On the occasion of the 2nd "Aalen Practical Days for Dosing of Aluminium of Cold Chamber Die-Casting machines" under the auspices of the world renowned die-casting expert Prof. Dr.Dr.hc. Klein, a number of presentations were given with regard to: **System Shot Sleeve, Plunger Lubrication (Porosity in Particular),** with special emphasis on Plunger Lubricant, which was identified as the major cause for defects.

Finally, a scientific investigation was presented on the following topic:

"The thermal reaction of different plunger lubricants and its influence on casting quality"

Summary of findings

- During application of the plunger lubricant a vast part of the lubricant evaporates. The fumes leave the sleeve through the pouring hole.
- During the pouring of the metal further evaporation of the remaining lubricant takes place, those fractions are transported with the aluminium and pressed into the casting. The result is: porosity and pinholes.
- A small part of black coke stays behind which serves to lubricate the plunger and to protect the sleeve against erosion.
- All plunger lubricants, whether they contain graphite or not, lead to evaporation of carbohydrates.
- With regard to white beads and light coloured oils, 98 % of the initial volume burns off or is transported and pressed into the casting. Only 2 % is left behind to lubricate and protect the sleeve against erosion.
- A new graphite bead has been developed which has, after evaporation of volatiles, a lubricating residue of 42 %.
- Graphite does not oxidise inside the aluminium smelt and does not form CO_2 gas when trapped inside the casting.
- Graphite beads in comparison to white beads or light coloured oils have a substantially higher amount of basic lubricant left behind. Subsequently the amount of lubricant used can be decreased by up to 75 %, whilst the protection of the sleeve is still guaranteed and the lubrication of the plunger more than sufficient.
- At this time highly loaded graphite beads and oils are the only way to produce pinhole-free and non-porous high pressure castings.

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As per Mr. Klein one can do an assessment on the porosity of a casting by simply looking at the gate, as follows:

Gate containing a high level of burnt oil; a high degree of gas porosity can be assumed with certainty

Gate with average degree of oil residue, gas porosity is possible

A clean gate; a gas porosity caused by the plunger oil can be excluded

Inclusion of petroleum coke under the casting surface; caused by oil residues of oils and beads, when used excessively.

The following investigation deals with different plunger lubricants by determining the cause and extent of

- casting porosity
- inclusions in castings and
- erosion of shot sleeve,

and how same are influenced.

Present state of casting technology

At this point in time there are white beads based on Polyethylenewax (PE-wax) as well as wax beads with different amounts of graphite in use.

This study will reveal that some beads are more suitable and other beads are less suitable for a successful die-casting process.

Furthermore, plunger oils with and without graphite have been scientifically evaluated.

These investigations are based on the following assumptions:

- The temperature on the inner lower surface of the shot sleeve during normal operation of a die-casting machine (600 tons and more) is around 300-350° C.
- Upon pouring the aluminium this temperature is increased for a short period of time to 600° C.

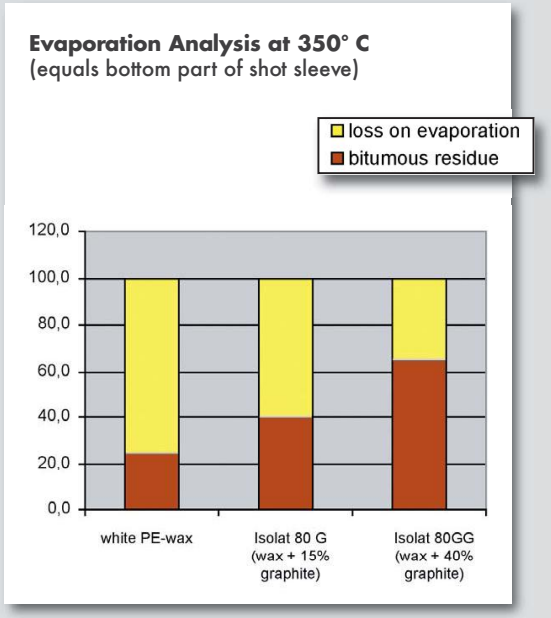
Details of the Investigations

- 2 gr. of plunger lubricant are evenly spread on the bottom of an aluminium bowl with a 70 mm diameter which is placed in a preheated muffle oven.
- It is left in the muffle oven for 2 minutes, the preheating time has been assumed as 1 minute.
- Thereafter the bowls are taken from the oven and placed on an analytical scale to determine the loss of evaporation.
- 2 tests are carried out with each specimen of samples, firstly at 350 ° C and subsequently at 600° C.
- The results are entered in a graph.

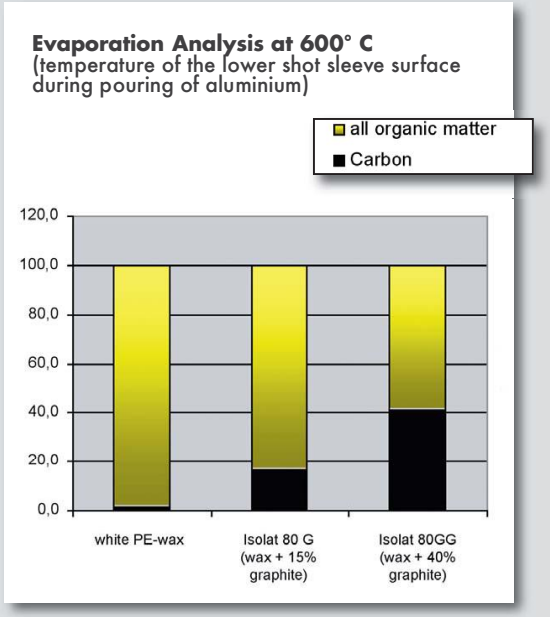
Visual Change of Different Plunger Lubricants

	room temperature	**350°C** heating 1 min at 350°C	**600° C** heating 1 min at 600°C
light coloured plunger oil			
white beads			
beads loaded with 15 % graphite			
beads loaded with 40 % graphite			

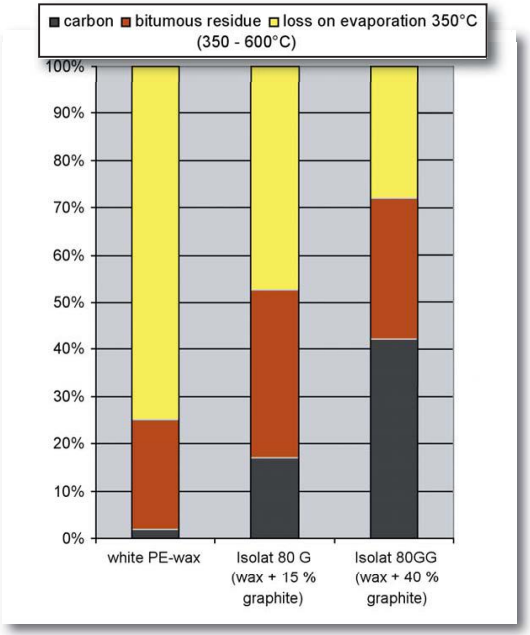
Evaporation Analysis at 350° C
(equals bottom part of shot sleeve)



Evaporation Analysis at 600° C
(temperature of the lower shot sleeve surface during pouring of aluminium)



Summary of Results



At 350° C (lower part of shot sleeve) combustion of volatile carbohydrates takes place, which escapes through the opening of the shot sleeve. Evaporation of the white beads is 70 % and more, and only 30 % and less for the graphite beads Isolat 80 GG.

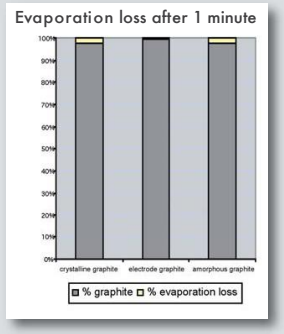
A brown, bitumous residue is left behind. During the pouring of the smelt this residue is heated to over 600° C for a short period of time, during which same evaporates and burns. Mixed with the liquid aluminium, the residues of these substances are transported by the plunger via the gate into the casting, and, after pressing at high temperature, generates gas which eventually forms pinholes and porosity. With regard to the 3 lubricants which have been analysed, this volatile fraction is between 20 and 30 %.

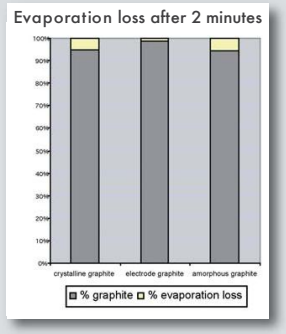
After the bitumous substances have been transported (moved) and inserted into the casting, a black residue of petroleum coke or graphite is left behind mostly on the surface of the lower sleeve. This coke or graphite is destined to lubricate and protect the sleeve against erosion. The petrol coke emanating from the white beads is crusty-hard without significant lubrication qualities; from time to time small parts of same break off and can eventually be found inside the casting. The residues of the graphite waxes are soft and shiny, and have excellent dry lubrication qualities, especially at elevated temperature. The amount of petroleum coke in the case of white beads is approx. 2 % and therefore much too low and insufficient for effective protection of the sleeve. This results in steel erosion.

Allegations have been made, that graphite in combination with oxygen forms CO_2 gas. For that reason the following research on the oxidation behaviour of different types of graphite has been investigated.

Oxidation behaviour of different graphite powders

All graphites which have been researched had a purity of 99.5 % carbon content. The evaporation investigation was carried out in a muffle furnace without inert gas in a normal atmosphere at temperatures of 600° C.





The analysis reveals clearly, that graphite heated for a short period to 600°C shows no or very little loss of weight. Synthetic electrode graphite shows better resistance to heat loss than natural graphite, whereas amorphous graphite has the highest evaporation loss.

Highly purified natural graphite, especially those of a macro crystalline nature, should be the preferred solid lubricant in plunger lubricants. This is because of its low friction value and excellent adherence to metal surfaces which is a result of its even lamellar structure.

In general one can argue that all types of graphite irrespective of its kind, when used in plunger lubricant do not cause pinholes through formation of CO_2 gas. Subsequently graphite has no adverse effect on the porosity of high pressure die casting parts.

Graphite can, provided it is fine and has lamellar structure, be used with confidence as the solid lubricant in plunger oils and waxes.

What happens to the plunger lubricant during the casting process?