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EXAMINATION OF CAST ALUMINUM ALLOY COVERS FOR CIRCUIT-BREAKER AND MOTOR-STARTER ENCLOSURES

by

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SUMMARY

Four SG70-T6 cast aluminium alloy covers were examined. One cover, which had failed in an explosion test was found to contain numerous grossly unsound areas, although in the sound areas the metal quality appeared satisfactory. The other covers were much sounder. It is recommended that in future the covers be radiographed before acceptance by the manufacturer. It is imperative that the covers be radiographed before explosion testing.

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INTRODUCTION

This report deals with the examination of four cast aluminium alloy (SG70-T6) covers for circuit-breaker and motor starter enclosures from safety circuit centres used in conjunction with coal mining equipment. The covers were received from the Electric Equipment Certification Section of the Fuels Division on 16 September, 1958 and their approximate dimensions were as follows: 28 in. x 24 in. x 17 in. deep, 26 in. x 20 in. x 9 in. deep, 27 in. x 17 in. x 8 in deep, and 20 in. x 17 in. x 7 in. deep. Their wall thicknesses varied from about 5/8 in. for the largest to about 7/16 in. for the smallest. (There were certain sections of each cover where the wall thickness was reinforced.)

One cover (the largest) had failed under explosion test and an examination of this, together with the smaller castings, was made to determine their metallurgical quality.

The explosion testing method consisted of detonating a charge inside the motor starter enclosure with the cover in place. Figures 1 and 2 show two views of the parts of the broken cover reassembled approximately into their original positions. It will be seen that the cover failed along the junctions of adjacent faces. One side was broken in half, the top had several shorter cracks and one small piece of the top was broken out (see Figures 1 and 2).

Figure 3 is a view of the inside of the broken cover taken towards the corner nearest the camera in Figure 2. The letters identify x-ray locations (see below) and the areas enclosed by broken lines indicate the sections from which test pieces were machined.

VISUAL EXAMINATION

Examination of the fracture surfaces revealed many areas of gross porosity and oxide and dross inclusions. Several of these areas are shown in Figure 4. The corner shown in Figure 4"A" was extremely unsound and from an examination of the top of the cover and the directions in which the broken parts were thrown and distorted by the explosion it seems probable that failure of the cover started at this corner, which is the one nearest the camera in Figure 2.

The stresses in the cover would be expected to be higher at the corners and the presence of gross unsoundness would make these regions likely places for failure to start.

X-RAY EXAMINATION

X-ray examination of the parts of the broken cover showed a number of very unsound regions. For example, Figures 5 and 6 are prints from radiographs showing porous areas near corners of the top of the cover. Another very unsound area is shown in Figure 7 which was taken near "F" (see Figure 3). It will be seen that there was very little sound metal in certain sections of the wall.

Radiographs of the three unbroken covers showed them to be generally sounder than the broken casting although there were some porous sections (see Figure 8, for example) and in one cover (approximate dimensions 26 in. x 20 in. x 9 in.) very severe micro-porosity was present throughout (see Figure 9).

Microporosity was present in all castings but, except in the case just mentioned, the regions free from gross defects were reasonably satisfactory.

CHEMICAL ANALYSIS

A sample from the broken cover was analysed chemically and the results obtained are given in Table 1 together with the composition limits for SG70 (Alcan 135) specified by the Aluminum Company of Canada, Limited.

Table 1

Results of Chemical Analysis

	Cu %	Fe %	Mg %	Mn %	Si %	Ti %
Sample	0.13	0.28	0.28	0.13	7.5	0.10
Specification Limits	0.2 max.	0.5 max.	0.2-0.4	0.1 max.	6.5-7.5	0.2 max.

It will be seen that with the exception of the manganese, (probably unimportant), the chemical composition fell within the specification limits.

TENSILE PROPERTIES

In order to determine whether or not the metal used in the broken cover would satisfy the appropriate specifications, test bars were cut from sections which were radiographically sound (except for some microporosity). Substandard size bars (0.438 in. diameter, 2 in. gauge length) were used and were taken from two sections whose thicknesses were approximately 5/8 in. and 1 1/8 in. respectively. The areas from which the test pieces were taken are shown in Figure 3.

The maximum, minimum and mean of the seventeen determinations are as shown in Table 2.

Table 2

Tensile Test Results

	Ultimate Tensile Strength (kpsi)	0.2% Yield Strength (kpsi)	Elongation % on 2 in.
Maximum	30.7	26.0	4.0
Minimum	26.6	21.5	1.0
Mean	28.3	23.3	2.5
Specification Minima*	30.0	-	3.0

* These minima are those specified in U.S. Federal Specification QQ-A-601B for alloy 356-T6 for separately cast test bars. For test bars cut from castings the specification minima for average tensile strength and average elongation are 75% and 25% respectively, of the values specified for separately cast test bars.

It will be seen that the tensile properties of the specimens exceeded the specification minima for bars taken from the casting as noted above. This indicates that for this casting, the quality of the metal, as poured, was satisfactory, and that the heat treatment was correct. It must be remembered, however, that these test pieces were cut from the soundest areas of the casting and it is obvious that the mechanical properties of the casting as a whole must be much below the reported average because of the number and size of oxide inclusions and porous areas.

DISCUSSION

The results of chemical analysis and tensile tests of samples taken from the fractured casting have shown that the quality of the metal as poured (melt quality) and heat treatment were satisfactory, at least for the fractured casting.

However, gross porosity and inclusions were present at a number of locations in the casting, notably at the edges and corners. In some areas, virtually the whole wall of the casting was unsound. This would be expected to have a particularly bad effect in highly stressed regions of the cover, such as corners, and from an examination of the broken parts it seems likely that failure originated at one such highly stressed, unsound region ("I" in Figure 3).

It is probable that the unsoundness in the broken casting was due to improper sand control, running, gating or risering, and it is recommended that these aspects of the foundry practice be improved in future castings.

A considerable improvement in soundness was observed in the unbroken castings. In one, (approximate dimensions 26 in. x 20 in. x 9 in.) however, the general microporosity was very heavy, indicating the presence of excessive gas in the melt, which would perhaps lower the mechanical properties below the specified minima.

In conclusion, it is suggested that all covers should be radiographed before acceptance, and castings with gross defects (as in the broken cover whose examination is reported here) be rejected.

It is surprising that it was considered worthwhile heat treating the castings without first checking their quality, since it is apparent that the increase in properties afforded by heat treatment cannot compensate for the deleterious effects of the gross porosity.

Fig. 1. - View of the parts of the broken circuit-breaker cover reassembled roughly in their original relative positions. Note that failure has occurred at the junction of each face. There are several smaller cracks in the upper face.

Fig. 2. - Another view of the broken cover shown in Figure 1. One face has broken in half. It is probable that failure started at the corner nearest the camera.

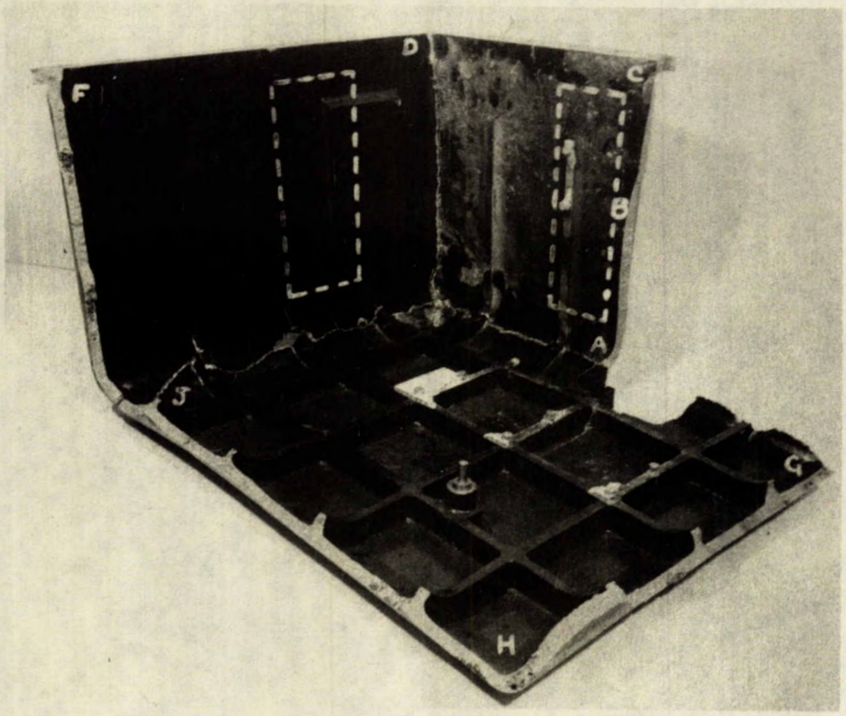
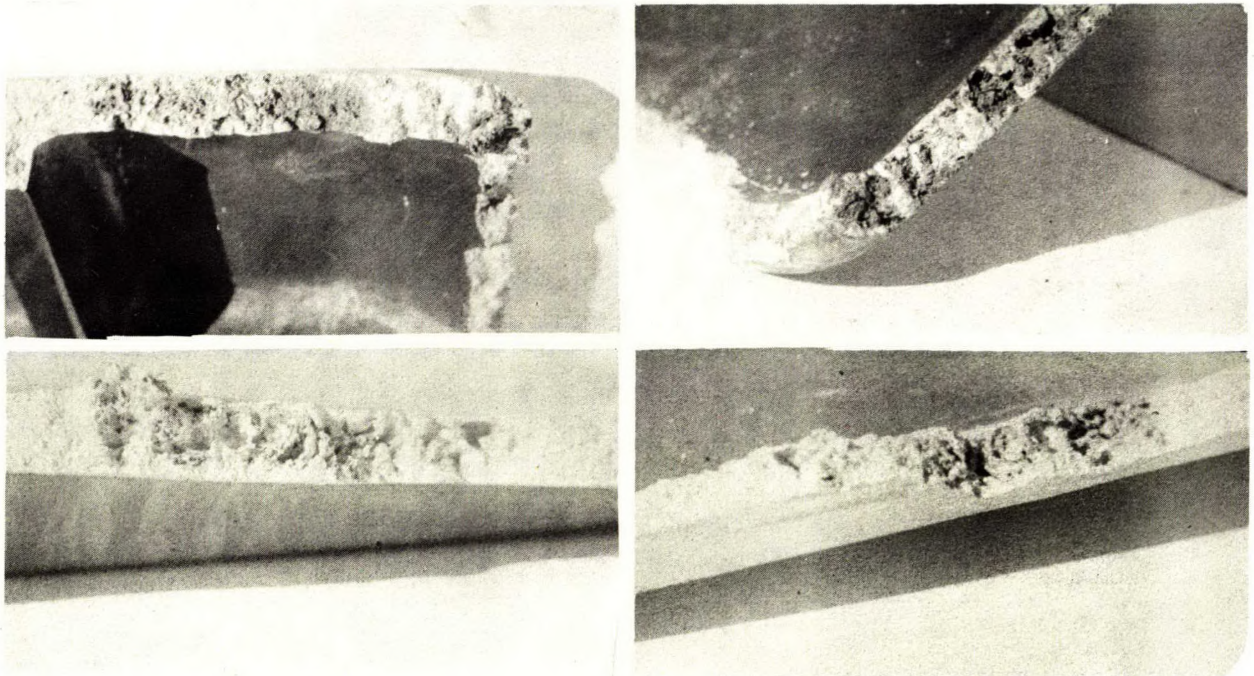


Fig. 3. - View of the inside of reassembled parts of the broken cover taken towards the corner "I" nearest the camera in Figure 2. Test pieces for tensile testing were taken from the areas enclosed by broken lines.

A B



C D

Fig. 4. - Views of various parts of the fracture surfaces of the broken cover showing unsoundness and dross inclusions.

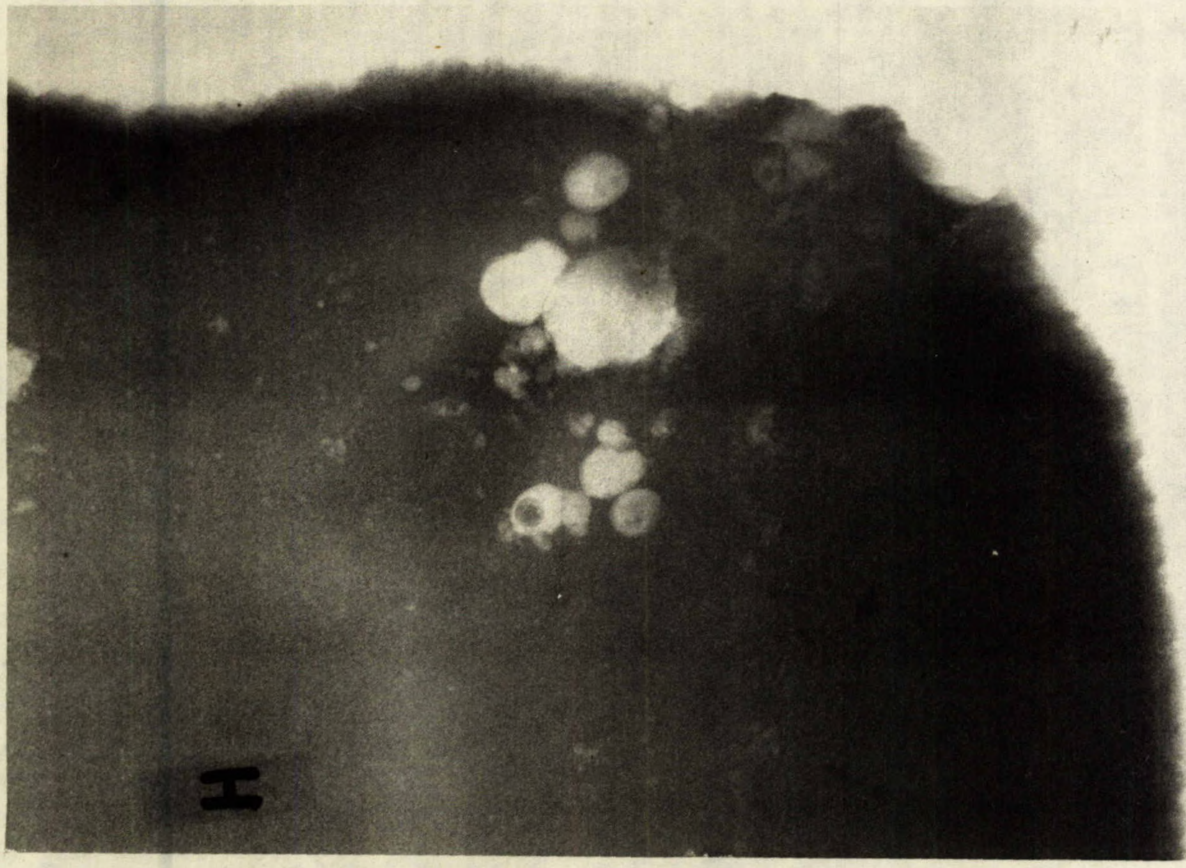


Fig. 5. - Print from a radiograph of the broken cover near "H" (see Figure 3) showing gross unsoundness.

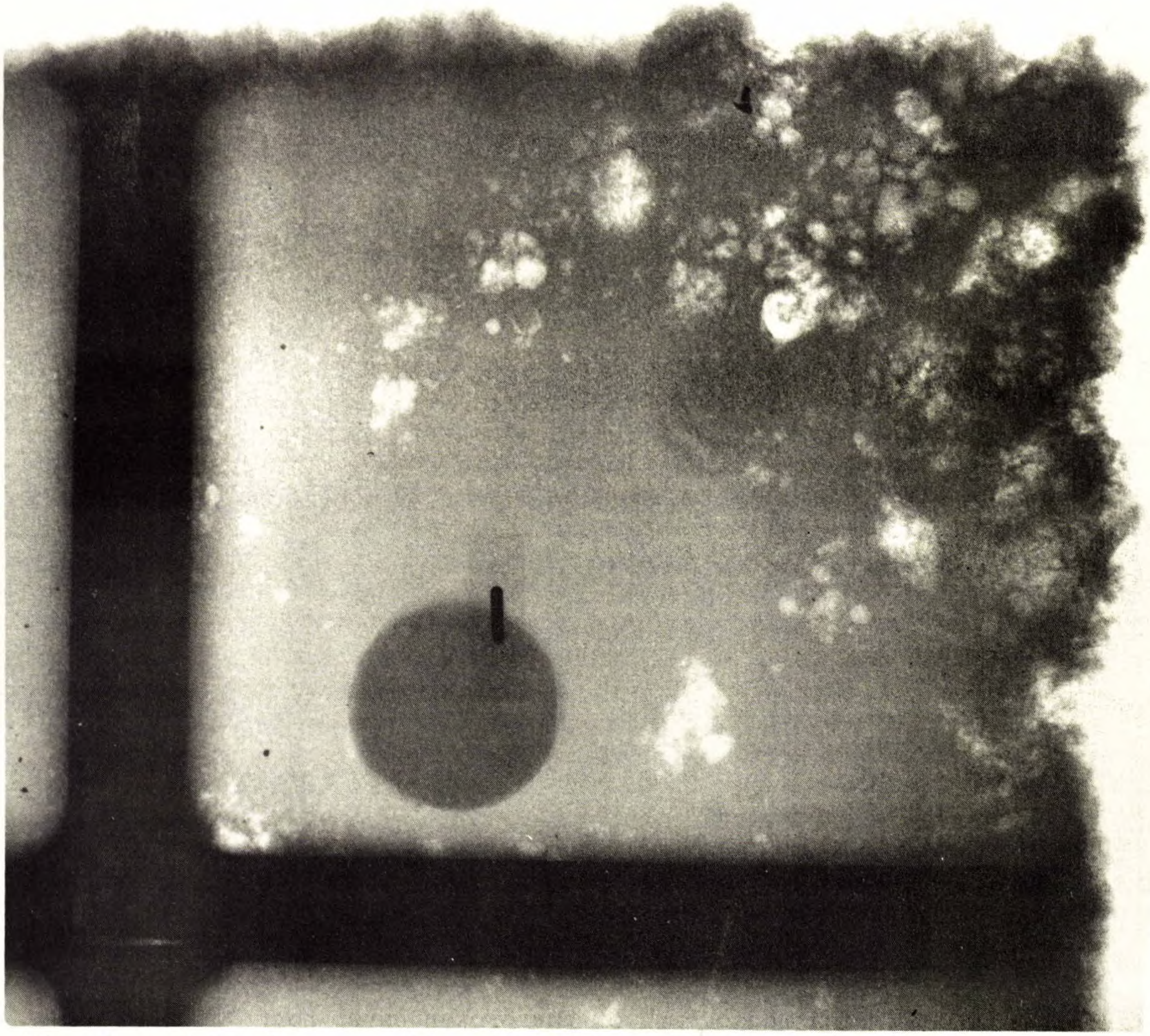


Fig. 6. - Print from a radiograph of the broken cover near "I" (see Figure 3) showing gross unsoundness.

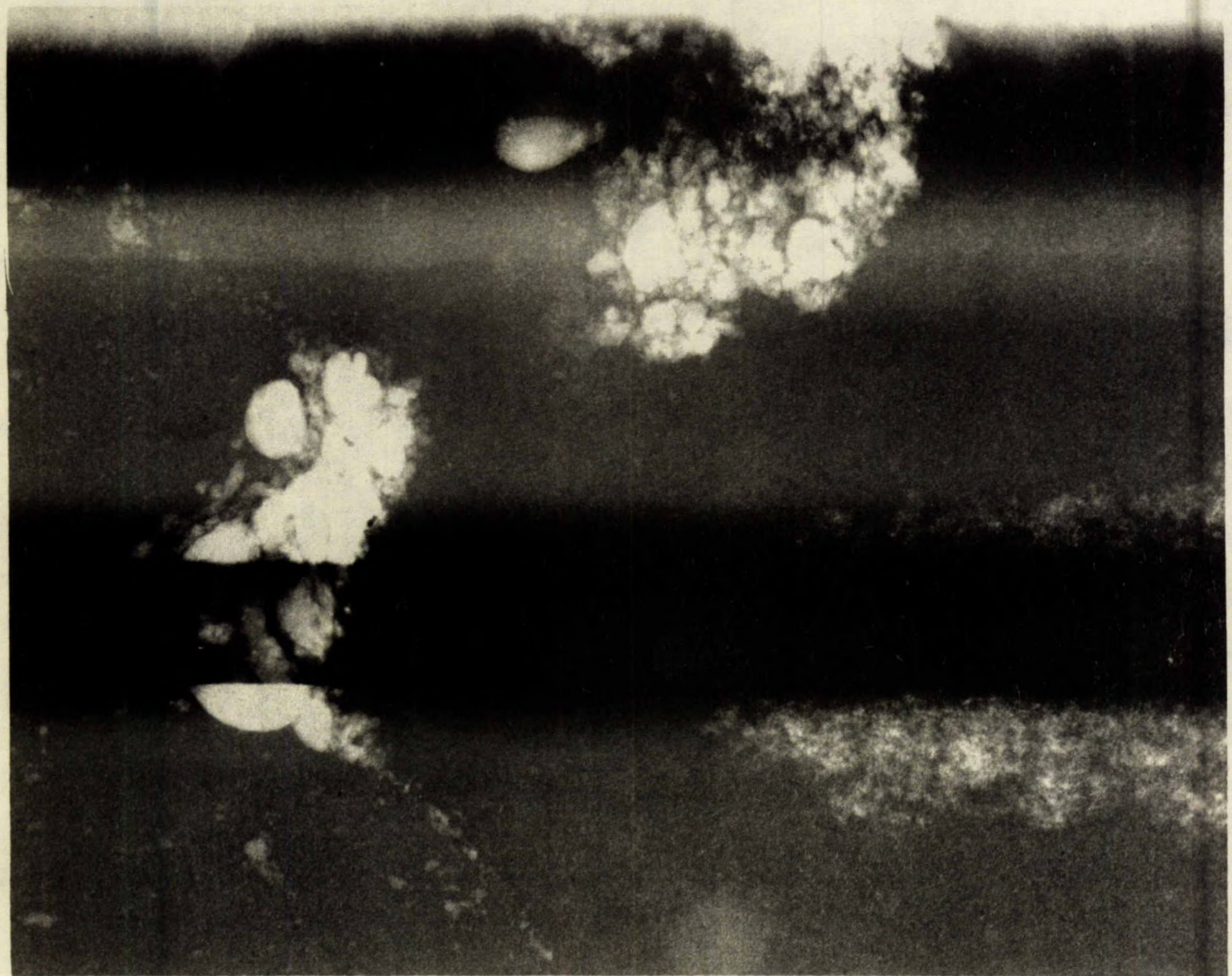


Fig. 7. - Print from a radiograph of the broken cover near "F" (see Figure 3) showing gross unsoundness.

Fig. 8. - Print from a radiograph of the smallest (approximately 20 in. x 17 in. x 7 in. deep) cover showing unsound region.

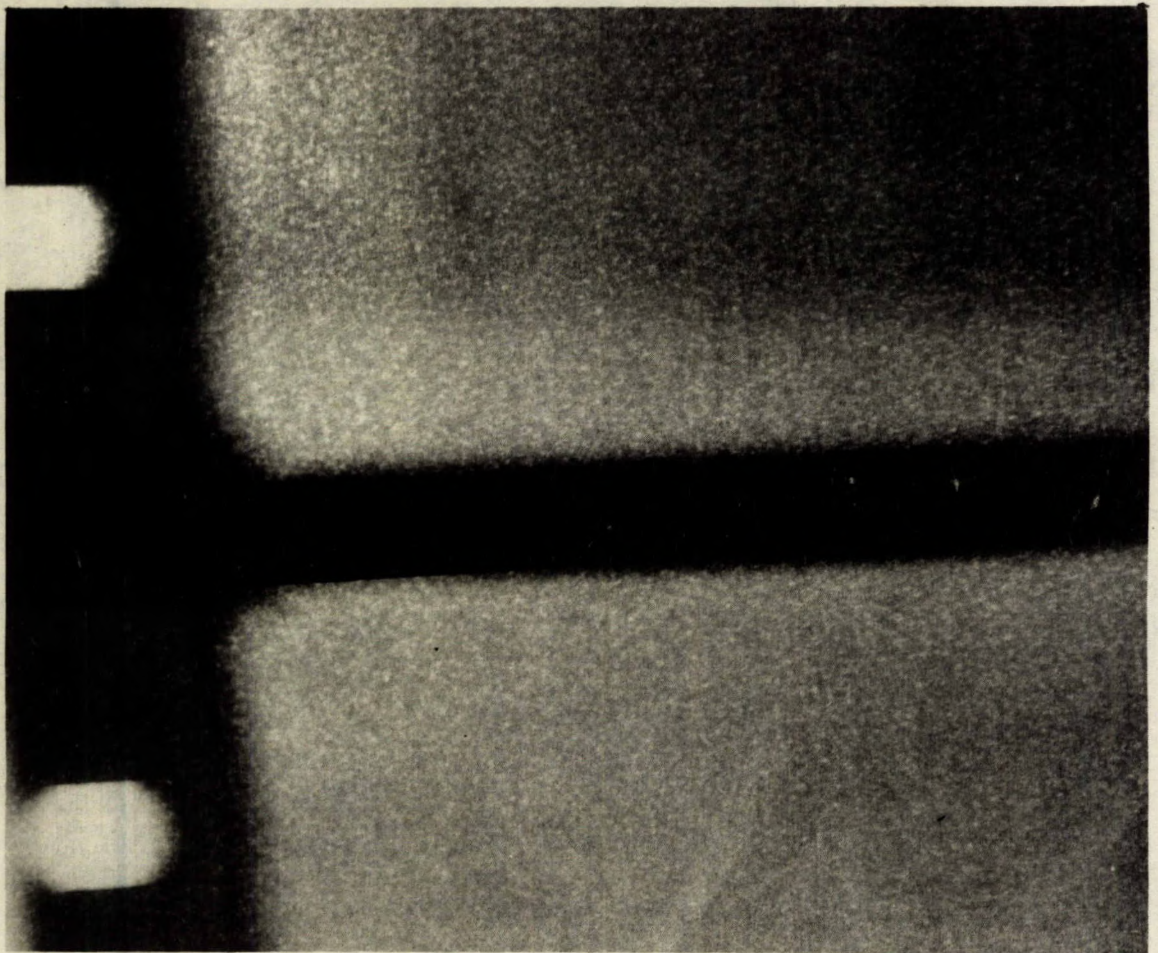


Fig. 9. - Print from a radiograph of an unbroken cover (approximate dimensions 26 in. x 20 in. x 9 in.) showing severe microporosity.