TRICKS OF THE TRADE

INCLUSION/SLAG CONTROL

TED KLEMP iii
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17600 NORTH SHORE ESTATES ROAD
SPRING LAKE, MI 49456

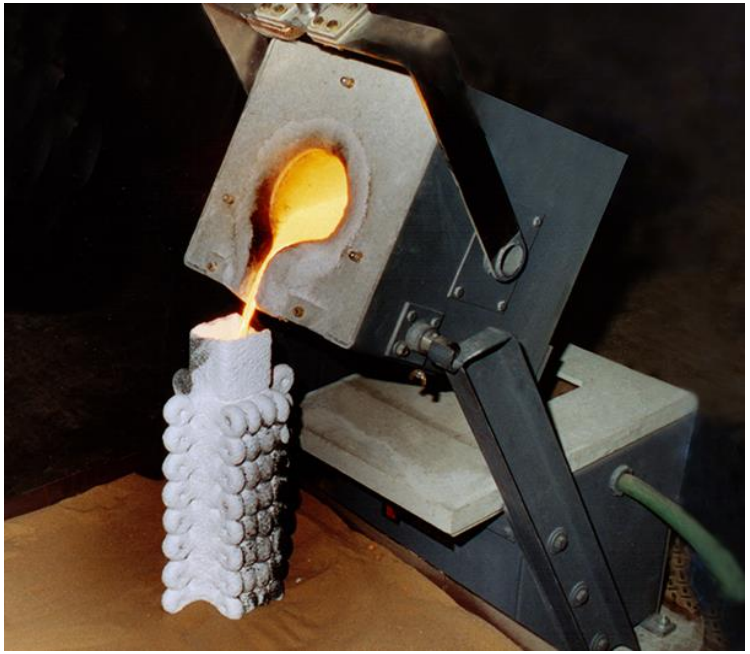
EXTRANEOUS

- FURNACE & LADLE REFRACTORIES
- SHELL RELATED

INDIGENOUS

MELTING

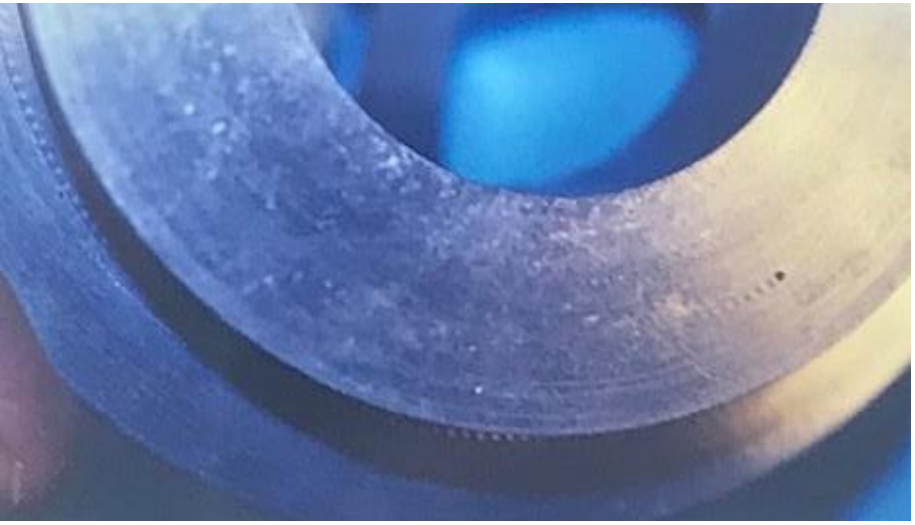
POURING



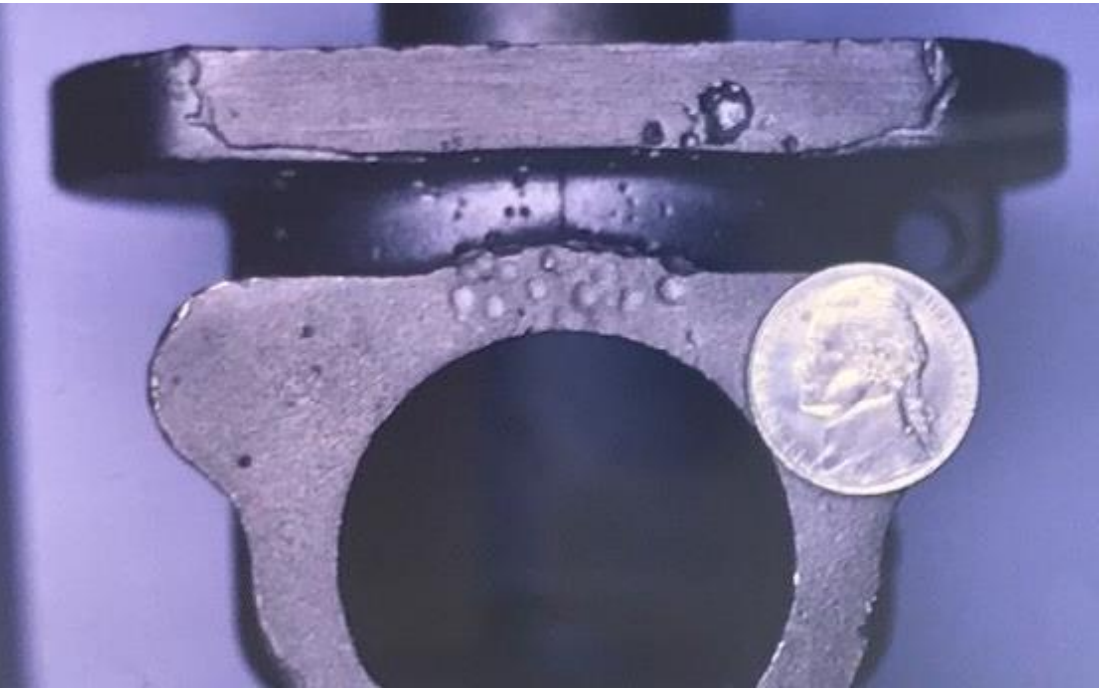
INCLUSION CATAGORIES

- EXTRANEOUS
- OXIDATION
- WATERY/SILACEOUS

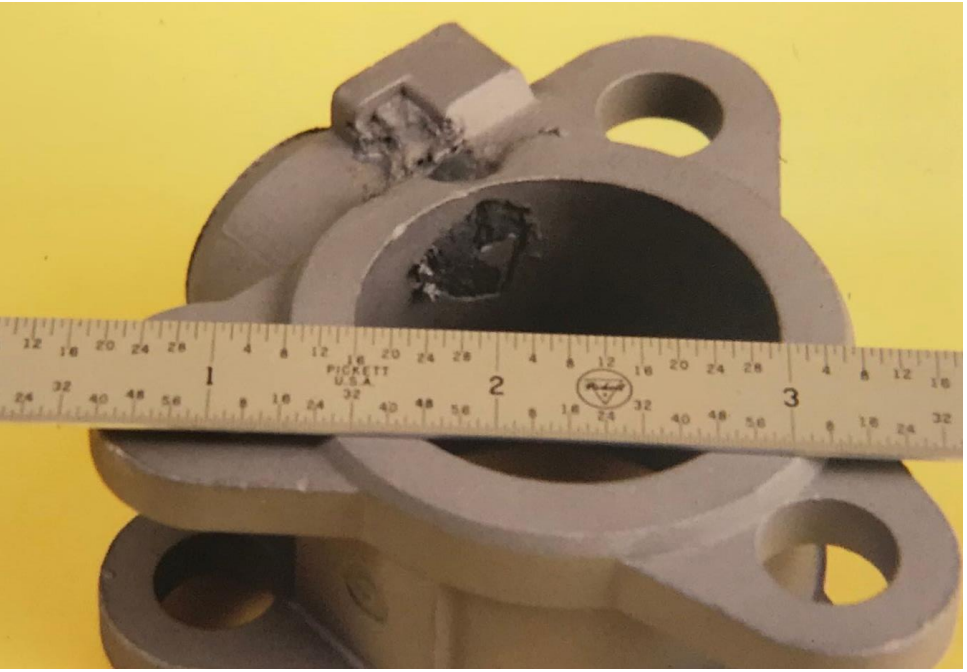
OXIDATION

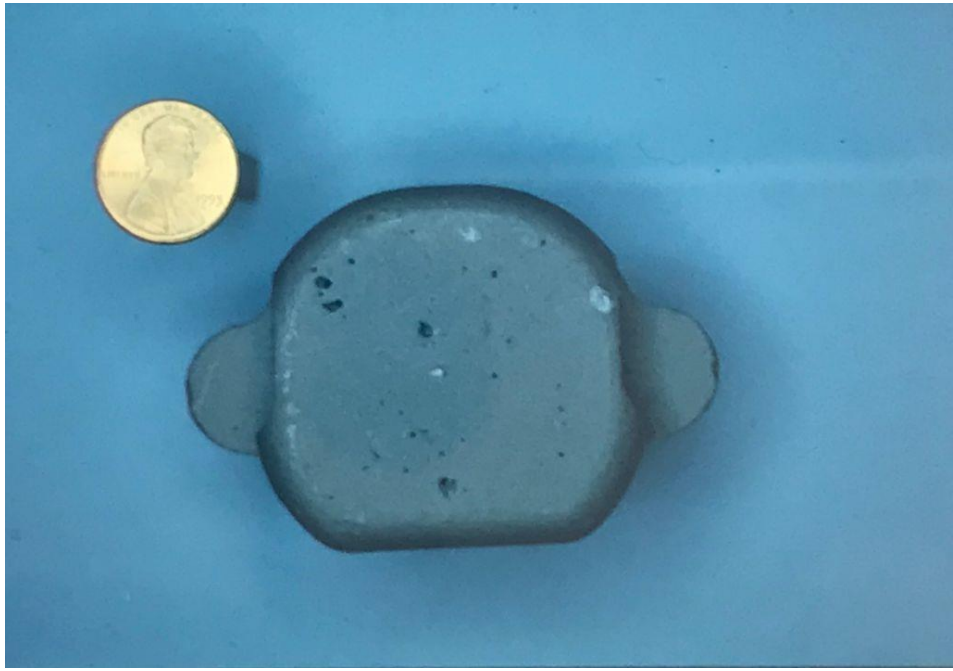


SILICIOUS



EXTRANEOUS





OXIDATION/SLAG VOLUME FACTORS

1. MELT STOCK QUALITY
2. MELT STOCK SURFACE AREA
3. FURNACE SURFACE TO VOLUME RATIO
4. TIME MOLTEN
5. SUPERHEAT
6. DEGASSING PRACTICE
7. USE OF INERT GAS “BLANKET” AND/OR BUBBLE

OXIDATION

OXIDATION OF THE MOLTEN BATH LEADS TO:

- **ALLOY FADE**
- **FLUIDITY DECREASE**
- **POOR SURFACE APPEARANCE**
- **BLACK SPOT DEFECTS**
- **LOSS OF DUCTILITY & TOUGHNESS**

OXIDATION

FORTUNATELY, A SIMPLE METHOD IS AVAILABLE TO MINIMIZE NON-METALLIC INCLUSIONS CONTENT

- **FLOTATION**
- **PREDICTIED BY STOKES LAW**

FLOTATION & STOKES LAW

- $V = \frac{2/9\ g r^2 (D_{L1Q} - D_{INC})}{L_{V12}}$

g = Acceleration due to gravity

r = Radius of slag particle

D_{L1Q} = Density of liquid metal

D_{INC} = Density of inclusion

L_{V12} = Viscosity of liquid metal

COMMON METALLURGICAL OXIDES AND BASE MATERIAL*

DENSITIES (g/cc)	
SiO_2	2.32
Al	2.38
CaO	3.32
MgO	3.58
Al_2O_3	3.77
Cr_2O_3	5.22
MnO`	5.50
Fe	7.02
Co	7.76
Ni	7.90
Cu	8.00

COMMON BASE METAL OXIDES

COBALT, COPPER, IRON & NICKEL COMMON OXIDES CAN BE REMOVE BY DESLAGGING

- **CHROMIUM OXIDE**
- **MANGANESE OXIDE**
- **SILICON OXIDES**

RELATIVE SURFACE TENSION AND VISCOSITY

	SURFACE TENSION	VISCOSITY
Al	914	1.2
Co	1873	4.2
Cu	1285	4.0
Fe	1872	5.5
Ni	1778	4.9

Inclusion Flotation*
300 lb. Crucible

INCLUSION RADIUS (in)	RATE OF RISE (in/sec)	Time to 16.5” sec.
0.001	0.034	485
0.010	0.340	48.5
0.100	3.40	4.85

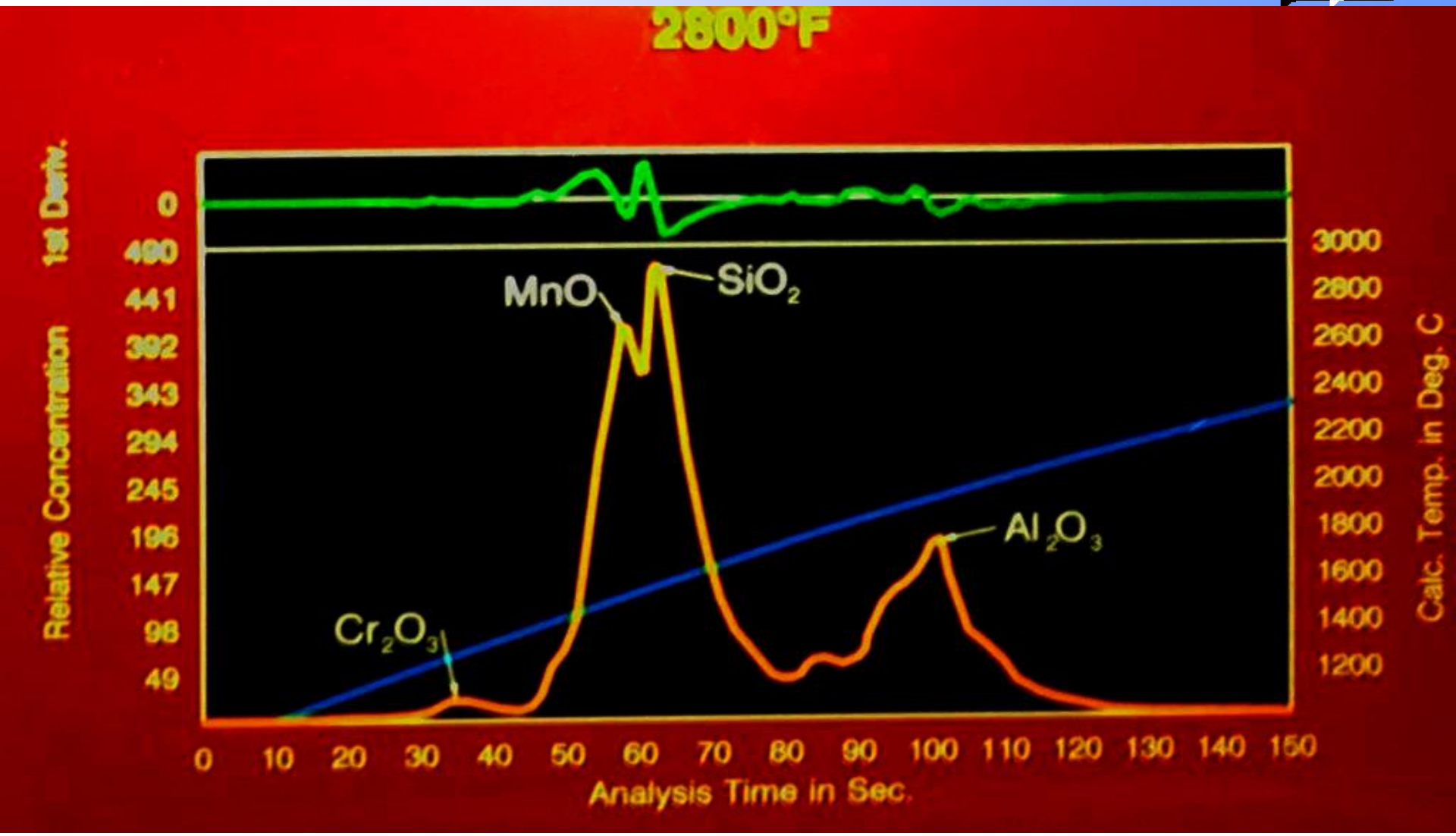
* Iron base alloys (cast steels)

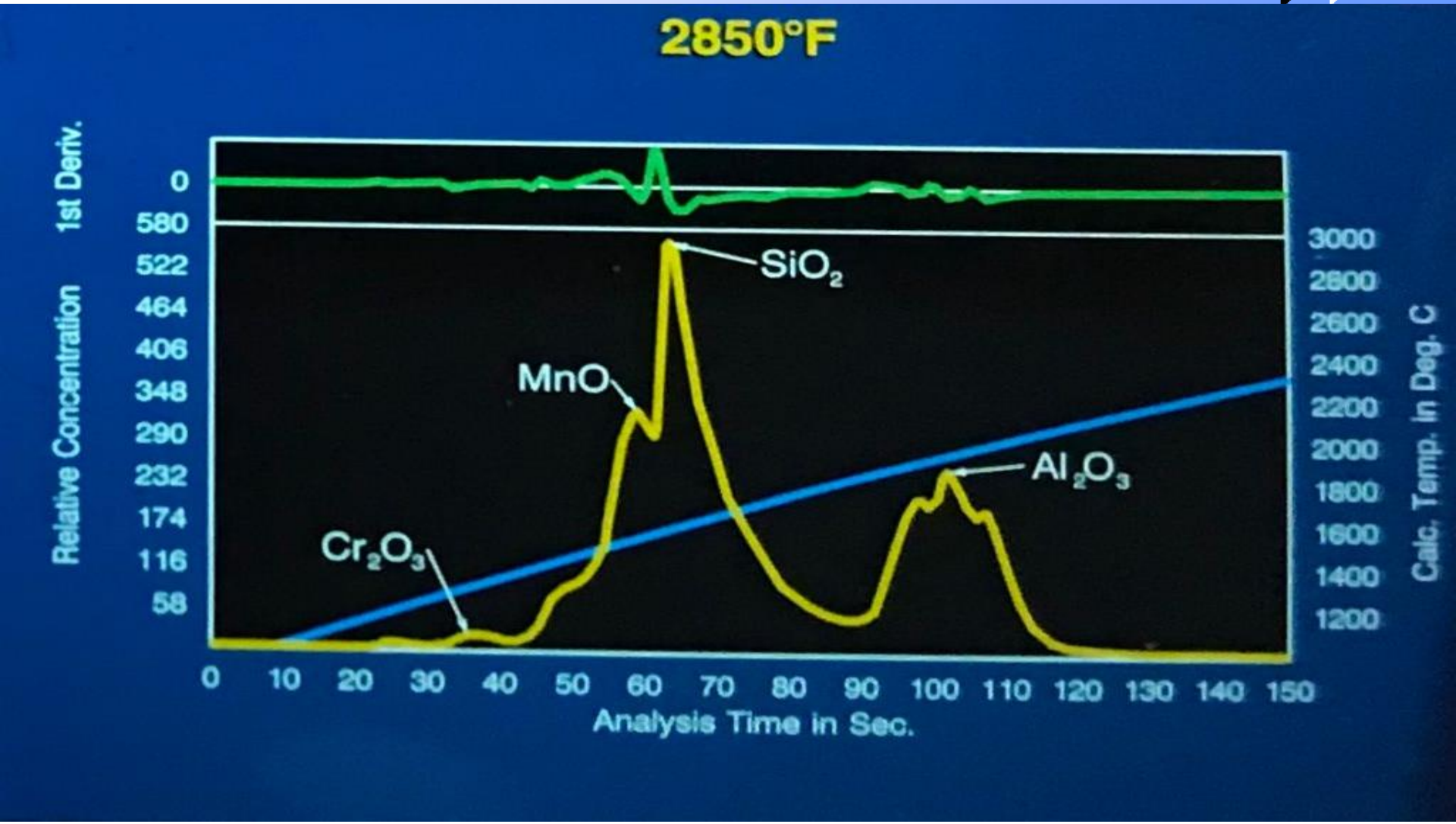
RATE OF FLOTATION

- DEPENDS ON VISCOSITY (STOKES LAW)
- DEPENDANT ON INTERFACIAL ENERGY/SURFACE TENSION
- Co, Fe & Ni SHOW SIMILARITIES WITH STOKES LAW
- Al & Cu SHOW A DIFFERENT BEHAVIOR

SUPERHEAT

- SYNERGIZED BY SUPERHEAT WHEN MELTING Co, Fe & Ni
- MOLTEN BATH IS RAISED TO 2950 F.
- ASSURES REDUCTION OF MnO
- ALSO INCREASES RISE/FLOTATION VELOCITIES OF $Si0_2$
- VERY EFFECTIVE FOR Co, Ni & Fe
- ESPECIALLY EFFECTIVE FOR REDUCING CrO BI-FILM DEFECTS


2800°F
1st Deriv.
Relative Concentration
0
490
441
392
343
294
245
196
147
98
49
MnO
SiO2
Cr2O3
Al2O3
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
Calc. Temp. in Deg. C
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Analysis Time in Sec.


2850°F
Relative Concentration
1st Deriv.
0
580
522
464
406
348
290
232
174
116
58
SiO_2
MnO
Al_2O_3
Cr_2O_3
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
Calc. Temp. in Deg. C
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Analysis Time in Sec.

Pour Temperature vs Oxide Content*

	Mn	Si	Al
2700 °F	17	14	16
2750	23	20	17
2800	27	33	26
2850	23	40	30

*ppm - AOD Refined ASTM F75

Oxide Reduction Temperatures*

FeO	500
Cr_2O_3	1200
MnO	1400
SiO_2	1500
TiO_2	1580
MgO	1800
Al_2O_3	1950

*Carbon Rich Atmosphere at 1 Bar

SUPERHEAT DESLAGGING PROCEDURE

- TARGET TEMPERATURE REACHED
- POWER TURNED OFF TO OBTAIN PLACID BATH OPTIMAL FLOTATION
- SLAG COAGULANT IS APPLIED LIGHTYLY TO BATH
- COAGULANT FACILITATES “KNITTING” OF SLAG PARTICLES.
- REPEAT DELAGGING 2 ADDITIONAL TIMES.

SUPERHEAT DESLAGGING PROCEDURE CON'T

- SHOULD BE NOTCIABLE REDUCTION IN SLAG AFTER EACH APPLICATION OF COAGULANT
- AFTER THIRD REMOVAL TAKE BATH TEMPERATURE TO DESIRED POURING TEMPERATURE.
- FINAL QUICK SLAG OFF, IF NECESSARY & POUR.

SILICIOUS SLAG

SILICIOUS SLAG

REMOVAL IS CHALLENGING!

THIS IS DUE TO:

- **ITS VERY FLUID NATURE**
- **TRANSPARENCY ON THE MOLTEN BATH SURFACE**

SILICIOUS SLAG

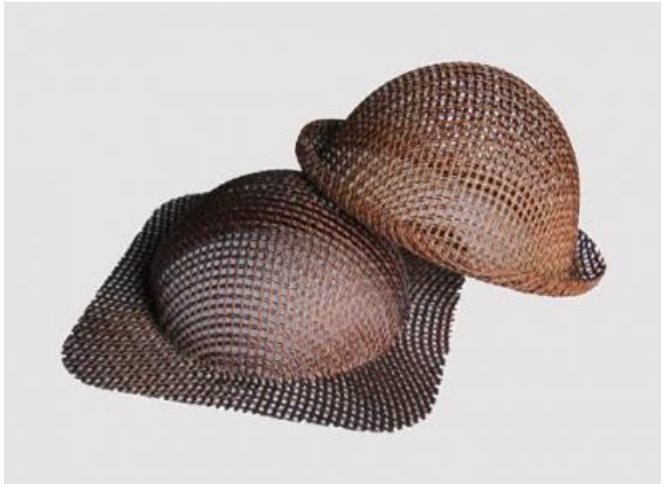
- $SiO_2 + Ti\ (FeTi) = Ti_3O_5 + Si$
- Ti_3O_5 IS “STICKEY” & EASILY REMOVED WITH CONVENTIONAL DESLAGGING PRACTICE

SILICIOUS SLAG DESLAGGING PRACTICE

- AFTER FINAL DESLAG RETURN FURNACE TO FULL POWER
- ADD 0.2 LBS. OF FeTi/100 LBS. MELT
- STIR IN FOR 10 – 15 SECONDS
- POWER DOWN & SLAG OFF
- OBTAIN TAP TEMPERATURE & POUR

OTHER FACTORS FOR CLEAN CASTINGS

- USE OF AOD/VOD REFINED INGOT
- USE OF POURING FILTERS



OTHER FACTORS FOR CLEAN CASTINGS
USE OF INERT GAS COVERS/BLANKETS

OTHER FACTORS FOR CLEAN CASTINGS

- POURUS PLUG BUBBLING