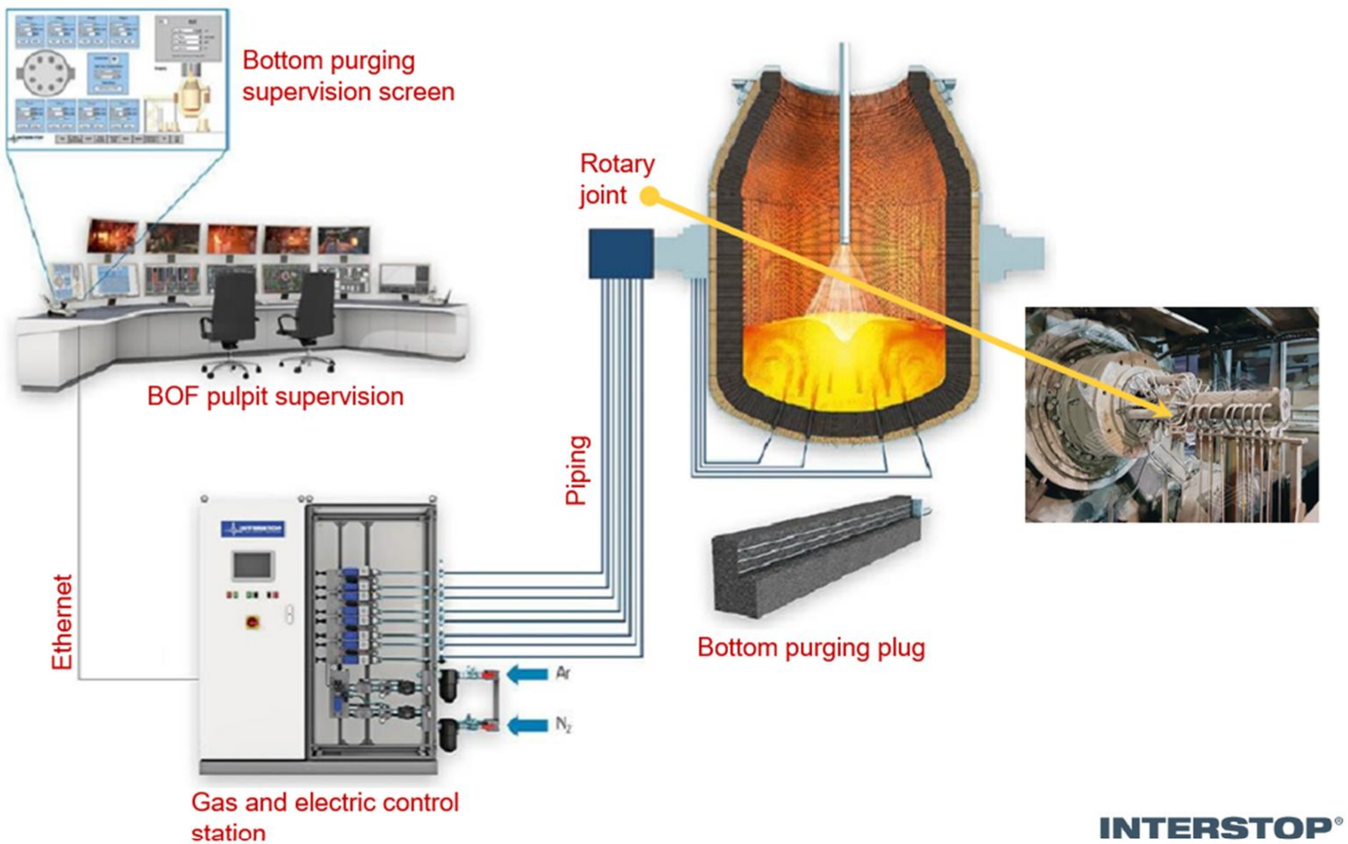
INSIGHT INTO CONVERTER BOTTOM PURGING

Kaushik Dasgupta

REFIS 4.0 23-24 September Bokaro Steel City Jharkhand India 2022

23-24 Sept 2022,Bokaro Steel City



Converter Inert gas Purging(CIP)

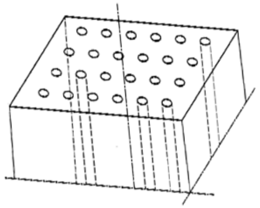
Purging plugs, piping, rotary joint

Gas Control Box(gas & control station)

Visualization, archival storage

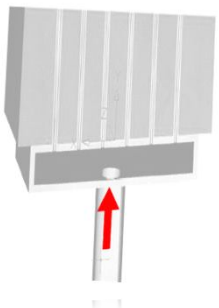
Bottom purging patterns linked to steel grade portfolio

2



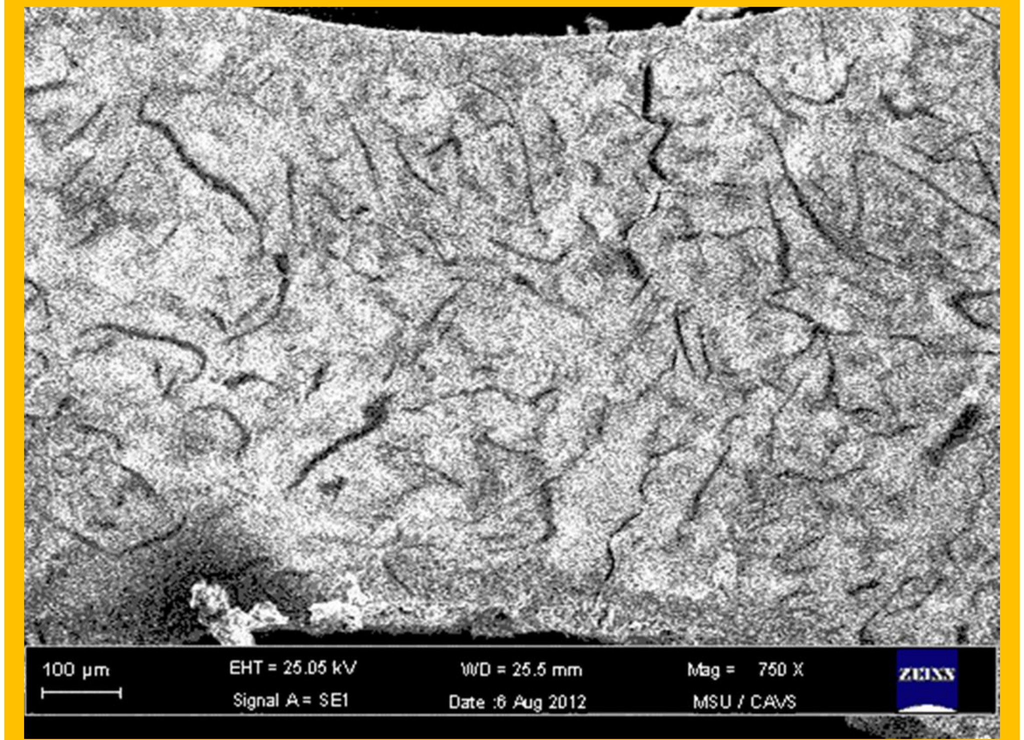
Magnesia carbon

Pipe ID:1-3mm



	MHP18	MHP24	MHP32	MHP40	MHP60	MHP100
Pipe Number	18	24	32	40	60	100
Ideal flow Nl/min	600	800	1000	1200	1700	2500

Brick design(MHP)



A bottom purging element is not just another piece of magnesia carbon brick that you build slits into and watch it delivering the gas!

Inadequately developed element results in:

Severe thermomechanical stress

Excessive wear and/blockage of slits at a very early stage of converter campaign

Metallurgical benefits achievable only for a meagre part of the campaign.

Temperature distribution in bottom during blowing

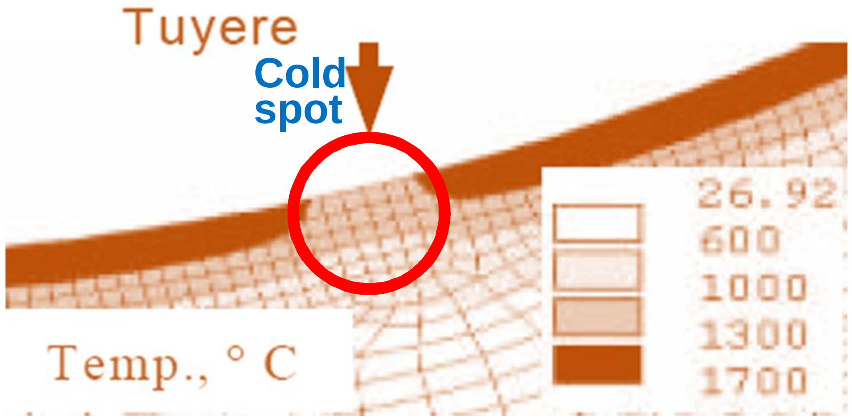
Without bottom-blowing, the measurements of bottom show regular fluctuations of the temperature during the cycle(empty-filling-blowing-tapping-empty).

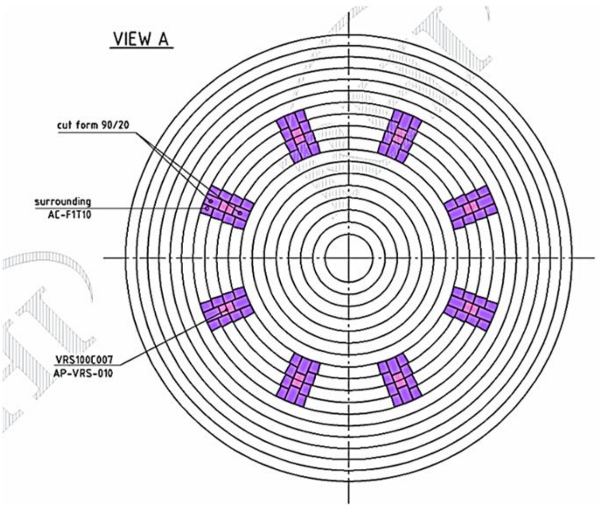
The temperature starts growing at the beginning of filling.

After tapping the lining cools down.

Temperature distribution in bottom during blowing

During bottom blowing, the inert gas cools down the lining around an active bottom blowing element**(cold spot)** and the cooling effect is proportional to the flow rate.

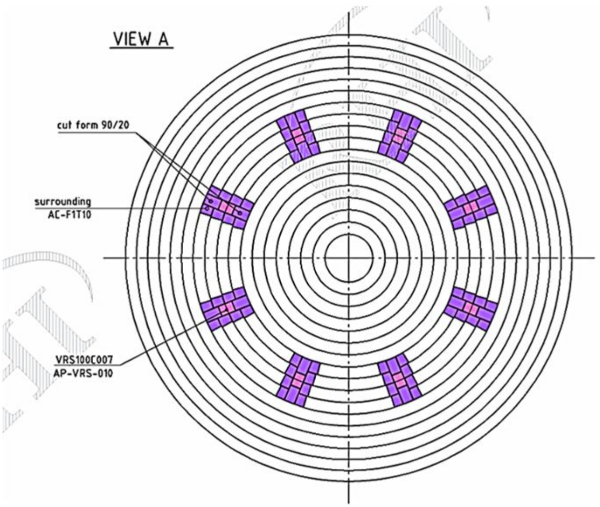


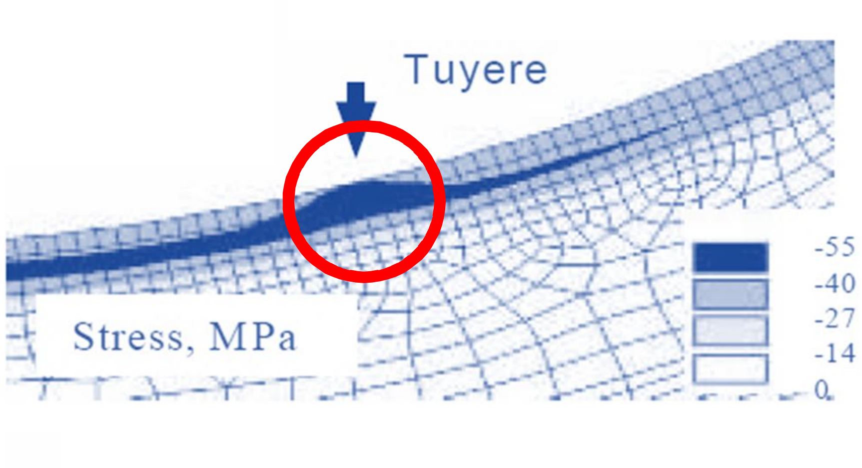


Hot face temperature around purge element is in “stiff” range than rest of the bottom………...

Temperature distribution in bottom during blowing

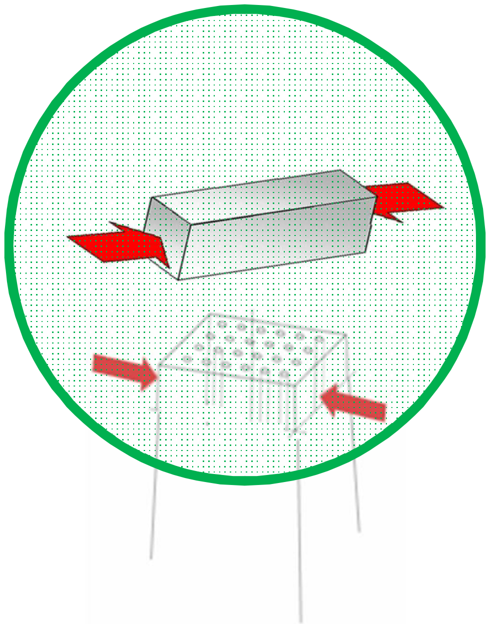
During bottom blowing, the inert gas cools down the lining around an active bottom blowing element **(cold spot)** and the cooling effect is proportional to the flow rate.





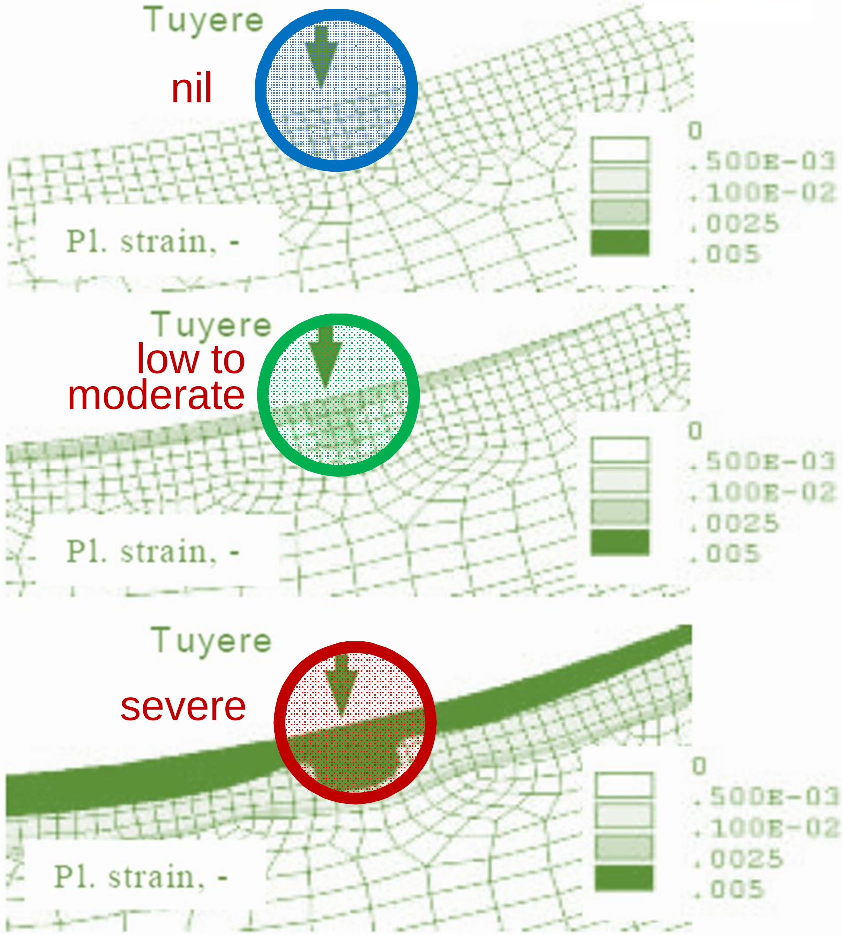
..........so compressive stress here is much higher than rest of the bottom

Plastic strains (compressive damage) during blowing



Compressive stress often high enough to exceed material strength

Makes the blowing element and bricks surrounding it, most vulnerable to compressive spalling.



MgO-C purge plug manufacturers are often tempted to use a refractory that is as strong as possible so that the material can withstand the stress due to cyclic loading.

Well, this holds good so long as the system remains free of cracks!

But cracks in MgO-C refractories exposed to fatigue conditions are inevitable!!

In these situations, knowledge of the fracture toughness is required to determine how long the brick can remain in service before the crack grows so long that the intact cross-section cannot support the load, and the brick fractures.

Difference between strength and fracture toughness

Designers must be concerned with both the strength and the toughness of the material being produced

optimization

The **strength** must be large enough so that the material can withstand the applied loads without deforming

The **toughness** must be sufficient for the material to withstand the propagation of fatigue cracks without failing catastrophically

For a given load, as fracture toughness increases, the refractory can tolerate a longer crack before fracturing!

Difference between strength and fracture toughness

Resistance to initiation of crack is important but more important is how ably you can control the crack propagation once it is generated!

This is where the right formulation of the matrix comes into play

- quality of magnesia aggregate and graphite flakes used
- grain size distribution
- aggregate-matrix interface
- porosity
- right additives and binder

Difference between strength and fracture toughness

Effective tortuousness of crack path

Only a full proof matrix can promote an effective tortuousness of crack path that transforms crack **"activation energy"** and energy dissipation, from **"burst type" to "slow releasing type"**.

Two important parameters for selecting the right kind of formulation for bottom purging elements

$R = \sigma(1 - \upsilon)/\alpha E$

- indicative of resistance to **crack initiation** by thermal shock
- represents the maximum temperature gradient before cracks are formed.

  That is, the higher the value of R, the greater the resistance to nucleate cracks due to stress by thermal origin

σ_T is the thermal stress
E is the Young´s modulus
α is the coefficient of linear thermal expansion
υ is the Poisson´s ratio

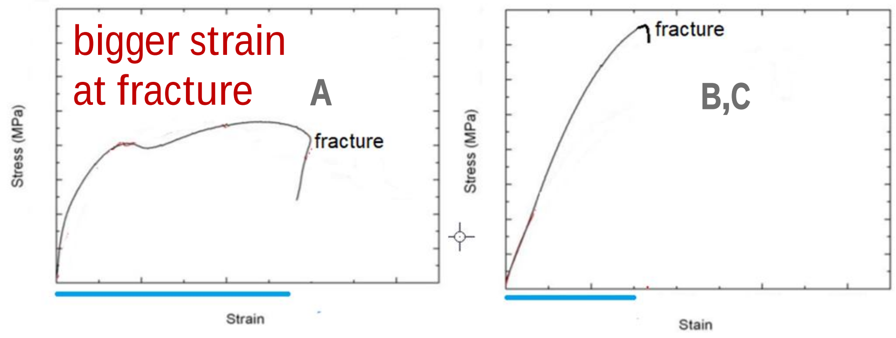
the parameter R´´´ is more relevant in refractories since these materials often contain a large population of inherent flaws (pores and microcracks)

$R''' = E/\sigma^2(1 - \upsilon)$

- Indicative of resistance to **crack propagation**
- indicates the minimum elastic energy, in the fracture zone, available for the crack propagation

  That is, the higher the value of R''', the greater the resistance to propagation of cracks

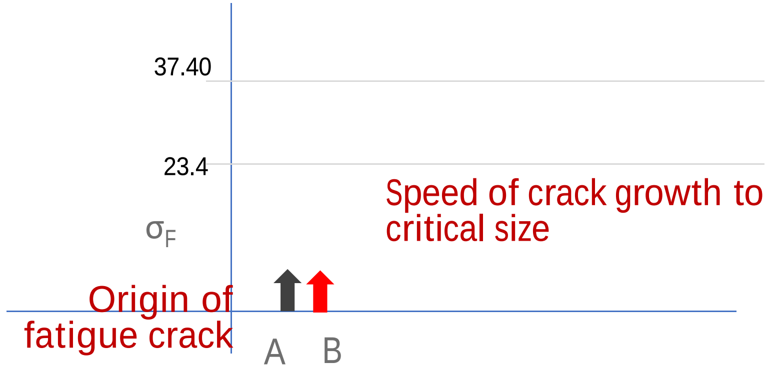
BRICK	σ_F (MPa)	ε_F (%)	R(^{O}C)	R'''($x10^{-5}$ Pa^{-1})
A	23.40	0.50	171	2.90
B	37.40	0.31	327	0.80
C	24.10	0.34	330	1.10



- The brick “A” meets the best combination of parameters R and R’’’

- Despite having a lower value of **fracture strength(23.4MPa)**, **“A”** has a higher value of **deformation % at fracture(0.5%)** owing to a much better placed R’’’, thus increasing the strain at fracture.

- For “**B**” and “**C**”, the higher values of fracture strength is **offset by a speedier propagation of a fatigue crack** to the point of fracture (lesser values of R’’’)



Factors needed to be addressed

Material properties

The most important parameter is the material flexibility and strength
The right balance of the two!

Bottom structure

Use of different qualities around bottom blowing elements and rest of bottom

Optimization of bottom blowing process

Reduce the cooling effect of the blown gas (optimizing flow rate, channel size)

Pressure, Flow, Velocity:

Determining which variable is Important

Understanding the interdependent nature of **pressure, flow and velocity** is important when designing a system but more important is understanding when each variable is the critical design parameter.

RHI MAGNESITA

Velocity

The force of a fluid comes from the fluid impacting at high velocity. The velocity is increased by forcing a volume of fluid through a constricted outlet. While the fluid is moving very quickly, it is not necessarily a high volumetric flow rate; this is a common misconception.

Flow

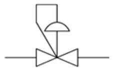
Flow is critical when the fluid needs to fill a space. You need to supply a given volumetric flow rate that continuously fills and replenishes the application space.

Pressure

If an application is expected to have a high back pressure, the system must be rated to operate at that pressure. Characteristics of a system with a high level of back pressure include multiple lengths or long lengths of hose or pipe and applications where gas is forced through small openings.

Concepts that go into making an efficient bottom purging

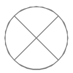
Back pressure



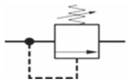
Volumetric flowrate & mass flow rate

$\dot{m}$ $\dot{V}$

The working principle of an efficient bottom purging



Closed loop fluid control

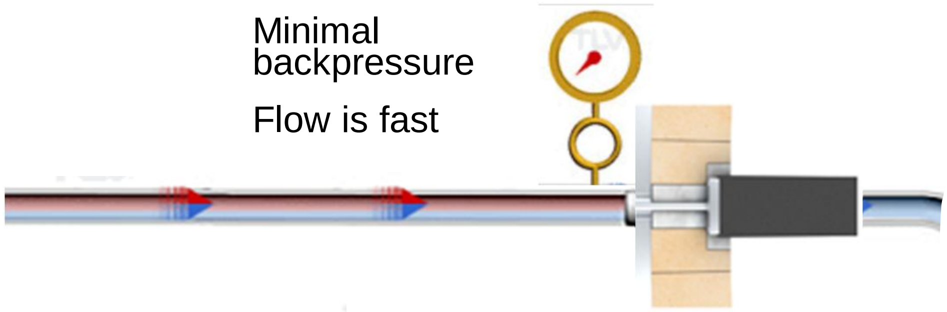


Pressure control & flow control

19

The concept of backpressure

When a fluidic substance moves through a pipe, it builds up a lot of kinetic energy and inertia. When that energy hits a wall(say a blockade by infiltrate in the plug), it bounces back like ripples.



How a backpressure works?

The flow remains essentially in the same direction, but the flow is reduced due to resistance.

Open-Loop vs. Closed-Loop Fluid Control

In the simplest terms, if the controller supplies **input**(action) via **feedback from the process itself** and this input is directly related to the **output response** or result, the system is closed-loop, if not it is considered open-loop.

An efficient CIP always thrives on a closed loop control

For obvious reasons, open-loop systems are less accurate, less repeatable and (generally) less costly.

Volumetric flow rate

Volumetric Flow Rate, also called the actual flow rate, is dependent on Pressure & Temperature and hence are recommended for measuring volumetric flow when high accuracy is not needed

Mass flow rate

Mass Flow Rate is independent of Pressure & Temperature and hence more reliable with higher accuracy and repeatability.

Relation between Mass flow rate & Volumetric flow rate

$PV = nRT$ ➡ $V = \ldots$

The ideal gas law

$\rho = \dfrac{m}{V} = \ldots$

$$\dot{m} = \rho \cdot \dot{V} = \frac{mP}{nRT} \cdot \dot{V}$$

- **$\dot{V}$** Volumetric flowrate
- **$\dot{m}$** Mass flow rate
- **m** molar weight
- **n** moles
- **R** real gas constant
- **P** pressure
- **T** temperature

Example: a 200 sccm flow sensor with a mass flow rate of 0.250 g/min (200 sccm) for N2

RHI MAGNESITA

STP

$\dot{m}$	0.250	g/min
m	28	g
n	1	mole
R	82.1	$(cm^3*atm)/(mole*K)$
P	1	atm
T	273.15	^oK

$\tilde{V}$= cm^3/min

Non std.conditions (T has changed)

$\dot{m}$	0.250	g/min
m	28	g
n	1	mole
R	82.1	$(cm^3*atm)/(mole*K)$
P	1	atm
T	298	^oK

$\tilde{V}$= 219 cm^3/min

volumetric flow is 219 cm^3/min

mass flow is sccm/min

Non std.conditions (P&T changed)

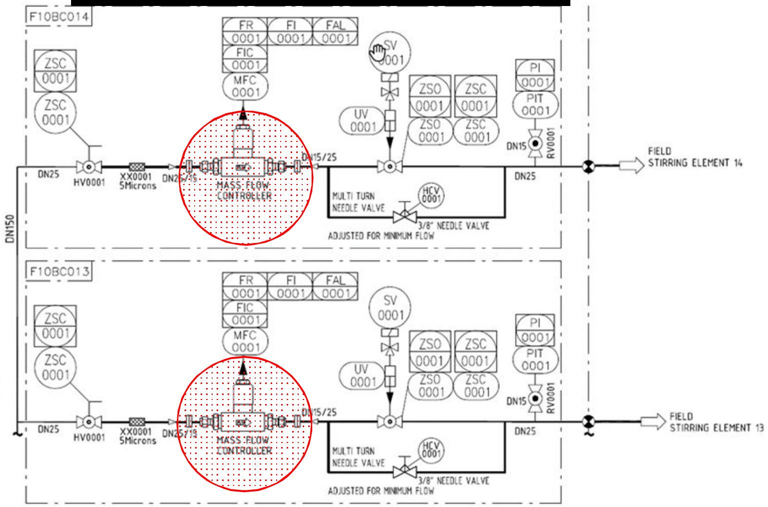
$\dot{m}$	0.250	g/min
m	28	g
n	1	mole
R	82.1	$(cm^3*atm)/(mole*K)$
P	1.5	atm
T	298.2	^oK

$\tilde{V}$= 146 cm^3/min

volumetric flow is 146 cm^3/min

mass flow is sccm/min

[redacted]



Mass compensation

The mass flow controller will automatically control the flow rate of a gas according to a set flow rate sent as an electric signal, the measured flow being **mass compensated** for any change in temperature and pressure

$\tilde{V}$= nRT/(mP)*ṁ

- $\tilde{V}$ Volumetric flowrate
- **ṁ** Mass flow rate
- **m** molar weight
- **n** moles
- **R** real gas constant
- **P** pressure
- **T** temperature

ṁ	**0.250**	g/min	**ṁ**	**0.250**	g/min
m	28	g	**m**	28	g
n	1	mole	**n**	1	mole
R	82.1	$(cm^3*atm)/(mole*K)$	**R**	82.1	$(cm^3*atm)/(mole*K)$
P	1	atm	**P**	1.5	atm
T	298.15	°K	**T**	298.15	°K

$\tilde{V}$= **219** cm^3/min

ORIGINAL SCENARIO

$\tilde{V}$= **146** cm^3/min

CHANGED SCENARIO

Practical problems encountered with a system that works without mass flow controller

Long response time

Systems need a few minutes until the new set values of flow rates are reached (MFCs have a response time <500ms).

This long switchover time increases the risk of blockage.

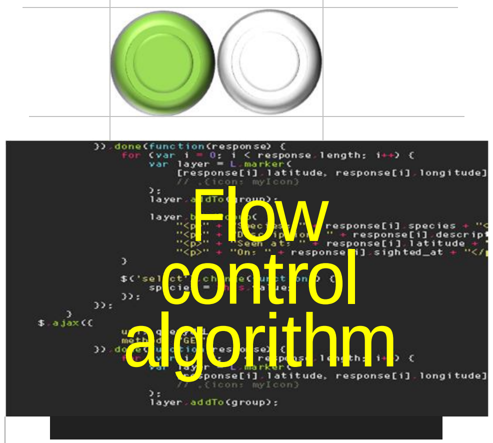
Inability to ensure precise and stable flow regulation

Particularly at low flow rates; this is especially critical during slag splashing and de-slagging, because minimum gas flow rates are normally applied during these process steps.

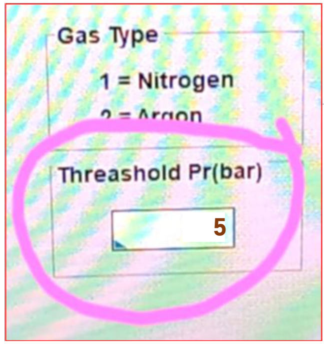
Merits of MFC

- Wide regulation ratio 1:50 of MFC(i.e., from 24Nl/min to 1200Nl/min or from 32Nl/min to 1600Nl/min.
- Fast step response of the MFC(5-95% in less than 1 second).
- High accuracy of MFC@+/-1.5%

Working Principle Of Bottom Purging

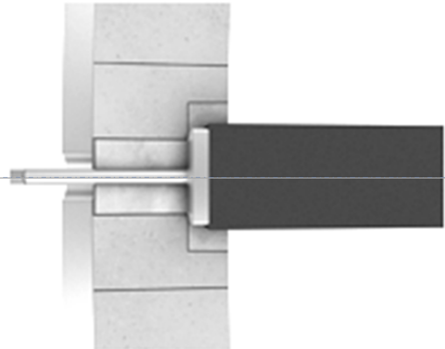


precise and
stable flow

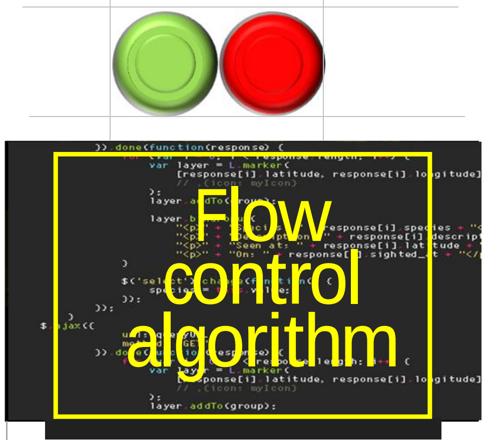


Threshold value of back
pressure

minimal
back
pressure

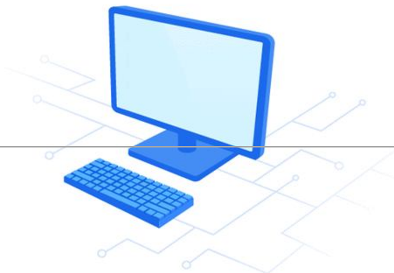


Working Principle Of Bottom Purging

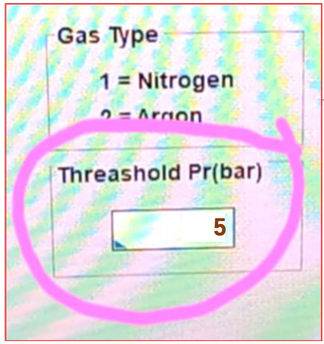


control changes automatically from **flow control to pressure control**

control valve then responds to a different control algorithm

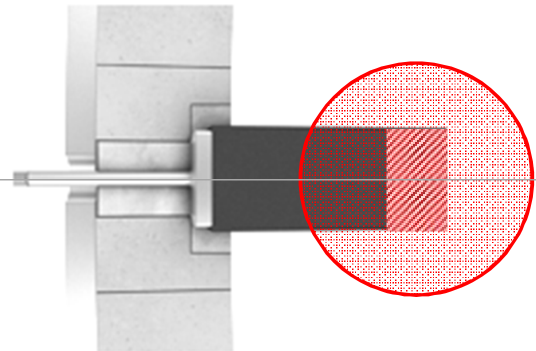


fluid slows down

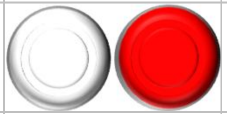


Threshold value of back pressure

Back pressure



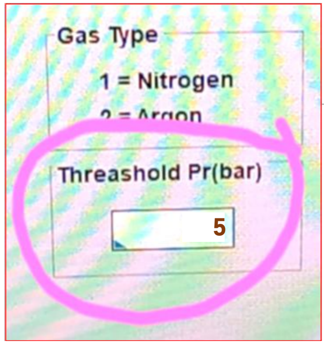
Working Principle Of Bottom Purging



control changes automatically from **flow control to pressure control**

control valve then responds to a different control algorithm

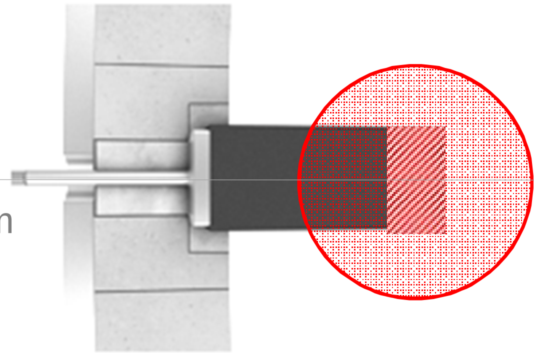
dramatic increase in fluid velocity



Threshold value of back pressure

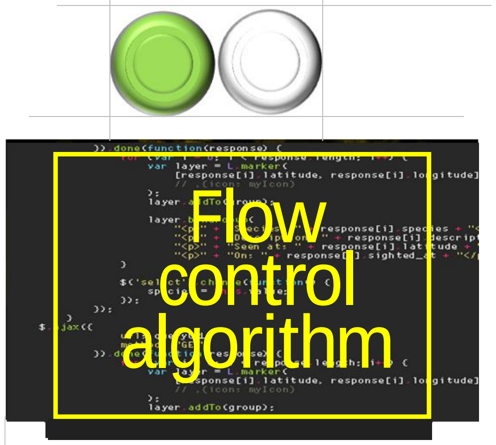
Back pressure

downstream pressure decreases



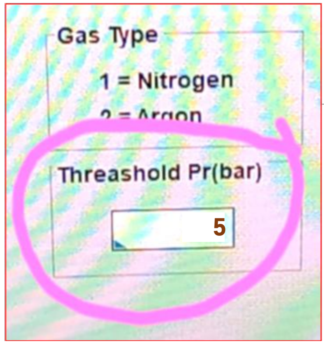
RHI MAGNESITA

Working Principle Of Bottom Purging



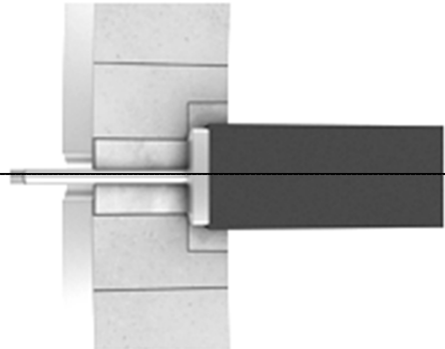
control automatically reverts to **flow control**

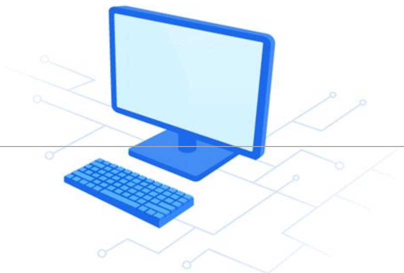
precise and stable flow



Threshold value of back pressure

minimal back pressure





INTERSTOP®

Reference List

Customer	Location	Commissioning
FINLAND		
SSAB EUROPE OY, BOF #1	Raahe	2016
SSAB EUROPE OY, BOF #2	Raahe	2016
SSAB EUROPE OY, BOF #3	Raahe	2015
POLAND		
ARCELORMITTAL POLAND S.A.	Krakow	2014
RUSSIAN FEDERATION		
Magnitogorsk I&S Works, BOF #1	Magnitogorsk	2022
Magnitogorsk I&S Works, BOF #2	Magnitogorsk	2023
Magnitogorsk I&S Works, BOF #3	Magnitogorsk	2023
SEVERSTAL CHEREPOVETS, BOF #1	Cherepovets	2019
SEVERSTAL CHEREPOVETS, BOF #2	Cherepovets	2019
SEVERSTAL CHEREPOVETS, BOF #3	Cherepovets	2018
SPAIN		
ARCELORMITTAL ESPANA S.A.	Gozon	2022

RHI MAGNESITA

Thanks!

Get in touch

Name_ KAUSHIK DASGUPTA
SFDTF - Steel Linings India Cluster I Expert·

RHI MAGNESITA INDIA LIMITED

Phone: +913340181204
E-mail: kaushik.dasgupta@rhimagnesita.com