CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 65-59

FRACTURED ALUMINUM ALLOY PRESSURE COOKER COVER

by

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PHYSICAL METALLURGY DIVISION

COPY NO. 1.

JULY 30, 1965

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SUMMARY OF RESULTS

Examination of a pressure cooker, which had suffered explosive failure in service, suggested that there was no unusual material defect in the cooker lid.

From the various factors, it appeared that the vent had become blocked and that the cooker had exploded when the internal pressure reached 50-100 psi, at which pressure, the safety valve had failed to operate.

It is suggested that pressure cookers should conform to a standard ensuring adequate protection against accidental over-pressure, and incorporating a safety valve that would not deteriorate with age.

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INTRODUCTION

In letters dated 28 April 1965 and 31 May 1965, Mrs. N.J. Steele, Dartmouth Rd., Site 5 Bedford, S.S. No. 1, N.S. described the circumstances surrounding the failure of the cover of a cast aluminum alloy pressure cooker and, with the second letter, the parts of the cover were received. A reply (J.O. Edwards, 18 May 1965) had been given to the first letter and, on receipt of the cooker parts, tests were undertaken to determine whether or not material defects were responsible for the failure.

In her letters, Mrs. Steele stated that the pressure cooker was apparently being used in the normal way at the time of the failure, that the food being cooked (bones and water for soup) was not likely to cause blockage of the openings in the cover, and that the explosion had occurred after the cooker had reached 15 psi and the burner had been turned to "medium".

The cover consisted of curved cast aluminum plate about 12 in. diameter; the main domed part had a radius of about 18 in. and this was connected to the rim by a section of radius about 3/8 in. Most of the cover was about 5/32 in. thick but the rim was thicker and included a machined seat for the gasket and lugs to attach the cover to the cooker.

There were three openings in the cover as follows:

1. Pressure gauge of the Bourdon type, which was damaged, presumably as a result of the explosion. The gauge was marked 0 to 20 (psi). The needle was in the position indicating over 20 but appeared to have been bent from its normal zero position.

2. Nipple screwed into the cover, with hole (about 3/32 in. diameter), which presumably carried the regulating valve and petcock, which were stated to have been lost in the explosion. The hole was unobstructed as-received.

3. Safety valve in the form of a hole about $\frac{1}{2}$ in. diameter closed with a rubber disc. This disc was present with the parts supplied.

The cover had broken into two large pieces (9 in.), six smaller pieces (2 in. to 8 in.) and thirteen small pieces, most of which were the lugs that held the cover onto the cooker.

The force of the explosion was considerable, as several pieces were driven into the plaster ceiling and the stove was damaged beyond repair.

All the fractures appeared brittle and there was only slight evidence of deformation before fracture. From an examination of the pieces it seems likely that failure of the cover started near the centre (where stresses would be expected to be highest) and the pieces then burst outwards so that the lugs holding the cover onto the cooker failed in bending.

There was no evidence that corrosion or fatigue damage had any influence on the failure.

RADIOGRAPHIC EXAMINATION

X-ray examination of the large pieces from the cover revealed the presence of overall, light microporosity.

CHEMICAL ANALYSIS

Drillings from the cover were submitted for chemical analysis and the results were as follows:

Silicon	(Si)	3.60%
Iron	(Fe)	0.39%
Magnesium	(Mg)	2.26%
Manganese	(Mn)	0.03
Copper	(Cu)	Trace
Zinc	(Zn)	n.d.
Nickel	(Ni)	n.d.

The only known specification covering this composition is for Alcan M116 made by the Aluminum Company of Canada Ltd. The properties to be expected in castings are not published as far as is known.

METALLOGRAPHIC EXAMINATION

A section was taken from the thin (5/32 in.) part of the cover near the radius joining the main centre section to the rim, and polished for metallographic examination. At low magnification considerable micro-porosity was observed (See Figure 1). At high magnifications the structure was seen to consist of silicon (Si), aluminum-magnesium silicide-silicon (Al-Mg_2Si-Si) eutectic and several minor constituents, probably containing iron (Fe), in the aluminum solid solution matrix. The relatively large amount of magnesium silicide (Mg_2Si) present would be expected to make the alloy brittle.

TESTS ON SAFETY VALVE

As the safety valve did not release before the cover failed (the rubber diaphragm was still in its seat), it was of interest to determine at what pressure it would release. Part of the cover containing the valve was cut out and air pressure was applied to one side until the rubber disc blew out. The tests were done at about 255°F - a temperature corresponding to the boiling point of water at 20 psi. Strict correspondence with conditions in the pressure cooker would require the temperature to vary with the pressure in the same way as the boiling point of water (e.g., at 50 psi the boiling point of water is about 303°F), but this was not attempted. However, tests indicated that the rubber diaphragms became weaker with increase in temperature so that in service they would be expected to release at rather lower pressures than those found in the tests once the pressure in the cooker exceeded 20 psi.

It was found that the rubber diaphragm, which was in the cover when received, blew out at about 50 psi at 255°F in one test. Only one test was possible because the disc cracked as it released. However, it should be mentioned that this disc had been flexed several times during the examination. Therefore, it may have been somewhat more flexible than when in the cover at the time of the explosion i.e., the 50 psi release pressure that was measured may have been less than that required to release the plug when it was actually in service.

Examination of the rubber disc showed that there was a marked dome shaped permanent set in the disc, and that it was covered with a fine pattern of overall cracks. It was no longer particularly flexible, and had obviously undergone marked deterioration with age or service.

For comparison purposes, two new diaphragms were obtained and tested together with two discs which had seen light domestic service for more than five years. These were all considerably more flexible than the original disc. At 255°F, the new diaphragms and one of the used ones blew out consistently at about 25 psi, the other used disc going at about 35 psi. At room temperature the two new and one used disc blew out at 65 psi, the other used disc at 75 psi, and the original disc at 100 psi. (The test on the original disc was done first, and the tests at 255°F were carried out later to check the effect of temperature).

The above tests confirm that the rupture value of the safety valve can increase with age, and that apparently the original diaphragm had aged markedly.

DISCUSSION AND CONCLUSIONS

Examination of the cover has shown that the material was cast (probably permanent mould) aluminum alloy of an unusual type whose properties are not published. However, from the structure it would be expected to be relatively brittle. Both radiographic and metallographic examination showed considerable microporosity but this would not be regarded as unusual in this type of casting.

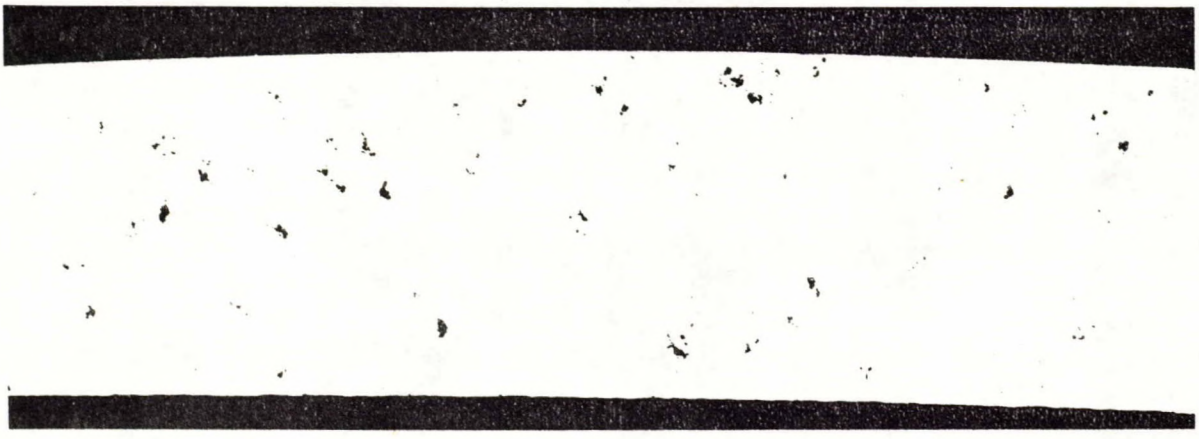
From the force of the explosion it does not seem probable that the cover failed at 15 psi. Tests have shown that the safety valve did not blow out until a pressure of about 50 psi was reached. Since the disc was intact in the lid of the pressure cooker after the explosion it must be assumed that the actual bursting pressure was less than this value.

Unfortunately, the shape of the cover did not permit reliable calculation of the pressure it would be expected to withstand, but a rough estimate suggested values of about 100 psi. Thus, allowing for some error in both the calculation and in the measured release pressure, both factors suggest that the cooker failed at a pressure of 50-100 psi.

Pressure vessels are commonly designed with a factor of a safety of four. One specification for domestic pressure cookers (British Standard 1746:1951) specifies that the bursting pressure should be six times the maximum operating pressure i.e., in this case 120 psi since the pressure gauge indicates danger beyond the 20 psi mark. There is no Canadian Standard for domestic pressure cookers.

Comparing the results of the tests on new and old rubber diaphragms it would seem advisable to replace these discs at regular intervals in order to ensure that the safety valve will operate at a satisfactorily low pressure. Because of the force of the explosion and other factors, it is concluded that the pressure cooker failed at a pressure of the order of 50-100 psi, and to generate this pressure within the cooker, the vent must have been blocked, and the safety valve must have failed to operate. However, since a vent blocked with food particles must be considered to be a normal operating hazard with this type of equipment, this again stresses the need for a reliable safety valve that will fail at a constant pressure.

In conclusion, it is suggested that, considering the serious hazards associated with an explosion such as occurred in the present case, pressure cookers should be made to conform with a standard such as the British Standard mentioned above, and should incorporate a safety valve which will not deteriorate with age.



X10

Figure 1 - Section through cover showing microporosity. (Unetched).