HIGHTECH

Pursuing excellent material

Making ESR flux with An Ingenuity Heart

ESR FLUX

Story of Success, Moment of Trust

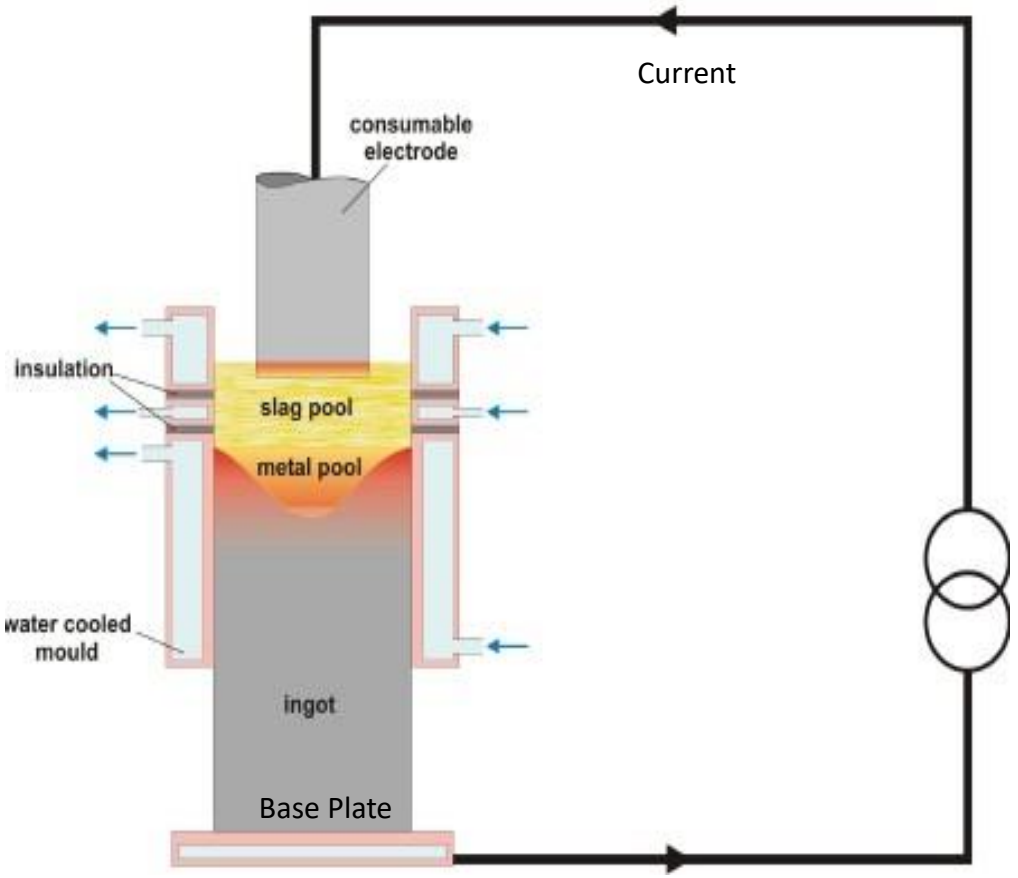
ElECTRO-SLAG REMELTING PROCESS

---For high purity and homogeneous microstructure

In the electro-slag remelting process, an ingot is built up in a water cooled crucible by remelting a consumable electrode in a molten slag bath. As the liquid metal droplet formed at the tip of the electrode passes through the hot metallurgical active liquid slag pool, the impurities like sulfur, oxygen etc and inclusions are washed out from the molten metal droplets. Then,

the clean metal droplets fall into the molten metal pool, where they solidify at a controlled rate in the water cooled copper mold.

Both of purity and microstructure of ESR ingots mainly depend on the properties of electro-slag and can be optimized by suitable assistance of electro-slag.



Standard ESR Process

THEORETICAL PHASE DIADRAM

The Diagrams 1, 2 show the ternary system CaOAl2O3-CaF2 as researched by Mitchell, Zhmodin and Nafziger. All our ESR-slag products are calculated by the following two diagrams. The diagrams indicate the melting behavior of electro-slags.

Diagram1 CaO-Al2O3-CaF2 system According to Mitchell

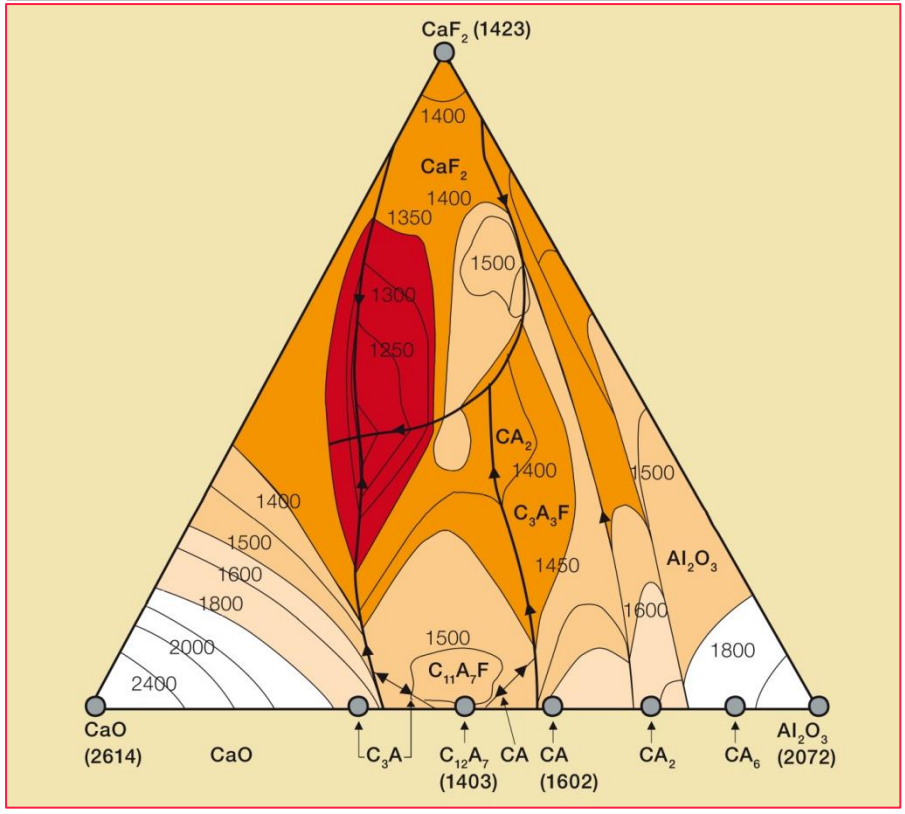
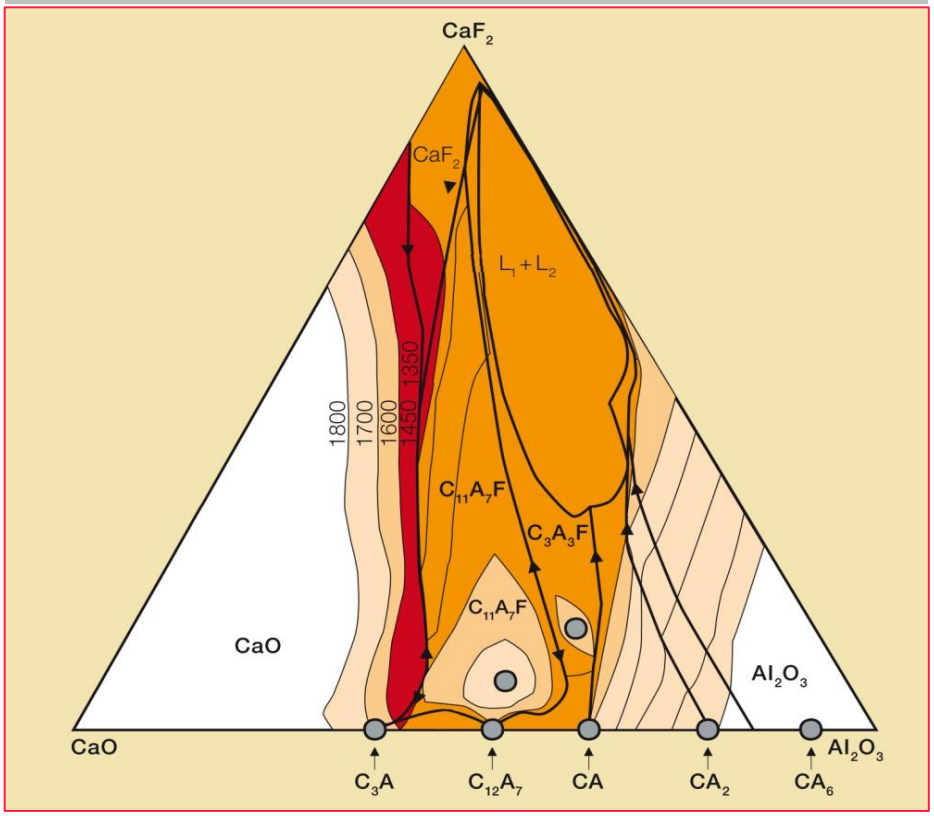


Diagram2 CaO-Al2O3-CaF2 system According to Nafziger



PHASE EQUILIBRIUM DIAGRAM

Ternary system CaO-Al2O3-CaF2 Our modeling shows the kinds of species formed in the slag pool will influence on the behavior of metal oxidation process and the phases present in the slag skin have a direct influence on the ingot surface quality.

Table 1 Invariant points in the system CaO-Al2O3-CaF2

Denotation	type	compositons			Temperature℃	Corresponding triangle	Nature of equilibrium
		CaO	AL_2O_3	CaF_2			
E1	Eutectic	31.0	61.0	8.0	＜1498°	$CA-C_3A_3F1-CA_2$	$L = CA + C_3A_3F1 + CA_2$
E2	,,	0.4	～2	97-98	～1390°	$CA_2-CaF_2-CA_6$	$L = CA_2 + CaF_2 + CA_6$
E3	,,	0.9	～2.5	96-97	～1385°	$C_3A_3F1-CaF_2-CA_2$	$L = C_3A_3F1 + CaF_2 + CA_2$
E4	,,	38.0	22.0	40.0	1230°	$CaO-C_{11}A_7F1-CaF_2$	$L = CaO + C_{11}A_7F1 + CaF_2$
E5	,,	35.0	58.5	6.5	＜1475°	$CA-C_{11}A_7F1-C_3A_3F1$	$L = CA + C_{11}A_7F1 + C_3A_3F1$
P1	Peritectic	6.0	6.0	88.0	1355°	$C_{11}A_7F1-CaF_2-C_3A_3F1$	$L + C_3A_3F1 = C_{11}A_7F1 + CaF_2$
P2	,,	56.2	42.5	1.3	1460°	$CaO-C_{11}A_7F1-C_3A$	$L + CaO = C_3A + C_{11}A_7F1$
M	Points of 4 phase monotectic reaction	18.0	48.5	33.5	1472°	—	$L_M = L_M^1 + C_3A_3F1 + CA_2$
M1		1.5	4.0	94.5			
N	,,	8	45	47	1515°	—	$L_N = L_N^1 + CA_3 + CA_6$
N1		1	6	93			
CaF2	Compound	—	—	100.0	1422°±1.5	—	Congruent melting
C_3A_3F1	,,	30.5	55.4	14.1	1507°±1.5	—	Congruent melting
$C_{11}A_7F1$	,,	43.7	50.7	5.5	1577°±2.5	—	Congruent melting

SPECIFICATION OF ESR-SLAG

Chemical composition Many other ESR-slags can be produced in conformance with strict quality assurance standards. Our process can control SiO2, contamination to as low as 0.6% by combining stringent and exacting raw material selection with highly controlled conditions in the fusing environment.

Table 2 Chemical composition of different type ESR pre-melted electro-slag

Grade	%CaF_2	%CaO	%MgO	%Al_2O_3	%SiO_2	%TiO_2	%FeO	%H_2O（650℃）	%C	%P	%S
HT-ESR 25	31.0±3.0	29.0±3.0	3.0±1.0	33.0±3.0	1.5±0.5	≤0.3	≤0.3	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 65	40.0±2.0	30.0±2.5	≤1.0	30.0±2.5	≤0.6		≤0.3	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 29	70.0±2.0	≤2.0		30.0±3.0	≤0.6	≤0.3	≤0.3	≤0.05	≤0.03	≤0.01	≤0.03
HT-ESR 27	68.0±2.5	15.0±2.5	≤1.5	15.0±1.5	≤0.6	≤0.2	≤0.15	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 37	58.0±3.0	18.0±2.0	≤2.0	20±2.0	≤0.6	≤0.2	≤0.15	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 22	58.0±3.0	15.0±2.0	2.0±1.0	23.0±2.0	1.0±0.5	≤0.2	≤0.3	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 52	97.0-100	≤2.0		≤2.0	≤0.6		≤0.3	≤0.01	≤0.03	≤0.01	≤0.03
HT-ESR 20	48.0±3.0	20.0±2.0	5±1.0	22.0±2.0	≤0.6	2.5-4.0	≤0.3	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 57	48.0±3.0	27.0±2.0	2.0-4.0	20.0±2.0	≤0.6		≤0.3	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 23	14.0±2.0	40.0±3.0	3.0-5.0	40.0±3.0	1.0-2.0	≤0.2	≤0.2	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 47	38.0±3.0	28.0±2.5	1.5-3.5	30.0±2.5	≤0.6	≤0.2	≤0.3	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 72	44.0±3.0	21.0±2.0	12.0±1.5	≤0.5	22.0±2.0	≤0.2	≤03	≤0.06	≤0.03	≤0.01	≤0.03
HT-ESR 25ELH	30.0±3.0	33.0±3.0	2.5-4.5	32.0±3.0	≤0.6	≤0.2	≤0.2	≤0.01	≤0.03	≤0.01	≤0.03
HT-ESR 37ELH	53.0±3.0	21.0±3.0	2.5±1.0	21.0±3.0	≤0.6	≤0.2	≤0.2	≤0.01	≤0.03	≤0.01	≤0.03
HT-ESR 29ELH	70.0±2.0	≤2.0		30.0±3.0	≤0.6		≤0.2	≤0.01	≤0.03	≤0.01	≤0.03
HT-ESR 32ELH		47±3.0	5.0±2.0	46±3.0	≤0.6	≤0.2	≤0.2	≤0.01	≤0.03	≤0.01	≤0.03
HT-ESR 18	40.5±1.5	25.0±2.0	1.5-3.5	28.0±2.0	1.5±0.5	≤0.2	≤0.3	≤0.06	≤0.03	≤0.01	≤0.03

PROPERTIES AND APPLICATIONS

Grade	Size	Electrical conductivity (1600℃)/$\Omega^{-1}cm^{-1}$	Melting point	Features and application
HT-ESR 25	0-10mm	2.2	1400-1410	■ High electrical resistance ■ General purpose slag ■ For tool steels, stainless steel
HT-ESR 65	0-10mm	2.7	1120-1230	■ General purpose slag
HT-ESR 29	0-10mm	3.3	1445-1455	■ General purpose slag ■ Efficient electrically
HT-ESR 27	0-10mm	4.4	1325-1335	■ Good all-round slag, Medium electrical resistance ■ For nickel/cobalt base alloys re-melting such HASTELLOY alloy series and high speed steels like MISI M2
HT-ESR 37	0-10mm	3.8	1285-1295	■ General purpose slag ■ For nickel/cobalt base alloys re-melting
HT-ESR 32	0-10mm	0.7	1345-1355	■ customized product according to requirements of client
HT-ESR 52	0-10mm	6.6	1375-1385	■ Efficient electrically ■ use where oxides not permissible
HT-ESR 20	0-10mm	3.6	1100	■ Low melting point ■ For nickel base alloys(containing Ti element), amount of TiO2 can be adjusted for alloy 718 ■ For bearing steels
HT-ESR 23	0-10mm	1.3	1325-1335	■ High electrical resistance ■ High Al2O3 content

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Smelting to Flux

---Standard process

Step 1
Batching according to each type

Weighing

Melting

Step 2
Inert gas melting/treatment

Step 3
Special cooling

Casting

Grinding

Step 4
Grinding according to requirements

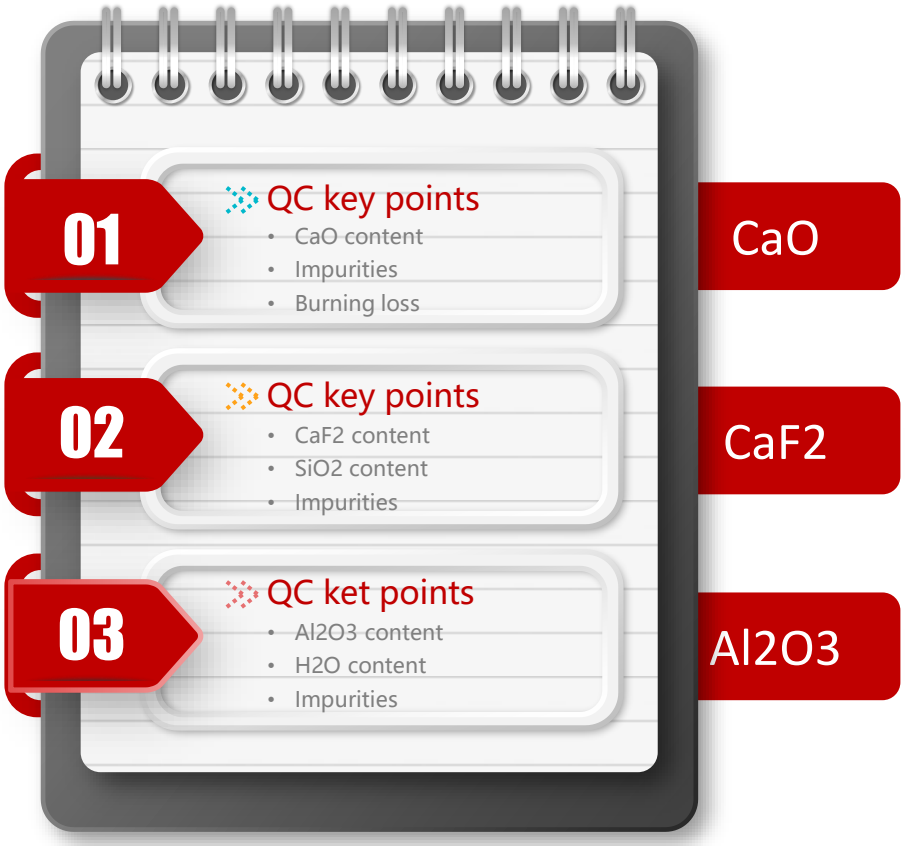
Step 5
Packing with bags/drums

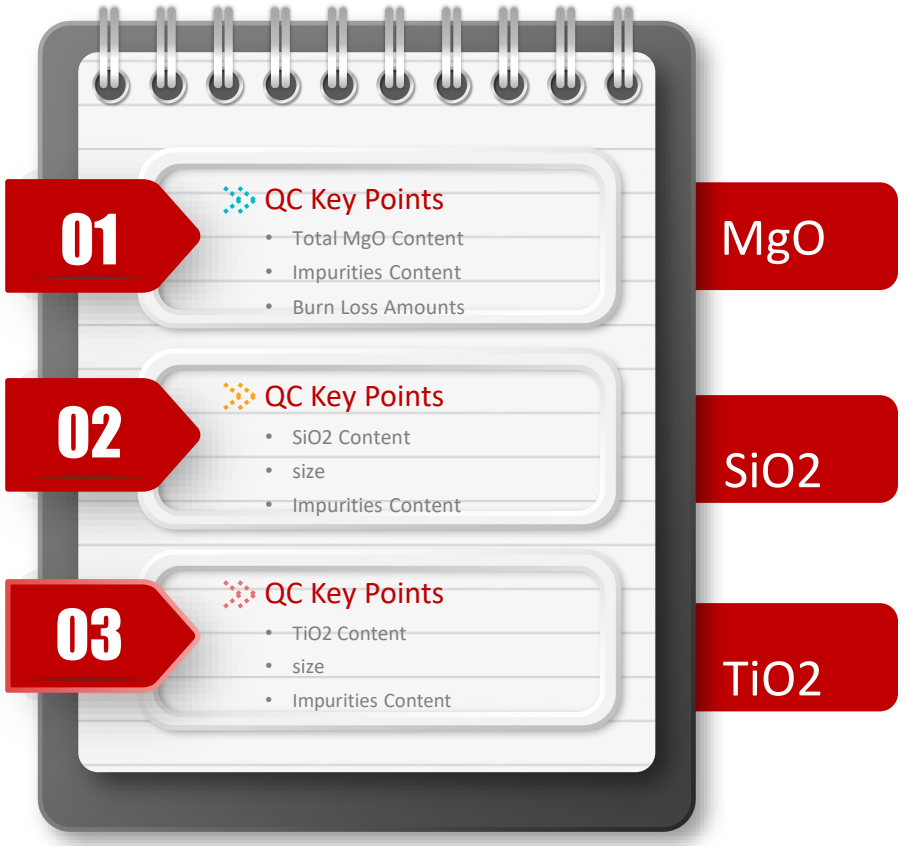
Packing

ESR FLUX

Standard process The pre-dried raw materials are mixed with accurately weighing control and then smelted according to our know-how. The liquid flux will be poured into cast iron facility for suitable cooling. After cooling, the solid flux will be grinded into particles. The following three figures show HT actual ESR slag products.

QC for Raw material





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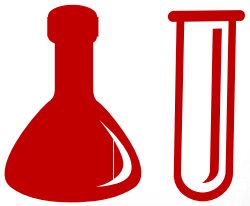
Quality Control



CaO
DIN 51084

Al2O3
DIN51084

MgO
DIN51084

C
GB / T 20123
ISO15350

F analyzer
Distillation

CaF2
ISO 5195.1
DIN 51048

H2O
GB / T 8170

FeO
GB / T 176.24
DIN51084

SiO2
GB / T 176.23
DIN51084

XRF
Oxides

P
DIN51084

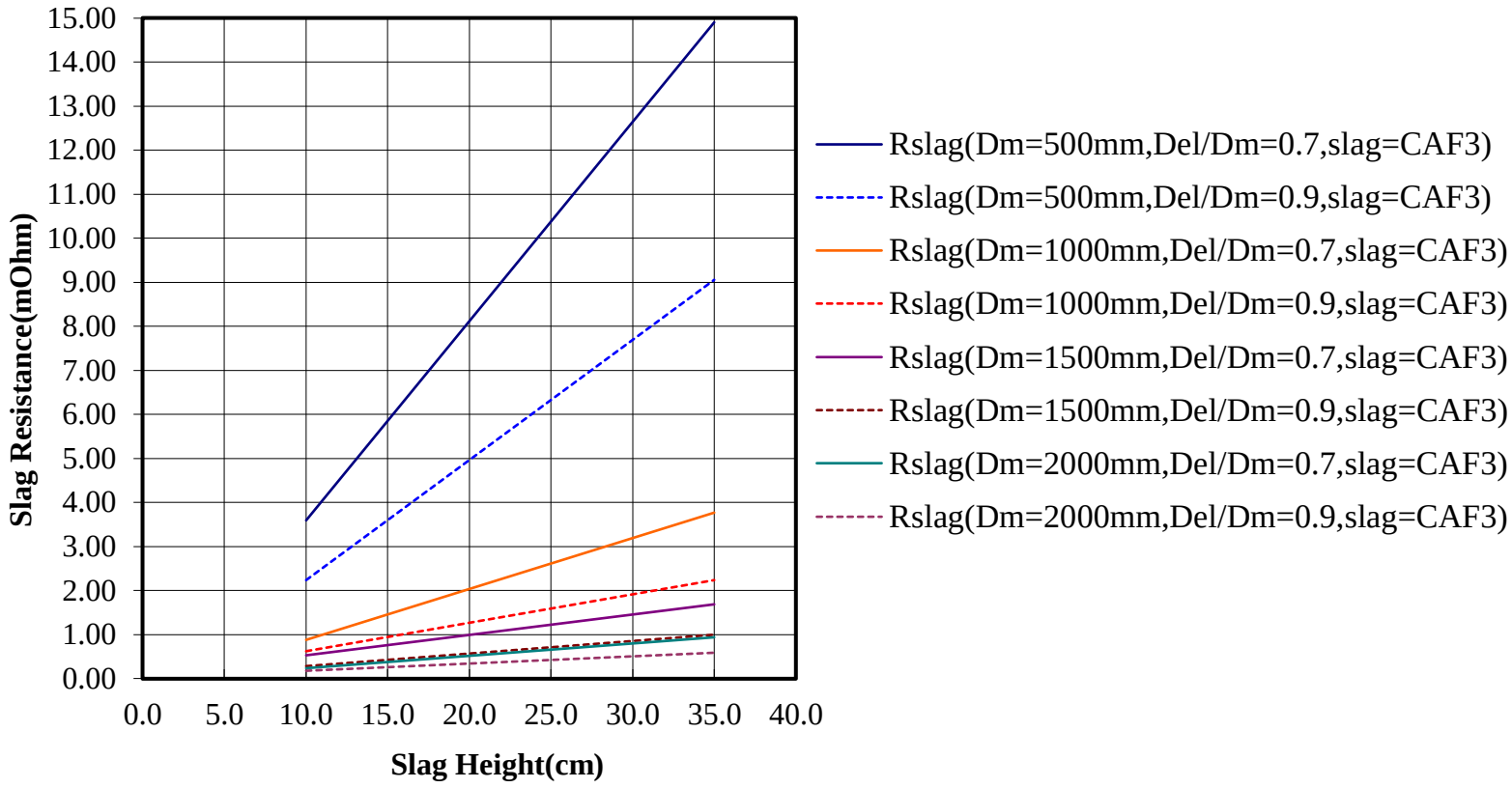
CS-Analyzer
CS 996
C/S：0.1PPM

TiO2
DIN51084

S
GB / T 20123
ISO15350

SLAG RESISTANCE

Influence of mold Diameter and slag bath height on the slag resistance for a fluorspar content 30% of the slag



SURFACE QUALITY (1)

- **ESR-SLAG type**

The chemical composition must be designed according to the steel grade.

- **Equilibrium (P,E)**

The phases which solidify an the order of solidification are very important to affect slag skin thickness and ingot surface quality.

- **Operation data**

Another important feature related to the surface quality is power input. It is found that better surface quality under higher power input.

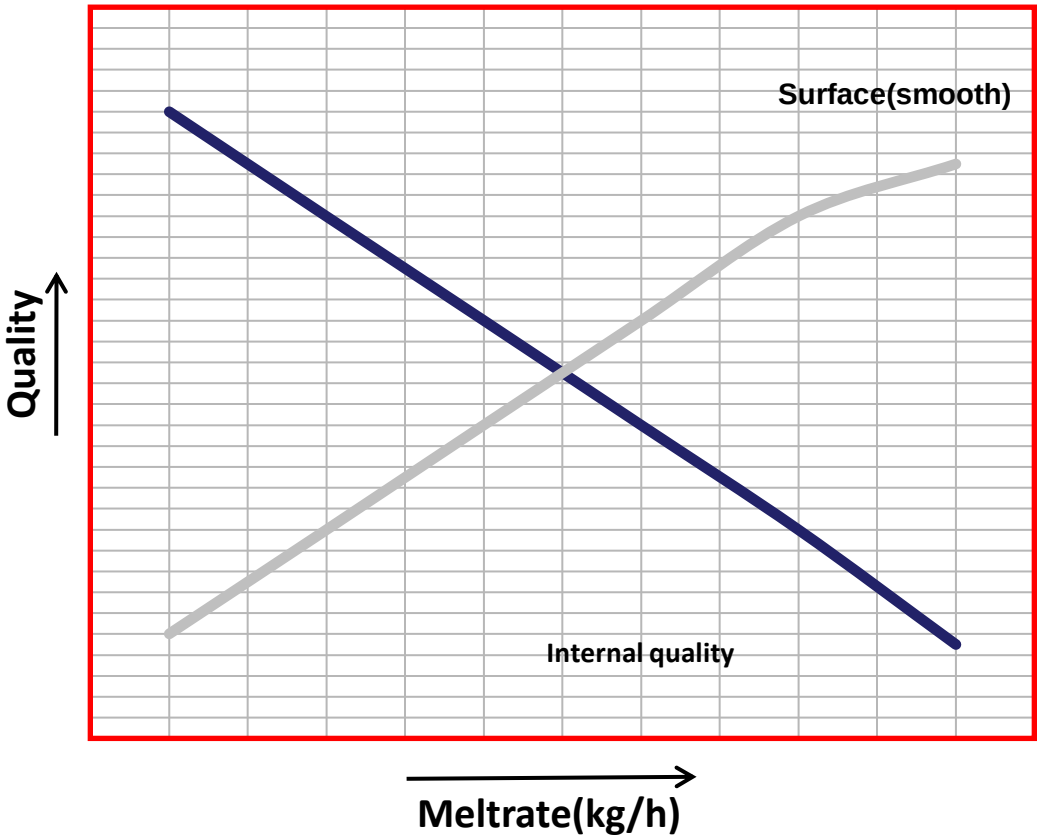
SURFACE QUALITY (2)

Surface quality Vs metal pool shape

The ingot surface will be also influenced by metal pool shape.

Usually, the deep liquid metal pool results in the ingot quality decreasing while the shallow liquid metal pool will make the ingot has good surface quality.

The shape of liquid metal pool will be controlled by meltrate. Deep liquid metal pool comes from high meltrate and shallow liquid metal pool is from low meltrate.



* Schuhmann, R. and C. Ellebrecht; Metallurgical and process problems related to electroslag remelting of forging ingots, 180~202.

Hydrogen pick up

---treatment and storage

■ Temperature between 100℃ and 400℃

Calcium aluminates react with the humidity of the atmosphere and absorb moisture.

■ Temperature above 600℃

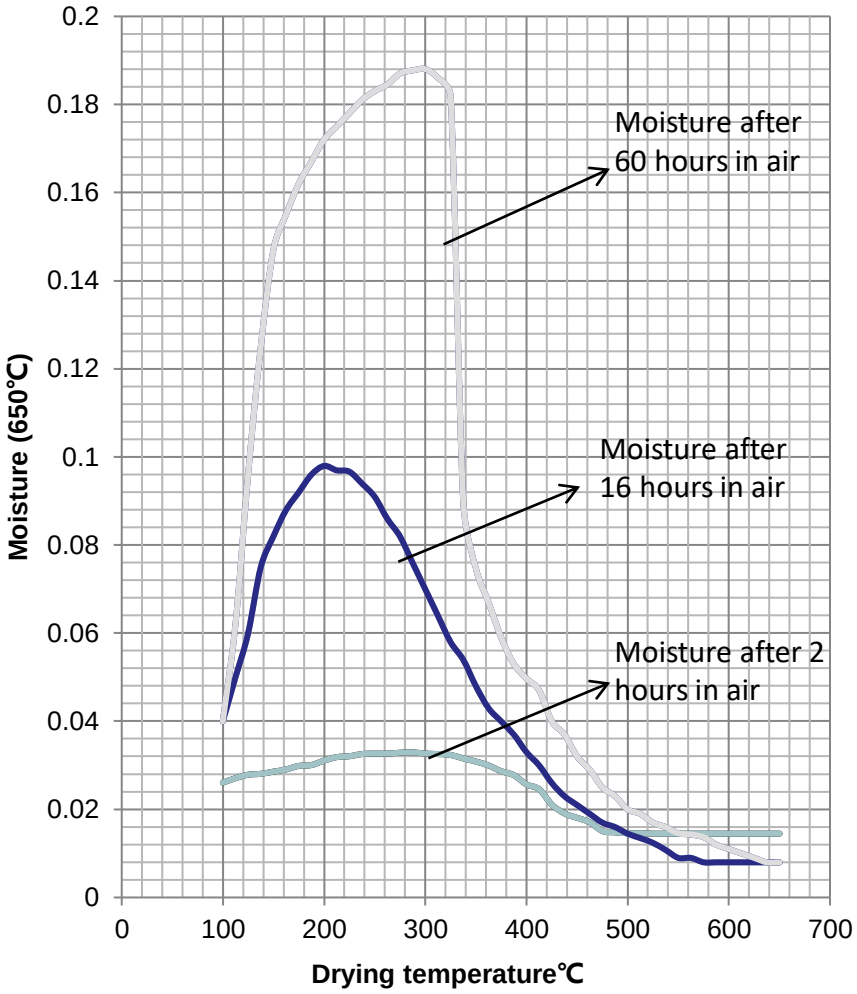
$CaF_2 + H_2O = 2HF + CaO$

■ Treatment

If processing is done correctly (dry ESR flux, dry air, inert atmosphere), then the hydrogen pick-up can be held within 0.5 ppm.

Note:

Adding 1.5 ppm of the electrode gives a total hydrogen level of 2 ppm in hydrogen sensitive steels.



INSTRUCTIONS FOR STORAGE AND OPERATIONS

The HIGH-TECH Pre-melted electro-slag products mentioned above are briefly introduced but some necessary simple instructions should be stressed here in regard to storage, pre-heating and operations.

- As for some steel grades being very sensitive to hydrogen cracking, except the pre-melted slag itself, if possible we suggest the customer to store the pre-melted electro-slag in humidity controlled warehouse with air conditioner or some drying device

- Please put attention to that good storage condition without moisture in the warehouse can not ensure there is no any moisture attaching to the mold surface, hood surface and so on. So, in case of wet air during some season, it is strongly recommended that each customer should purge the dry inert gas into the furnace before re-melting to dry the furnace itself. Otherwise, it has the a little risk to find the hydrogen pick-up in the ingots.

- If the pre-melted electro-slag has already found the phenomenon of moisture pick-up, the slag must be re-dried by preheating before re-melting process start. The preheating temperature shall reach to the temperature range from 470℃ to 600 ℃ as soon as possible to avoid the decomposition of premelted slag.

FEATURES of HIGH-TECH ESR Flux(1, 2)

■ Standard operation process

The whole production process from smelting, manufacturing, packaging, storage to transportation is according to both of our very rigid standard specification and special requirements from customers.

■ Characteristics of Products

The heart of ESR remelting process is the melt-rate controlling which is great influenced by the slag properties. The key characteristics of HIGH-TECH premelted electro-slag are as follows:

1) Are found among the monophase stable liquid (without separation phenomena in actual operation) and perfect homogeneity in the ternary system CaO-Al2O3-CaF2.

2) Have reliable consistent metallurgical effects for desulfurization and washing out of non-metallic inclusions.

3) Have the lowest impurity levels like hydrogen and carbon content.

4) Are with both of appropriate electrical conductivity and liquidus temperature for formation of a constant geometry of liquid slag/steel pool, keeping the good temperature distribution and constant melt-rate controlling.

FEATURES of HIGH-TECH ESR-SLAG(3, 4)

■ All products developed by very close cooperation with customers

HIGH-TECH products are researched and developed by keeping very close cooperation with related customers and metallurgical universities in long time. Based on these close cooperation with customers, HIGH-TECH has obtained the know-how in the whole production process and give the maximum technical supporting to our deer customers.

■ Individual service and keeping confidentiality

HIGH-TECH can organize mass production according to the special requirements (like different chemical composition, packaging and so on) of the customers and keep confidential for them. In addition, HIGH-TECH has series know-how and technologies for special melting and we can provide our optimum solution for the individual requirements from customers.

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a voestalpine company
GMH GRUPPE


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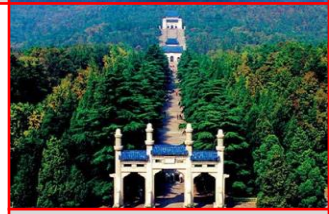
ThyssenKrupp

DOOSAN



SCMG
SPECIAL METALS