THE FILTRATION OF LARGE CASTINGS IN SELECTED IRON AND STEEL FOUNDRIES

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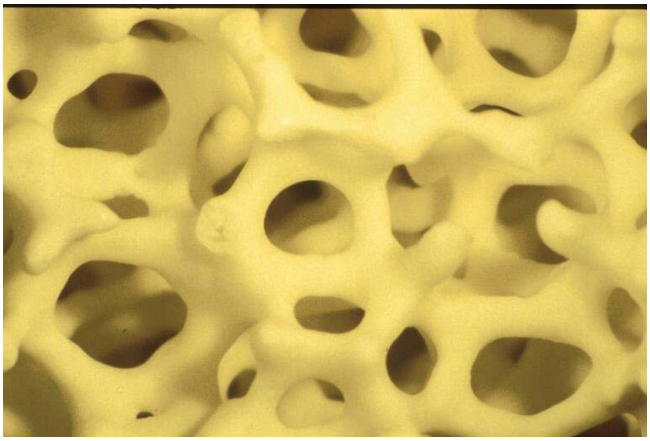
UDICELL is the protected trade name of the foam ceramic steel filter made from pure Zirconia by VESUVIUS HI-TECH CERAMICS, Inc.. These high duty oxides enable the filtration of all types of steel up to temperatures of 1720°C. In Europe and North-America more than 12.000 tons of steel castings are poured through UDICELL-Filters each month.
Increased efficiency of manufacturers by the reduction or elimination of rework, together with optimum use of existing gating systems are the main benefits of using filters.
This paper shows how filter are presently being used in production as a cost-effective productivity enhancement. It provides a description of the filter material, this unique structure, and how it works. The unique properties which remove slags, inclusions and other contaminants that cause defects and enhance productivity will be presented, as well as pouring times of filtered castings and expected flow rates of filters.
The development of new techniques has allowed the filters to be used for the production of very heavy castings in excess of the normal range up to around 25.000 kgs.
The Filters-Brick-Set is placed at each ingate allowing the filtering of large sized castings.
The Filter Carousel is preferred for more compact, heavy castings; a carousel-assembling having a capacity to filter up to 25.000 kgs of liquid steel.

FILTER MATERIAL PROPERTIES

The reticulated ceramics structure is a continuous ceramic network and its complement, a continuous network of void space made up of many pores in dodecahedral cells. Molten metal flows through these tortuous, convoluted pathways. The ability to make this ceramic structure from high performance oxides has allowed these materials to be optimised for the filtration of steel alloys at temperatures up 1700°C.
The premier ceramic material used for filtering these alloys is a partially-stabilised zirconia (PSZ/Mg) utilizing magnesium oxide as the stabilising agent. This material exhibits excellent thermal shock resistance due to the discontinuous distribution of micro-cracks formed as a result of the unique composition and manufacturing processing.



When filters are employed to improve casting quality, attaining adequate filling rate and assuring compete filling of moulds is critical. Filters must be able to withstand a variety of severe environments encountering in various casting processes. To achieve this, the material must have very good chemical, mechanical and thermal ruggedness.

Some filter material properties necessary to attain these process goals will be described as follows:

- Temperature capability
- Chemical inertness
- Physical properties
- Mechanical properties
- Thermal properties

The ceramics used are capable of withstanding the thermal upshock from room temperature to 1700°C without creeping or melting. They are chemically inert and, therefore, able to withstand the corrosive effects of the alloys and the slags with which they come contact.

FILTER PERFORMANCE REQUIREMENTS

Satisfaction of the following requirements is essential for successful filtration:

- high filtration efficiency
- satisfactory casting rate
- chemical stability
- mechanical and thermal ruggedness
- cost effectiveness

Filters must also have a very high filtration efficiency to eliminate as much slag, oxide inclusions and other contaminants as possible. Most importantly, they must be of consistent quality and dependability, to be cost-effective.

These filters have a very high surface area, maximizing the amount of zirconium oxide available to come in contact with the inclusions and remove them from the melt stream. They have a very low bulk density therefore low thermal mass, so they require very little heat transfer to attain temperature permitting initiation of metal flow. They have the mechanical integrity to withstand the impact of the initial metal flow as well as the metal static head which develops while castings are poured quickly through them.

Filters used in productions must be consistent in flow, strength and uniformity of web and pore size. Eliminating pore blockages during filter manufacturing is critical to assuring consistent flow rates and fill times for the user.

Defects which can be detected in the filter macrostructure are webs that are not fully rounded and have sharp triangular edges. These have the potential to break off and contaminate castings. Blocked pores throughout the filter can reduce flow rates or cause inconsistencies in flow rates from one filter to another. Filter openness can be easily checked with bright back-lighting and is a suggestion for quality comparison.

EXPECTED FLOW AND CAPACITY RATES

Flow rates are determined in general form for stainless steels in table 1.
Stainless steel, e.g. 18% Cr. 8% Ni at pouring temperatures of 1530 – 1590 °C show an experienced flow rate of 0,25 kgs/sec/cm². That is the basic guide line the reader finds in column 10 PPI. A 4X4” filter, 10 PPI has an effective filter area of 64 cm²; multiplied with the a.m. factor 0,25 you get a flow rate of 16 kgs per second. All other calculation are based on this experience.
These numbers are deliberately conservative and variations from these numbers would be expected.

The variables that directly effect flow through filters are:

- metal fluidity
- metal static head above filter
- size and amount of contamination
- method of desoxidation
- filter installation
- sizing of runner system
- pouring temperature

Table I Flow rate and flow capacities with UDICELL-PSZ

Flow rate high alloyed steel, pouring temp. 1530-1590°C

Filter size		ledge size	effective filter area	effective filter area	kgs/sec (0,25)	kgs/sec (0,22)	kgs/sec (0,20)	Flow capacities direct pouring	indirect pouring
Inch	mm	mm	mm	cm²	10 PPI	15 PPI	20 PPI	kg	kg
2"∅	50,8∅	5	40∅	12,5	3,1	2,7	2,5	30- 50	20- 40
2x2"	50,8²	5	40x40	16,0	4,0	3,5	3,2	40- 70	30- 50
2x3"	50,8x76,2	5/10	40x55	22,0	5,5	4,8	4,4	70-100	50- 80
3"∅	76,2∅	10	55∅	23,8	5,9	5,2	4,7	90-120	60- 90
3x3"	76,2	10	55x55	30,0	7,5	6,6	6,0	120-150	80-110
3x4"	76,2x101,6	10	55x80	44,0	11,0	9,6	8,8	130-180	100-130
4"∅	101,6∅	10	80∅	50,0	12,5	11,0	10,0	150-200	110-140
4x4"	101,6²	10	80x80	64,0	16,0	14,0	12,8	180-250	120-150
5x5"	127²	15	105x105	110,0	27,5	24,2	22,0	250-350	150-200
6"∅	152,4∅	15	120∅	113,0	28,0	24,8	22,6	250-350	150-200
6x6"	152,4²	15	120x120	144,0	36,0	31,6	28,8	350-450	200-250

FILTER INSTALLATION METHODS

HI-TECH CERAMICS recommends methods for filter installation that allow the customer to achieve their desired results. Typically the foundryman then develops many other filtration methods to meet his own needs. After understanding the basic concepts of filtration, filters are considered user-friendly. Imaginative thinking is the only limit to successful filtration.

With the experience of nearly one decade of filter practice in steel sand foundriey, plenty of individual installation methods have been created, customshaped.

Two basic systems have been developed:

- direct pouring
- indirect pouring

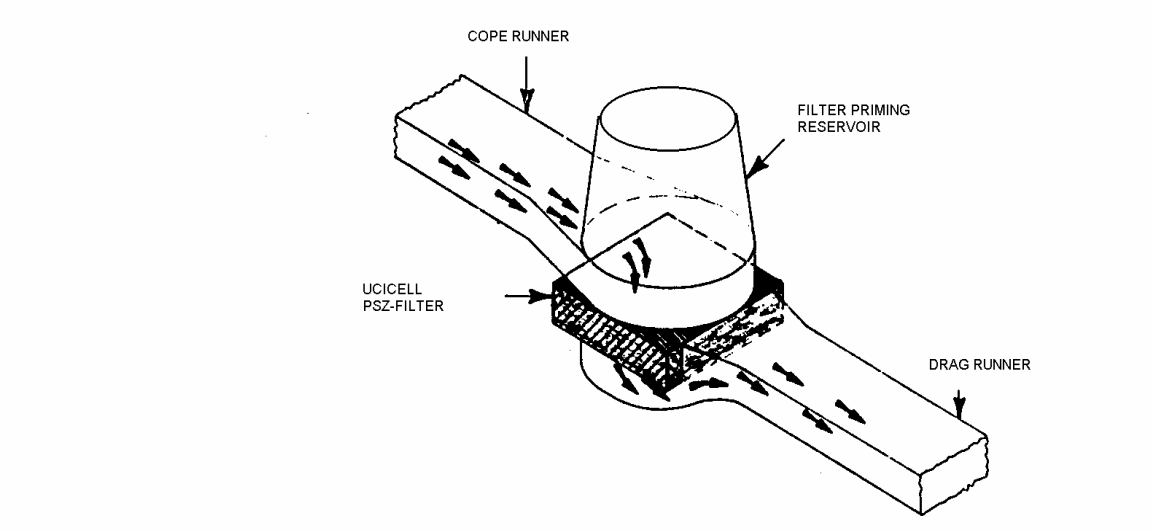
DIRECT POURING

Direct pouring, known in investment casting processes for two decades, allows the filling of the mould cavity directly through the filter, either in the down sprue or in the feeder. The dynamic impact to the filter surface increases the filtration capacity up to 50 % and more, compared to indirect pouring systems. On the other hand direct pouring is limited by weight, as only one or two filters can be used, stainless steel is poured up to 600 – 800 kgs with a single 8” diameter filter, manganese steel e.g. passes the same filter with 1.300 kgs.

Filter-Boxes are vacuum-formed alumina fiber pouring cups that can be used more then once to support the filter and act as a pouring basin. They can be installed on top of the mould in a simple metal frame, allowing the filter to be installed without any expensive equipment modifications, providing immediate trial results.

INDIRECT POURING

Indirect pouring is the system with the most variable techniques. Zirconium oxide, the filter ceramic, requires a certain amount of heat to allow the metal to pass the reticulated filter: so called PRIMING. The filter takes this heat from the first metal steam. Not to create a blockage a reservoir is build above the filter surface to give the necessary thermal volume.



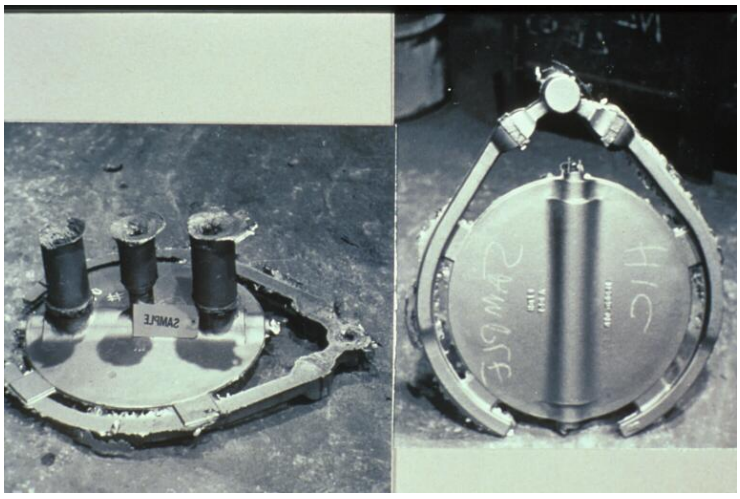
HORIZONTAL FILTER POSITION

Horizontal filter positioning permits enlargement of the filter area. This is best suited for situations with low viscosity alloys, having good fluid life. No Priming reservoir necessary.

HORIZONTAL FILTER POSITION WITH RESERVOIR

This is standard application of a filter in a runner. Calculation of filter cross-section is related to steel quality, quantity and pouring temperature. The height of reservoir and the depth of the well also come into play. Typically, a well that is twice the depth of the filter thickness and a reservoir that is approximately three times the well depth provides enough thermal mass to preheat the filter and initiate instantaneous flow through the filter. It also allow gross liquid slags to float in the reservoir above the filter such that they do not reduce filter capacity.

VERTICAL FILTER POSITION IN GATING SYSTEM



Photos above show the vertical position. This allows for easy placement of the filter in the gating and is only recommended for high alloy steel which has a low viscosity. The simple addition of a print to the gating system allows for easy installation of square filters.

The left photo shows a typical aircraft turbocharger with gating and vertical filter placement.

The right photo shows two 2,5 x 2,5 X 1” 10 PPI filters vertical in the gating for an 18” Butterfly Valve Disc.

FILTERGATING SYSTEM WITH FILTERBRICK-SET

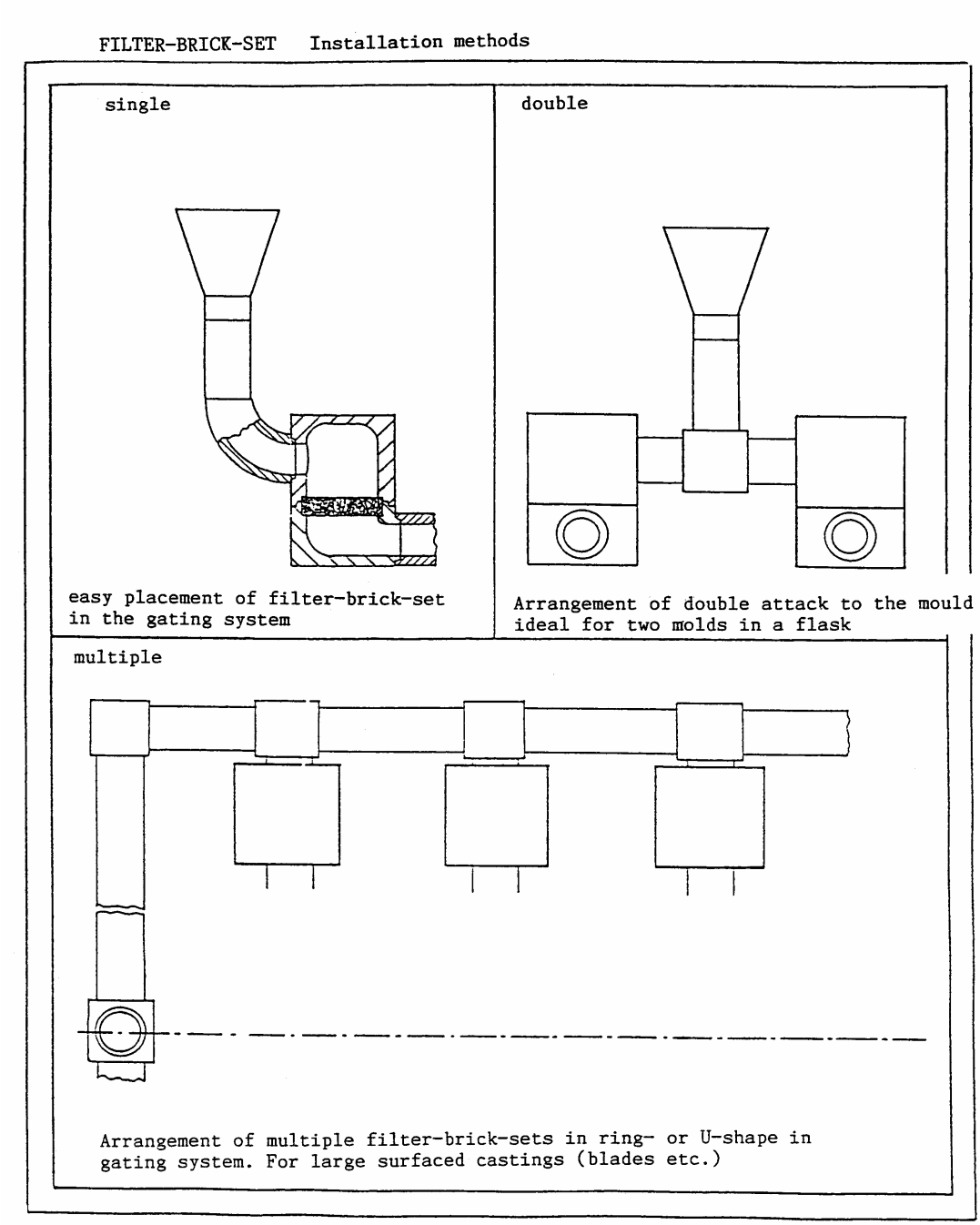
Refractory gating system has been designed to fit in with the various sizes of filter and multiple, unlimited filter positioning. They also have been designed to fit to existing gating systems. The combination of multiple systems allow the pouring of large, heavy and clean castings.

The system finds its applications or levels. All refractory gated at multiple positions or levels. All refractory pieces can be connected by male/female joints and allow the pour into the mould at various positions to flood the mould cavity.

The refractory item with the filter print is located in front of each ingate. The ingate can be positioned at the top, the bottom or the sides. The ratio of the cross section is selected as follows:

DOWN SPRUE		TOP RUNNER		BOTTOM RUNNER		EXIT
1	:	1,3	:	1,2	:	1

The runner balance after the down sprue should be devided, the sum of the cross sectional area to be of the correct ratio. By choosing multiple runners it is possible or pour casings of all sizes. Using bottom pouring ladles it is recommended to use multiple nozzles or ladles.



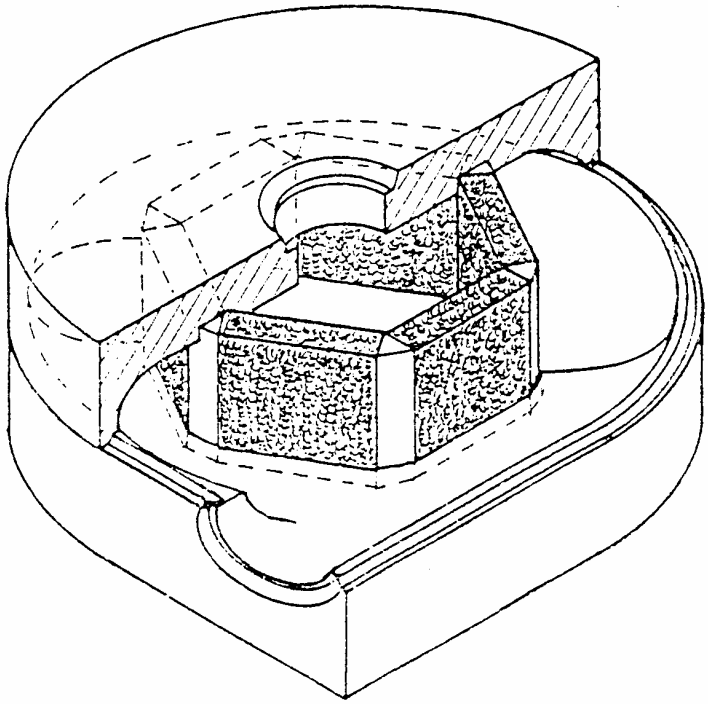
FILTER CAROUSEL - FOUNDRY APPLICATION

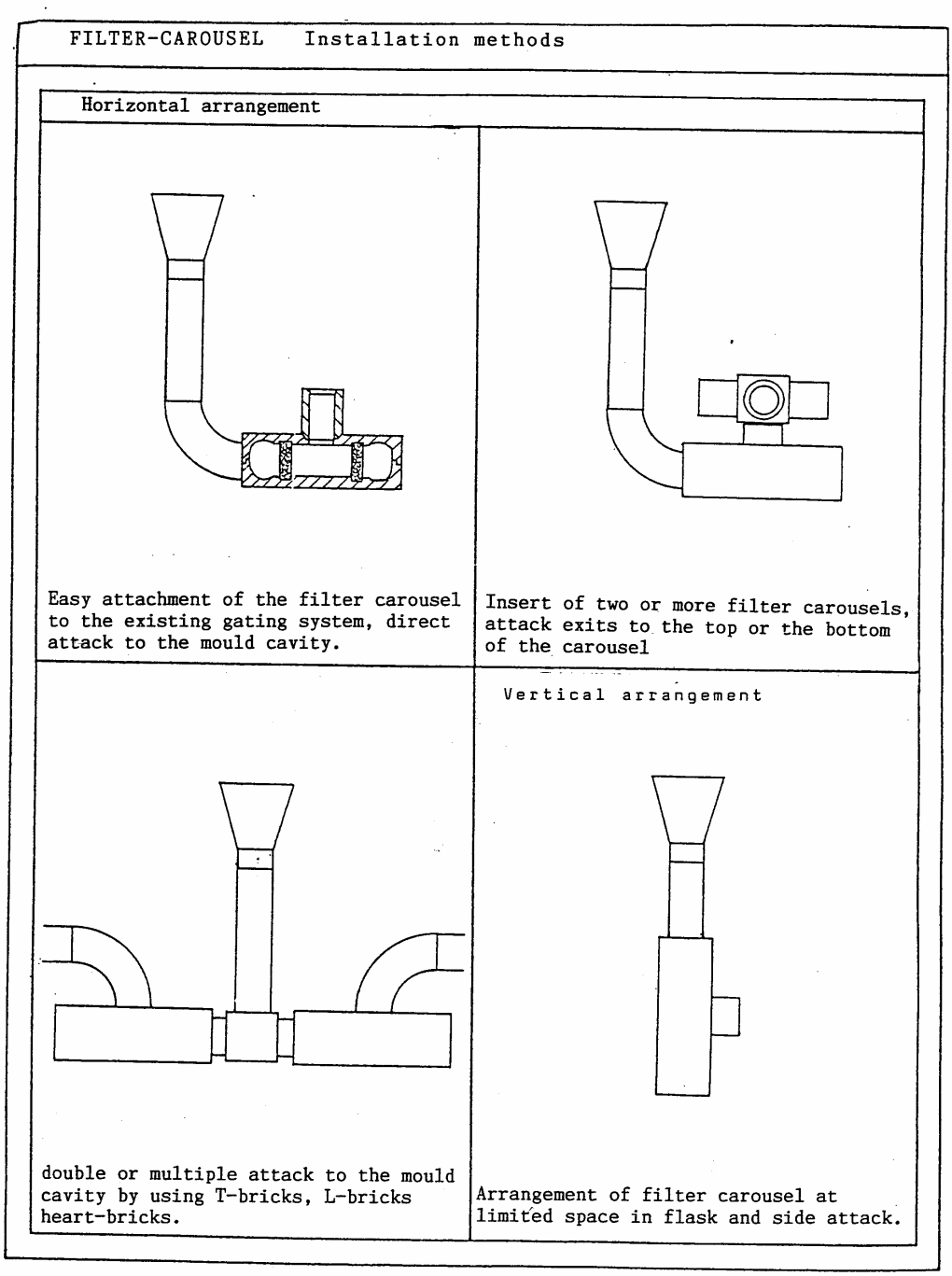
The concept of the invention is to allow a tangential flow of metal into the ring or channel infront of the filters. A convexity is incorporated at the top and bottom of the channel to allow the segregation of lower density particles keeping the filter more free for deep-bed-filtration.

The tangential flow also facilitates the prevention of coarse impurities approaching the filter surface. Finally the metal penetrates the filter and exits at the top or bottom of the carousel to enter into a connected refractory gating system or directly into the mould cave.

A filter carousel type 6/4Q contains 6 filters 4x4x1,25” and is capable of filtering steel in a range of 1,5-3,0 tons. In daily practice castings up to 8 tons pouring weight are filtered through the system to foundrymen´s satisfaction.

A filter carousel type 6/6Q contains 6 filters 6x6x1,25” and is capable of filtering steel in a range of 2,5-6,0 tons. The largest casting made with four of these carousels is a caplan blade with 16 tons poured weight.





PERFORMANCE RESULTS

FLOW MODERATION

A filter acts as a choke, controlling the flow and allowing a head to be developed on the upstream side of the filter. This promotes secondary flotation, preventing large gross contaminants from entering the mould itself. As the metal passes through the filter and exits the downstream side of the filter, the stream is very laminar and non-turbulent. This reduces erosion potential and gas entrapment through out the gating system to the casting, as well as kinetic impact of the metal stream on the mould.

DEGASSER

Degassing resulting from filtering is particularly useful in many circumstances. Degassing has proven to be beneficial in sulfurized stainless and high pour weight, thinwall, low alloy steels. Reticulated ceramics create backpressure as flow steam coalescence occurs within the structure. This allows gas to escape as energy is reduced and surface area is minimized.

INCLUSION REMOVAL

Filtration is accomplishes, primarily on oxides, resulting from melt processes. Oxides formed from the erosion of crucibles, walls, ramming mixes and topping mixes are removed by the filter. These oxides are of a different density than the metal stream, so as the metal passes through the tortuous paths of the reticulated structure they come into contact with the high surface area of the filter. Because metals are typically non-wetting to oxides, the oxides reduce their free energy by contacting the surface of the filter. This permanently attaches the oxide inclusions to the filter so subsequent metal streams do not wash them back of . This conclusion has been proven by sectioning filters and then using a scanning electron microscope to analyze the oxide built up on filters after “dirty” alloys have been poured through them.

SLAG REMOVAL

When filters are used properly and a metal head is generated above the filter, on opportunity for secondary flotation is given. Glassy slags of specific densities lower than the molten alloy, will float to the surface in the pool of metal above the filter. Glassy slags and snotty slags that have specific gravities similar to or greater than the metal have a tendency to become entangled or wrapped around the webs as the metal passes through the tortuous path of the filter media.

The main benefits foundrymen realize by using UDICELL – PSZ (Mg) filters are listed below:

- Calming of the metal flow / Creating laminar flow
- Reducing / eliminating slags and non-metallic inclusions
- Degassing of the melt
- Increasing yield by reducing runner systems
- Increasing yield by direct pour method
- No or less rework
- Longer life a machining tools
- Reduction of manufacturing tolerances
- Reducing thermal cracks
- Shorter delivery terms – castings are often ready for shipment soon after pouring
- Turn non-profitable jobs into profitable ones
- Develop new market with higher quality demands

Table II Production data of selected steel castings filtrated with carousel filters

Casting	Weight kg	Quality	Material DIN	Pouring temperature °C	Pouring time sec.	Number of carousel	Customers remarks
Swivel bearing	1.950	C-25	1.0406	1590	34	1	About 50 % fettling time reduction and about 60 % machining tools service life increase.
Roller rings	1.500	X 330 NiCr 4 2		1290	36	1	Other usual non metallic inclusions on the edge (outer part) of the rings were eliminated for the greatest part. Scrapate decrease of about 45 %.
Cylinder cover	600	17 CrMo 5 5	1.7357	1590	11	1	For these castings, there were so far many customer's complains related to non metallic inclusions. No complaining any more, now.
	1.750	17 CrMo 5 5	1.7357	1590	35	1	
Piston rings	1.800	17 CrMo 5 5	1.7357	1590	38	1	Over 55 % of the finishing costs could be reduced and success rate increased to 95 %.
	2.900	17 CrMo 5 5	1.7357	1580	50	2	
Roll tires	1.850	X 270 CrNi 9 6		1430	42	1	The production ot these castings used to be refused up to now, due to too many non metallic inclusions. Nowadays customer's satisfaction and high speed finishing is a guarantee.
Housing (casing)	2.100	15 Mn 3	1.0467	1580	45	1	45 % less finishing.
Housing lower part	1.750	GS-45	1.0446	1570	35	1	50 % less finishing.
Housing	1.985	C-25	1.0406	1595	42	1	Particularly smooth running at all casting stages ; no noticeable change in the casting process. Due to its unquestionable quality, the casting was immediately taken to the mashining shop, whereas 3 identical components, cast out of the same heat needed a heavy and costly fettling.
Housing	2.400	G-X 8 CrNi 13 1	1.4008	1 560	19	2	A 975 DM saving on finishing, compared to unfiltered housings.
Rotors	3.850	WBL 410-81	1.4405	1564	46	2	30-50 % less welding costs compared to previous rotors.
Pump casing (housing)	3.930	SIS 2324	1.4460	1514	75	2	
Rotor	11.730	G-X 6 CrNiMo 18 10	1.4408	1530	60	2	Surface defects reduced to over 50 %. Faster and much lighter finishing as there are no subsurface sand or slag inclusions.
Rotor	9.500	ASTM A 747-84a		1535	60	2	
		CB 7 Cu-2		1535	60	2	

SUMMARY

UDICELL, the advanced reticulated filters, made by HI-TECH CERAMICS, have been generated to the application in steel foundries al a cost effective productivity enhancement.

Materials have been optimized for the filtration of steel alloys up to 1700°C. The premier ceramic is a partially stabilisized zirconia (PSZ(MG)) with excellent thermal shock resistance.

They are capable of removing inclusions, eliminating trapped gas and provide laminar streams of metal to fill the mould.

New refractory gating systems have been designed to allow the pouring of large, heavy and clean castings. Filter Carousels allow tangential flow of metal and clean pouring of heavy castings and ingots.

Alumina-Filter-Boxes are for uncomplicated trials and direct pour applications.

By using filter installation techniques that the best suit individual foundry practices, profitability can be improved by 10 % or greater on problem castings, turning non-profitable jobs into profitable ones and enhancing customer satisfaction.

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