QUALIFLASH APPARATUS FOR TESTING THE INCLUSION QUALITY OF ALUMINUM ALLOY BATHS

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ABSTRACT

Ever faster changes in technique are leading to the production of castings that, while increasingly complex, must be reliable. To produce such castings, stages of production under control are necessary. Currently, the melting and hold of the liquid metal are rarely checked for inclusion cleanliness. And yet alumina skins have dramatic effects on the mechanical properties of castings. The current way of avoiding them is not preventive but remedial - the placement of filters in the molds -, because there is no device combining the following qualities :

- Low investment cost
- Suitability for shop use
- Simplicity of use
- Practically instantaneous results
- Reliable results

QUALIFLASH is shop apparatus that can be used to make sure of bath quality before casting. The test is simple, and only a small quantity of metal is sampled. The device is based on filtration, more particularly the clogging of a filter by oxides. It consists basically of a temperature- controlled shell with a filter at the bottom. The filter and the thermocouple used to measure the temperature of the liquid metal are the only consumable elements. The cleanliness of the sample is estimated instantaneously, using a nomograph, specific to each alloy, that indicates the degree of cleanliness according to the quantity of metal that passed through the filter. This makes it possible to decide whether the bath is ready to pour or must undergo another de-oxidation treatment. QUALIFLASH thereby makes it possible to control the quality of the alloy from the earliest stages of casting. It can also be used to estimate the quality of deliveries of liquid metal or of ingots. For the start of the new production, it can be used to optimize - i.e. minimize - flux consumption.

INTRODUCTION

The presence of various types of inclusions, in particular alumina skins, can gravely impair casting quality. There is a likelihood of :

* a considerable decline in mechanical properties, especially in fatigue, accompanied by a loss of ductility;

* a lack of tightness, making weld repairs or impregnation necessary;

* a surface condition unsuitable for anodizing, perhaps even too poor for paint or varnish;

* a loss of machinability, etc.

There are various means of prevention or cure. In theory, treatment with a flux makes it possible to gather together the drosses, which can then be eliminated, but ensuring contact between the whole bath and the flux is difficult. Filtering in the mold is one recourse, but 100 % effectiveness is not assured, and using a filter is expensive and, in a permanent mold, difficult.

To make sure that the metal contains no inclusions that might be entrained in the castings, develop a cleaning process, and reduce flux consumption, an effective and rapid measuring instrument is needed.

Among the recently-developed methods reviewed by D. Apelian (1), we may mention the PODFA method and the LIMCA apparatus (2). The former requires pressurized equipment and, more important, micrography, so the response time is rather long. The LIMCA, on the other hand, delivers an immediate response, but concerns small inclusions and seems best suited to measurement in continuous casting spouts. Making measurements with these two systems is rather expensive.

The Centre Technique des Industries de la Fonderie (3) had developed a method for sand casting. The metal flows through a filter and fills a cavity that has two electrical contacts, at the low and high positions. The filling time is affected by clogging of the filter by any oxides present. The drawback is the need for mold-making.

We accordingly attempted to apply the same principle to permanent molding, with the aim of devising an inexpensive method yielding a response that is as rapid as possible and easy for shop personnel to interpret.

PRINCIPLE

The measuring principle is simple. It involves the intentional near-complete clogging of the section of the filter by inclusions. The cleanliness of the alloy is estimated instantaneously (once the metal has stopped flowing through the filter). The cleanliness is indicated by the quantity of metal that flowed through the filter.

To develop the method, it was necessary to produce macrographs. We chose a cross-section parallel to the section of the filter to reveal the oxides trapped by the filter. This measurement turned out to be more reproducible than one on a perpendicular cross-section. Figures 1, 2, and 3 show that the quantity of oxides increases in proportion to the induced contamination of the bath.

The quantity of oxides on the filtered section is measured by image analysis (Cambridge 570). This is done on the negative of the macrograph. The digitized image is processed to optimize contrasts (figure 4). The white (oxidized) zones are then selected by applying a grey-scale threshold and the apparatus calculates their surface area (figure 5). This measurement is converted into oxides as a percentage of the filtration area.

The oxides clog the filter gradually. The "dirtier" a bath, the faster the clogging. However, flowrate trials yielded only low correlation coefficients. The clogging in fact depends on the random presence of oxides in the volume of metal sampled.

The parameter that must be used is the ratio of the measured quantity of oxide to the quantity of metal that has flowed through the filter. This yields an excellent correlation (figure 6) for a given alloy cast at the same temperature.

DESCRIPTION OF THE APPARATUS

The apparatus is mounted on a trolley (figure 7) so that it can be moved about more easily in the shops. A funnel-shaped shell is used to cast the sample of metal taken. It is heated by a resistance collar and its temperature is regulated. A fresh extruded ceramic filter is used for each measurement. It is held against the bottom of the shell by a spring plug. There is an ingot mold under the shell to recover the metal that flows through the filter. This ingot mold has ten steps. The ingot mold and the shell can be moved by hand about a horizontal axis to remove the excess metal left in the shell and the metal that has flowed. There is also a thermocouple with the apparatus to exactly measure the temperature of the metal in the spoon before it is poured into the shell. There is an electric control box to power up the unit, control the shell temperature, and read the temperature of the metal in the spoon.

USE

Using the system is simple. The temperature of the shell is regulated to between 420 and 430°C. This temperature lets the metal flow through the filter until it clogs before solidification starts. It is also essential to control the temperature of the metal in the pouring spoon. A temperature range appropriate to the alloy to be tested is specified to optimize the sensitivity of the system to differences in oxide levels.

The metal flows through the filter for about 20 seconds, at most. The result can therefore be read instantaneously, simply by counting the number of steps covered in the ingot mold. Prior calibration makes it possible to judge whether the bath is clean enough for the work to be done or whether the risk of scrapping is high.

After the cast ingot and the excess metal in the shell have solidified, they can be removed. Once the shell temperature has fallen to the setpoint, which takes about ten minutes, a new filter can be set in place for the next measurement.

INFLUENCE OF METAL TEMPERATURE WITH VARIOUS ALLOYS

The temperature of the alloy at the time of pouring is very important. If the temperature is too low, solidification will start before the filter is clogged by the oxides, making the system much less sensitive. A few alloys have been tested to determine a minimum temperature for proper measurements.

* Al-Si7Mg03 (A 356), unmodified, modified by strontium, and modified by sodium (figure 8).

* Al-Si12 (A 413) modified by sodium

* Al-Si7Cu3Mg (B 319) modified by strontium

All of the alloys were cast with baths treated with a deoxidizing flux.

It can be seen in figure 8 that, at a given casting temperature, a smaller quantity of metal passes through the filter when the metal is modified with sodium. Strontium, on the other hand, has no significant effect.

Sodium alters the surface tension of the alloy. This increases the pressure drop across the filter, slowing the flow of metal. The minimum pouring temperature for Al-Si7Mg03 (A 356) modified with sodium is therefore 740°C, while for the same alloy unmodified or modified by strontium it is 720°C.

The trials are being continued with other alloys, in particular alloys close to the eutectic and Al-Si-Cu alloys.

EVOLUTION OF MASS VERSUS OXIDE LEVEL.: CASE OF AlSi7Mg03 (A 356) MODIFIED WITH STRONTIUM

The pouring temperature was kept between 720 and 720°C. The oxide level measured by image analysis ranged from 0 to 50 % and the mass of metal passing the filter from 2.7 to 0.8 kg.

Under these conditions, almost the whole of the available scale (10 steps) is used: as the oxide level goes from 0 to 50 %, the number of steps covered decreases from 8 to 2.

The device is therefore highly sensitive to the oxide level.

DISCUSSION

The tests performed with different alloys and under different conditions reveal two parameters that are important and must be known for valid measurements to be made.

The overheat beyond the solidus point and the surface tension, modified by the possible presence of sodium, affect the time available before the alloy starts to solidify.

This time must be long enough for the measurement to be sensitive to differences in oxide level.

These remarks mean that two measurement results may be compared only if the testing conditions are identical: same alloy, same temperature, and same pouring modification condition.

The parameters mentioned are the same that affect the castability of an alloy. Comparative tests with castability are in progress. The first results seem to show that there is no correlation between oxide measurements and castability.

CONCLUSIONS

We have developed a simplified new way of estimating the quantity of oxides, basically alumina skins, in an aluminum alloy bath. Its main advantage is speed: by contrast with existing methods, the result is immediate. The measurement is very simple and makes use of shop equipment that can be operated even by relatively unskilled personnel. The only consumable product is the filter, which must be replaced for each measurement.

The obvious application is to assessing the quality of a preparation before casting. Use in developing or testing bath washing fluxes is also possible. The speed of the response makes it possible to judge the quality of a delivery of molten metal. It is also possible to judge the quality of a delivery of ingots, by remelting a sample under specified conditions.

This device is patented and its name, "QUALIFLASH", is a registered trade mark.

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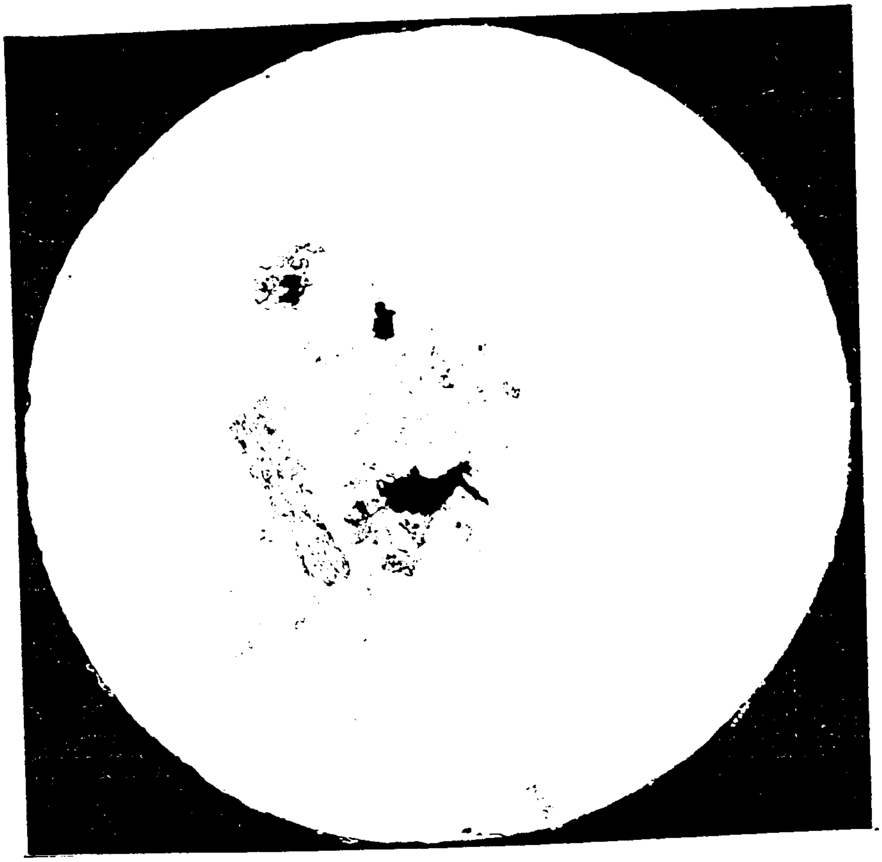

Figure 1. macrograph of an Al-Si7Mg03 having a low oxide content

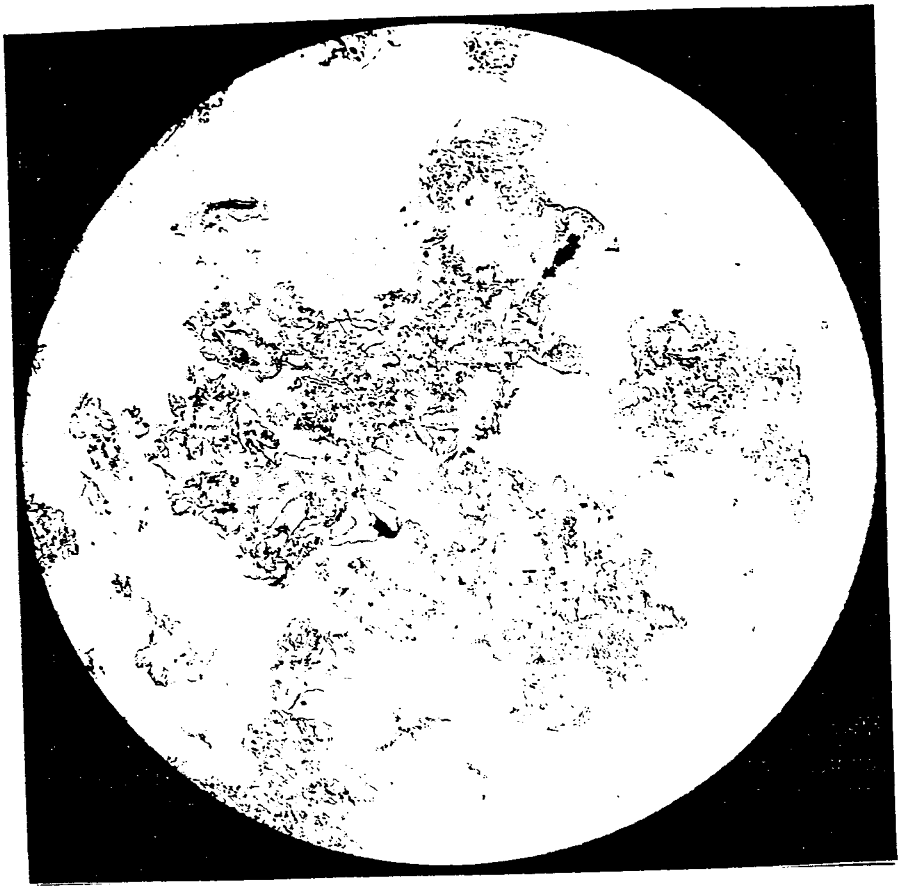

Figure 2. macrograph of an Al-Si7Mg03 having a moderate oxide content

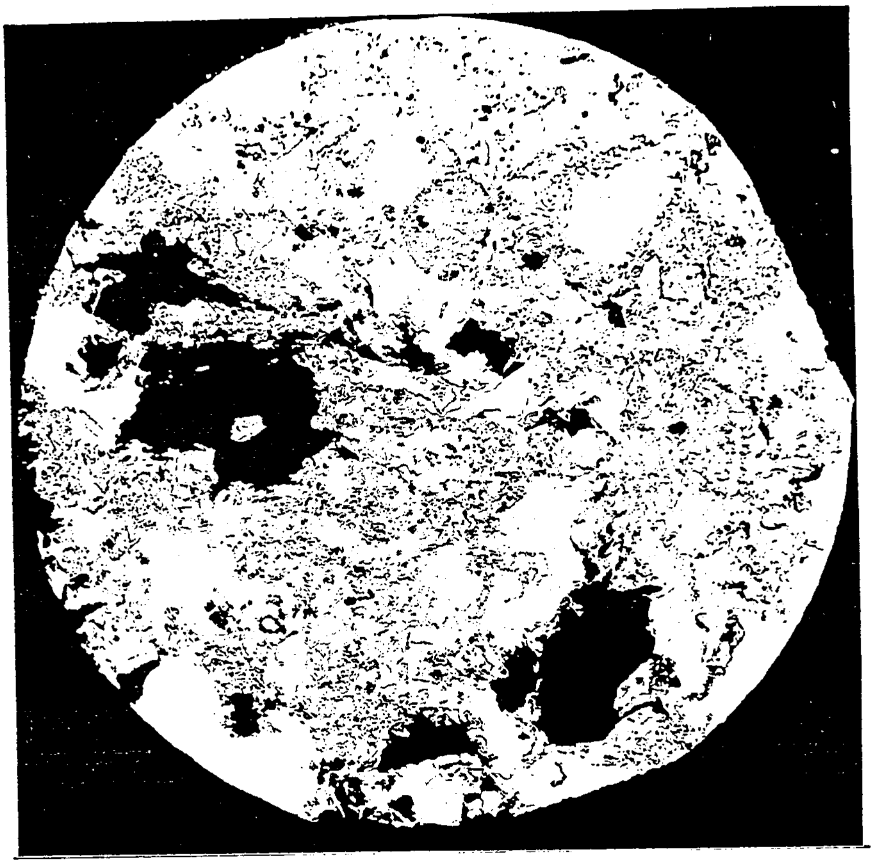

Figure 3. macrograph of an Al-Si7Mg03 having a high oxide content

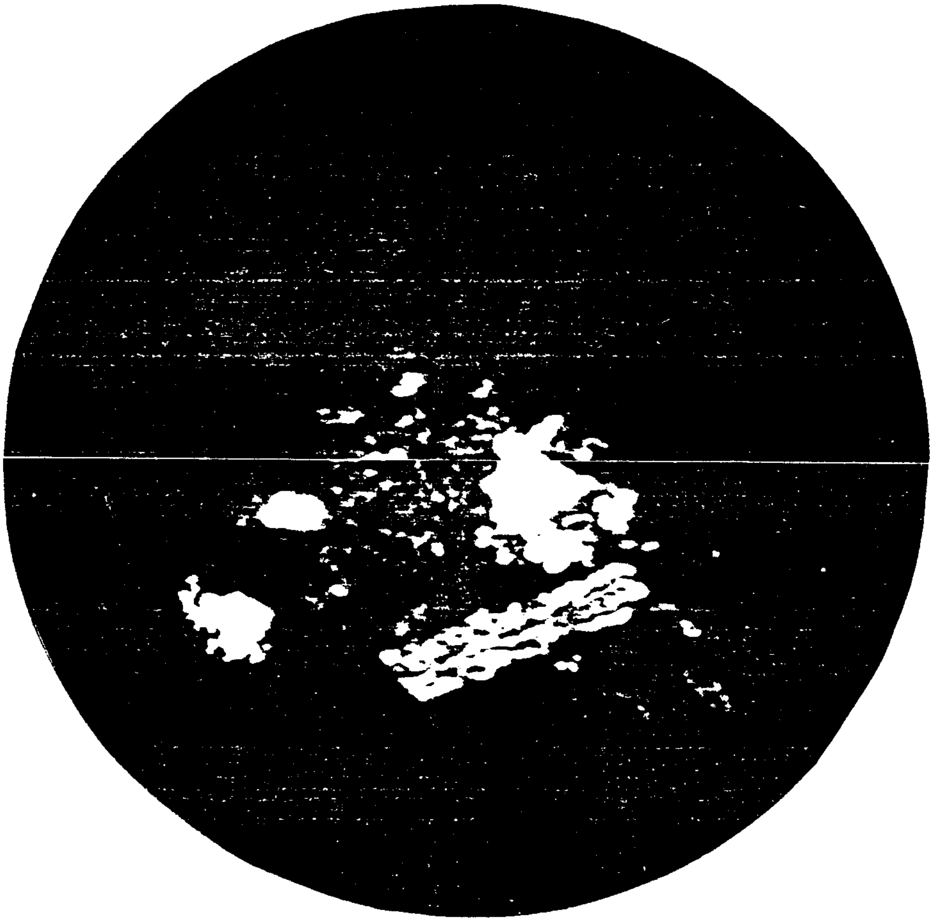

Figure 4. image of oxidized zone, processed by image analysis, of an Al-Si7Mg03 having a low oxide content

Figure 5. measurement of oxide level by application of thresholds: 6 %

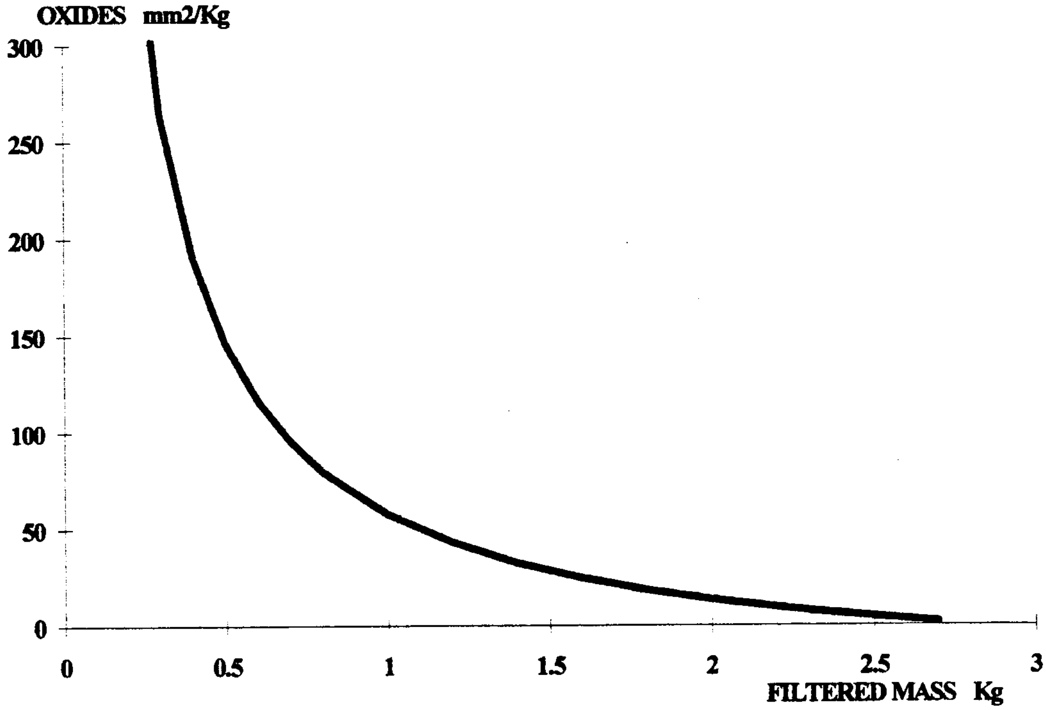

Figure 6. mass of Al-Si7Mg03 that passes the filter versus quantity of oxides

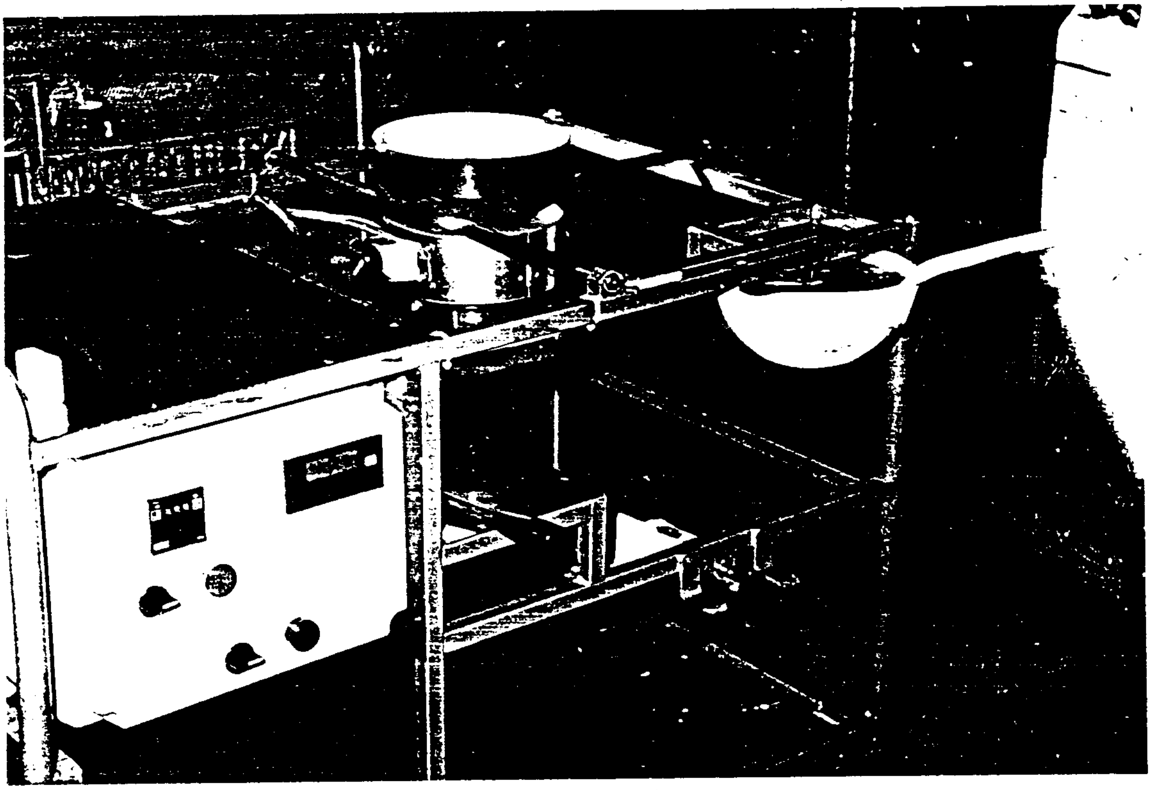

Figure 7. the QUALIFLASH

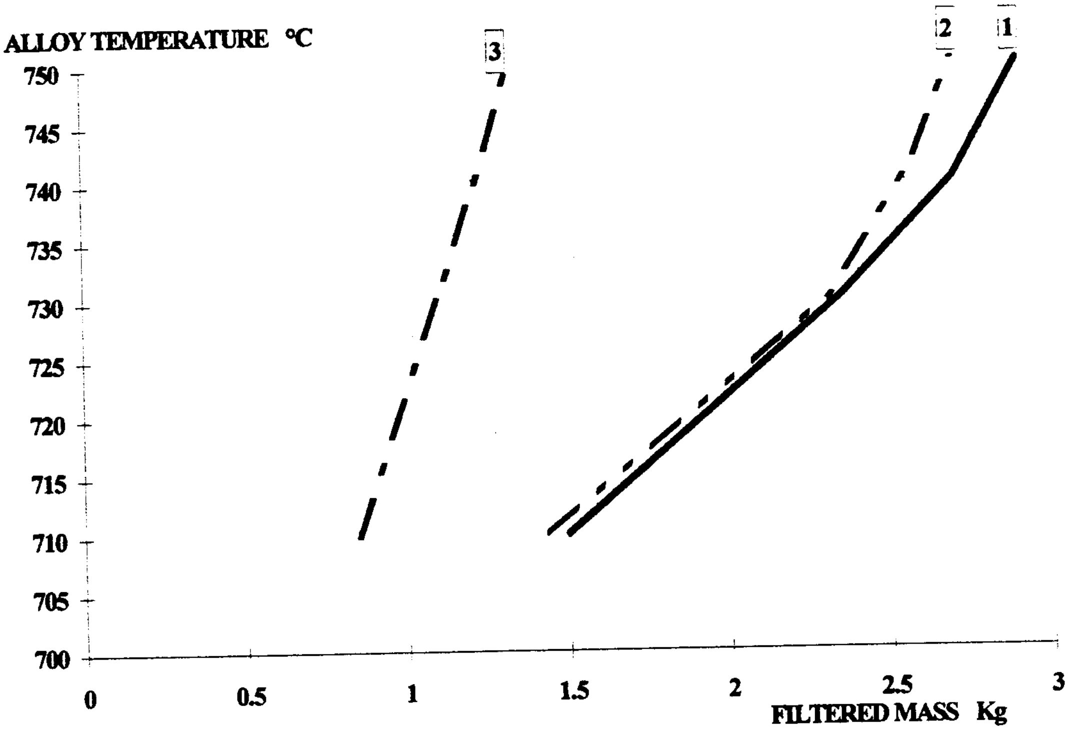

Figure 8. influence of the temperature of an Al-Si7Mg03 - unmodified ①, modified with strontium ②,and modified with sodium ③