a structure typical for this type of alloy and an average grain size of 0.005 inch. No microporosity or other defects were detected.

Figure 3.

X100, unetched.

Figure 4.



X100, etched in 5 per cent acetic acid.

RESULTS OF INVESTIGATION:

Test No. 1.

Stresscoat No. 1200 was used; the calibration results of the stresscoat are given in Table II. The strain sensitivity of the lacquer used, No. 1200, was about 1200 to 1300 micro-inches per inch.

Examination of the surface of the piano plate after this coating did not reveal characteristic stress patterns. It was decided to apply a stresscoat of lower sensitivity.

(Table II follows,
(on Page 8.)

TABLE II. - Stresscoat Calibration, Test No. 1.

DATE OF SPRAYING Day	Hour	Strip No.	Stress-coat No.	WHEN LOADED a) After drying, b) before drying.	STRAIN, micro-inches At 1st break	At 2nd break	Strain Sensitivity as taken from Chart No. 8	DRYING TEMPERATURE, ° F. Wet Bulb	Dry Bulb	LOADING TEMPERATURE, ° F. Wet Bulb	Dry Bulb	DATE OF LOADING Day	Hour	REMARKS
March 4, 1946.	4 p.m.	A	1200	b	1100	1200	1100	53.0	72.0	53.0	72.0	Mar. 5	10 a.m.	Sensitivity test; calibration strips only.
	"	B	"	a	1380	1480	"	"	"	"	"	"	"	
	"	C	"	a	1390	1470	"	"	"	"	"	"	"	
	"	D	"	a	1420	1530	"	"	"	"	"	"	"	
	"	E	1200	a	1200	1300	"	"	"	"	"	"	"	
March 6	4 p.m.	A	1200	b	1340	1440	1350	62	80	62	80	7	9 a.m.	Sensitivity test; calibration strips only.
7	"	B	"	b	1220	1260 / 1335	1050	54	72	54	72	8	"	
8	"	C	"	b	1285	1320 / 1390	1150	57	75	57	75	9	11 a.m.	Piano plate and calibration strips tested.
"	"	D	"	a	1290	1340	1150	"	"	"	"	"	"	
"	"	E	"	a	1130	1200	"	"	"	"	"	"	"	
"	"	F	"	a	1160	1235	"	"	"	"	"	"	"	
"	"	G	"	a	1120	1190	"	"	"	"	"	"	"	

Remarks: As a guide in the interpretation of the stress patterns the strain sensitivity is regarded as 1200 to 1300 micro-inches per inch.

The surface under investigation has shown only very few and not distinctive stress cracks. A more sensitive lacquer was chosen for the second test.

(Results of Investigation, cont'd) -

Test No. 2.

Since Stresscoat No. 1200, used in the first test, was not sensitive enough, the No. 1204 coat was used in this test. The results from the calibration are given in Table III. The strain sensitivity of the lacquer used, No. 1204, was about 700 micro-inches per inch, a comparatively sensitive coat.

The most distinct strain patterns in Test No. 2 were obtained in regions A, B, E, F, I, K and L, marked with arrows in Figure 2. The details of the stress patterns at these places are shown in Figures 5 to 13.

The other places, showing only a few small cracks, have not been recorded because of the intention to use, later, another stresscoat of a higher sensitivity than 700 micro-inches per inch.

The loading on the magnesium plate in Tests Nos. 1 and 2 was applied by tuning up to the same pitch while the plate was mounted on a wooden resonance box. After tuning, and during relaxation of the strings, the piano plate was kept at constant atmospheric conditions (given in Tables II and III).

(Table III and Figures 5 to 13)
(follow, on Pages 10 to 16.)

TABLE III. - Stresscoat Calibration, Test No. 2.

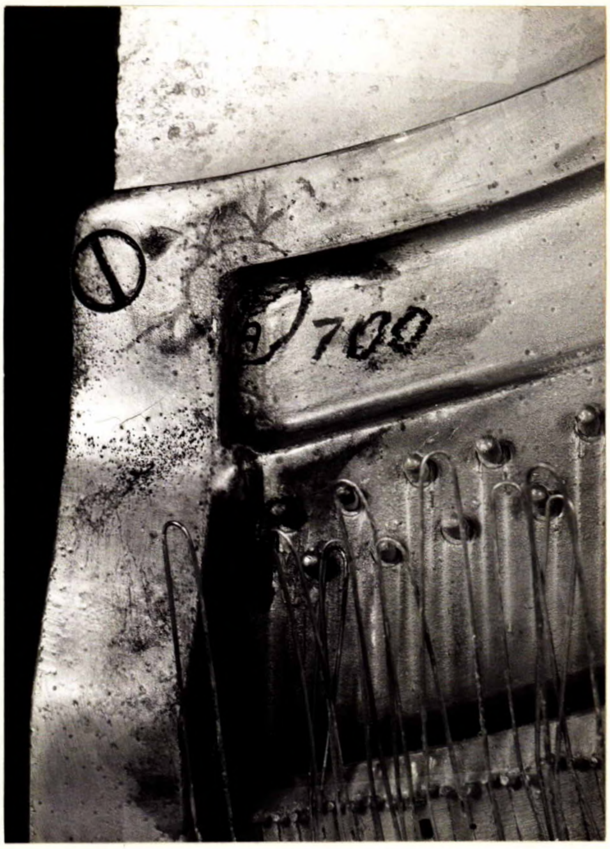
DATE OF SPRAYING Day	Hour	Strip No.	Stress-coat No.	WHEN LOADED a) After drying, b) before drying	STRAIN, micro-inches At 1st break	At 2nd break	Strain Sensitivity as taken from Chart No. 8	DRYING TEMPERATURE, ° F. Wet Bulb	Dry Bulb	LOADING TEMPERATURE, ° F. Wet Bulb	Dry Bulb	DATE OF LOADING OR UNLOADING Day	Hour	REMARKS
March 11	4 p.m.	A	1204	b	730 780	830	650	54.0	74.5	54.0	74.5	Mar. 12	9 a.m.	Sensitivity test; calibration strips only
"	"	B	"	a	700	770	"	"	"	"	"	"	"	
"	"	C	"	a	660	730	"	"	"	"	"	"	"	
"	"	D	"	a	750	830	"	"	"	"	"	"	"	
"	"	E	"	a	900	1000	"	"	"	"	"	"	"	
March 12	6 p.m.	A	1204	b	700	750	750	56	75.5	56.0	75.5	13	10 a.m.	Plane plate and calibration strips tested.
"	"	B	"	a	780	830	"	"	"	"	"	"		
"	"	C	"	a	880	920	"	"	"	"	"	"		
"	"	D	"	a	820	880	"	"	"	"	"			

Remarks: As a guide in the interpretation of the stress patterns the strain sensitivity is regarded as 700 micro-inches per inch.

The surface under investigation has shown distinctive stress patterns, described in Figures 5 to 13.

(Results of Investigation, cont'd) -

Figure 5.



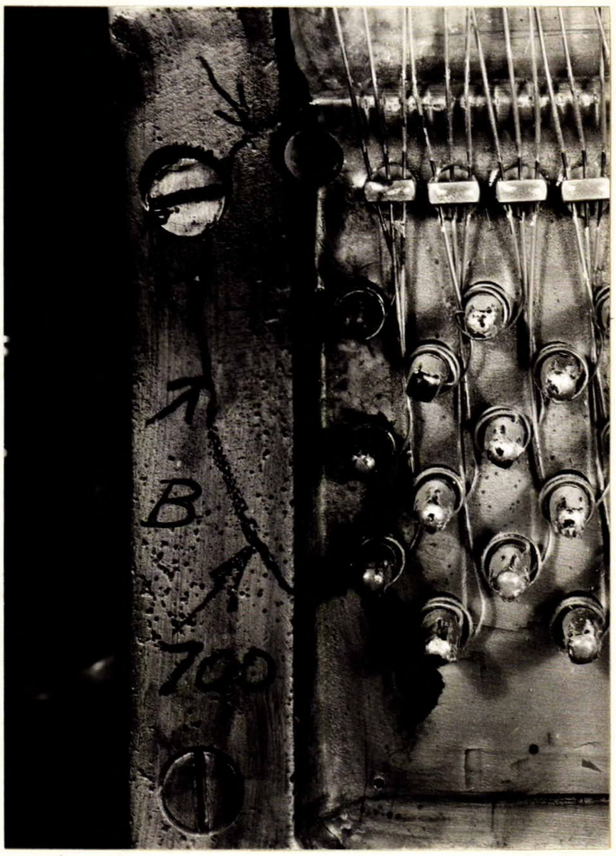
REGION "A" OF THE MAGNESIUM PLATE SHOWS CRACKS CONCENTRATED MAINLY IN RADIAL DIRECTION STARTING FROM THE CENTRE OF THE RADIUS DRAWN FROM THE CORNER.

These stress patterns show compression stresses directed perpendicularly to the radial cracks, as shown by arrows.

-

(Results of Investigation, cont'd) -

Figure 6.



REGION "B" SHOWS PARALLEL CRACKS DIRECTED PERPENDICULARLY TO THE EDGE OF THE VERTICAL BEAM A-C (see Figure 2).

The fact that the stress pattern appears only on one side of the beam proves that it is bent towards the side showing the stress pattern.

Figure 7.

REGION "E" SHOWS CONCENTRIC CRACKS OF A SHAPE MARKED WITH PENCIL.

These stress patterns prove the presence of compression stress, with the maximum directed perpendicularly to the circular cracks.

-

Figure 8.

The web in region "E" has a parallel stress pattern directed transversely to the length of the web, with increasing density of cracks towards the base of the web, which indicates an increase of the compression stresses in the same direction.

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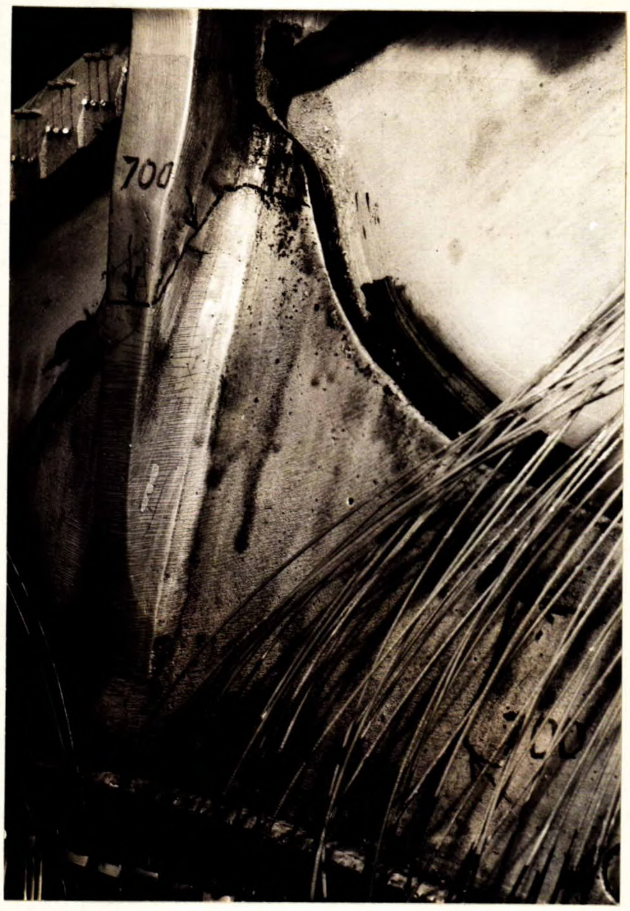
(Results of Investigation, cont'd) -

Figure 9.



PHOTOGRAPH OF THE SAME REGION ("E") AS FIGURE 8, SHOWING SIDE VIEW OF THE WEB WITH THE STRESS PATTERN ALONG IT REVEALING AN INCREASE OF COMPRESSION LOAD AS THE WEB SECTION DIMINISHES.

The web in region "E," shown in Figures 8 and 9, serves as a supporting column for the upper part of the magnesium plate and takes the main part of the compression and bending loads superimposed by all strings. The bending moment caused by inaxial loading is directed in such a way that the compression stresses are higher on the top surface and lower on the surface which is attached to the wooden box. The regions where the stress patterns were observed are marked with pencil and arrows pointing to the cracked surface.

-

(Results of Investigation, cont'd) -

Figure 10.

THE STRESS PATTERN IN REGION "G" SHOWS COMPRESSION STRESSES ON THE INSIDE, AROUND THE CORNER BETWEEN HORIZONTAL BEAM AND VERTICAL COLUMN.

-

Figure 11.

THE PATTERN IN REGION "I" IS SIMILAR TO THAT SHOWN IN FIGURE 10.

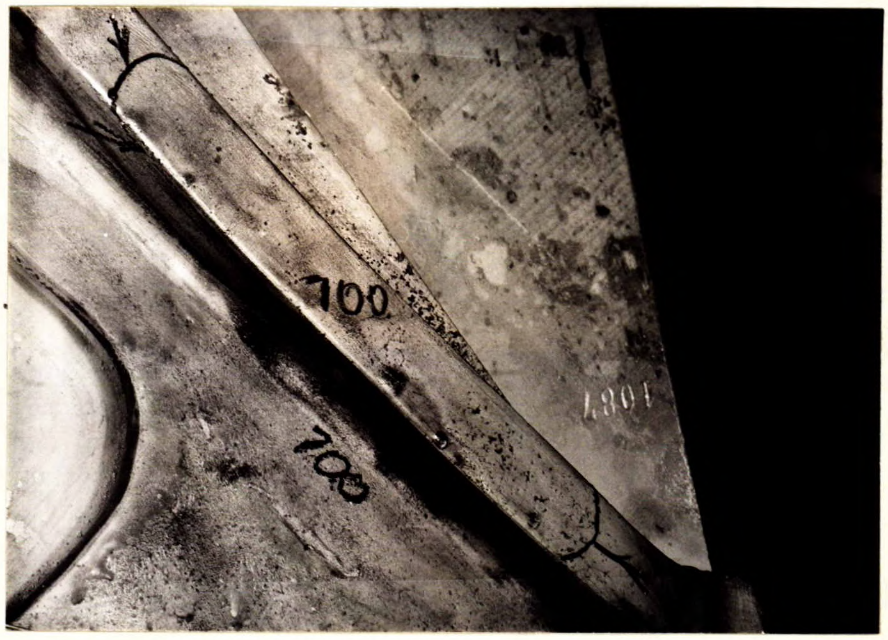
-

(Results of Investigation, cont'd) -

Figure 12.

SHOWING ONE OF THE MAIN COLUMNS, WITH REGION "K" COVERED WITH STRESS PATTERN IN THE SECTION WEAKENED BY A DEEP CYLINDRICAL CUT.

Figure 13.



THE BOTTOM PART OF A COLUMN COVERED WITH STRESS PATTERN IN REGION "L", AS MARKED WITH PENCIL.

On both sides of the column the lacquer cracked only up to 1/4 inch from the top surface.

Discussion of Results; Conclusions:

The stress pattern shows, in Figures 5 to 13, marked regions where a distinctive cracking of brittle lacquer No. 1204 was noticed. These regions are exposed to compressive strains of at least 700 micro-inches per inch. The upper limit should be expected around 1300 micro-inches per inch. This is the strain sensitivity of the Stresscoat No. 1200 used in the first test. The modulus of elasticity for magnesium alloy used was assumed to be 6,500,000 p.s.i., which gives approximately:

700 micro-in./in. = 4,550 p.s.i.
1,300 " " = 8,450 "

Other regions of the piano plate, not shown in Figures 5 to 13 and which have not developed a distinctive stress pattern, are either loaded in tension or in compression but below the strain sensitivity of Stresscoat No. 1204 which is 700 micro-inches per inch, corresponding to a stress of 4,550 pounds per square inch.

The second test (Stresscoat No. 1204) has revealed distinctly that the regions B, E and F are the places most overloaded, and that quite high concentrations of stress should be expected there.

The fact that so few places on the plate had shown the stress patterns calls for the application of a stresscoat of higher sensitivity. This will help to point out the regions very lightly loaded and will permit final conclusions to be drawn as to where the working sections may be reduced in order to reduce the weight and where they must be increased to attain the necessary safety factors and rigidity of the plate.

The directions perpendicular to the cracks indicate the directions of principal stresses. Knowledge of these directions is very helpful in choosing the positions of the

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

measuring length of strain gauges which are to be fixed in order to obtain the direct values of strains in the most important places.

The results of this investigation suggest that it is necessary to increase the section in regions B, E and F in order to obtain more evenly distributed stresses in the plate as a whole.

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