Use of Fluxes
in Ductile Iron Melting, Holding and Pouring

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The Guildford Sheraton
Surrey, B.C Canada – May 12-13, 2010

Why add Fluxes ?

Integrated Steel Mill Processing

- **Adding fluxes has been a vital part of steel making for decades.**
- **Lime/Fluorspar (CaF_2) additions are commonly used for desulphurization, phosphorus reduction, deoxidation and improving metal cleanliness.**
- **Steel mill furnace and ladle linings are very robust.**

Fluxes in Non-Ferrous Applications

Aluminum Casting Industry

- Fluxes are used to remove impurities, reduce dross formation, improve Al recoveries.
- Most fluxes are based on a mixture of metallic salts, especially Chlorides, Fluorides, and Borates

Copper / Brass/ Bronze Casting Industry

- Fluxes are used to remove impurities, reduce oxide formation, improve Cu, Zn recoveries.
- Most fluxes are based on a mixture of metallic salts, especially Chlorides and Fluorides

Iron Casting Foundries

Benefits of fluxing mostly ignored

- **Until recent years, most fluxes were based on fluorspar**
- **Refractory erosion and inclusions resulted, causing negative aspersions within the industry.**
- **New developments in non-chloride, non-fluoride fluxes now offer numerous benefits of improved refractory life, cleaner iron, and improved melting efficiency**

Examples of Ductile Build-up in Induction Melting

Fluxing, Why is it needed?
Controlling Build-Up

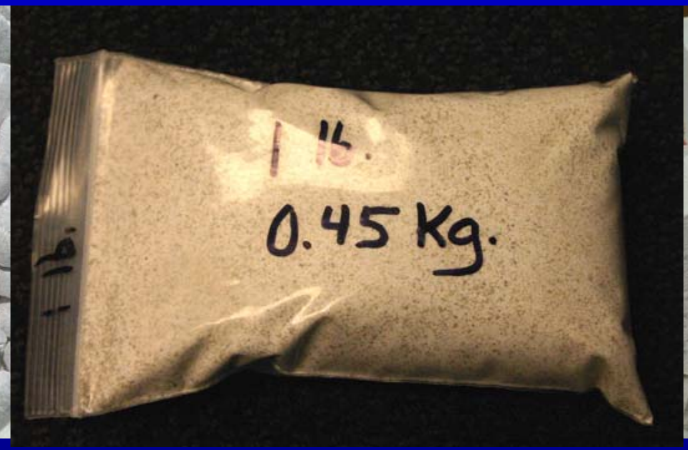
Conventional methods of dealing with Build-Up in a melting, holding or pouring application,

- ***Low heel superheating***
- ***"Green Poling"***
- ***Addition of iron oxide and manganese oxide***
- ***Addition of Silicon Carbide***
- ***Mechanical Scraping***

Now what?

Something more Effective is needed to help with the Removal of the build-up in the melt operation. That is where fluxing worked.

Fluxing
for Ferrous Melt and Pouring Applications



A Mild Fluoride-free, Chloride-free Flux, Redux EF40$_{\text{(patented)}}$ is used successfully to combat most build-up conditions in ferrous melt and pouring conditions.

Daily Build-Up Problems facing Ductile Iron Foundries

Insoluble Build-up in Coreless Melting

Channel Induction Furnaces:
Loss of Inductor Power due to Throat or Inductor Restriction

Loss of Capacity/Uppercase Build-Up, Reduce Service Life

Pressure Pouring Channel Furnaces Build-Up holding treated ductile iron

Magnesium Treatment Tundish Ladle Build-Up

Courtesy of Inductotherm Corp

Coreless Induction Melting and Fluxing

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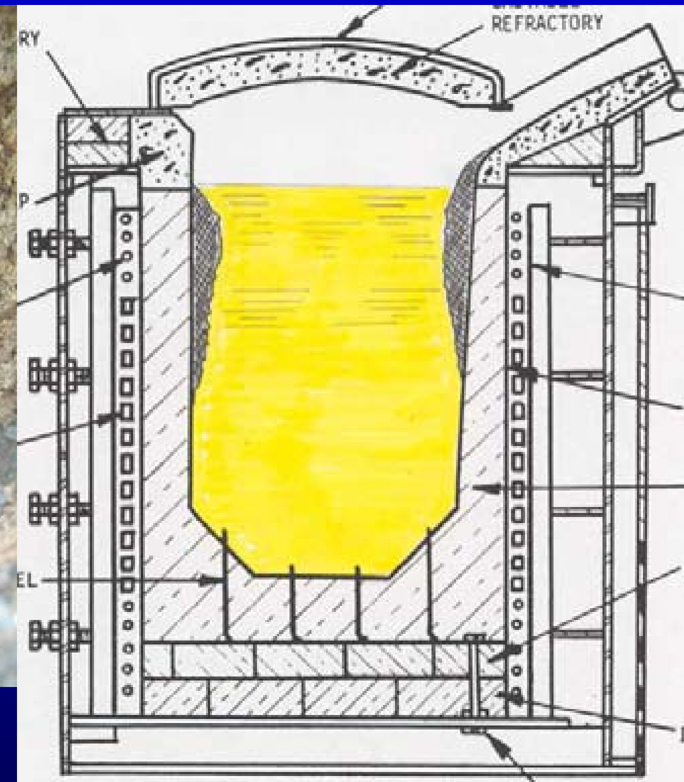

Insoluble Build-up depositing on walls of Coreless Induction Furnaces

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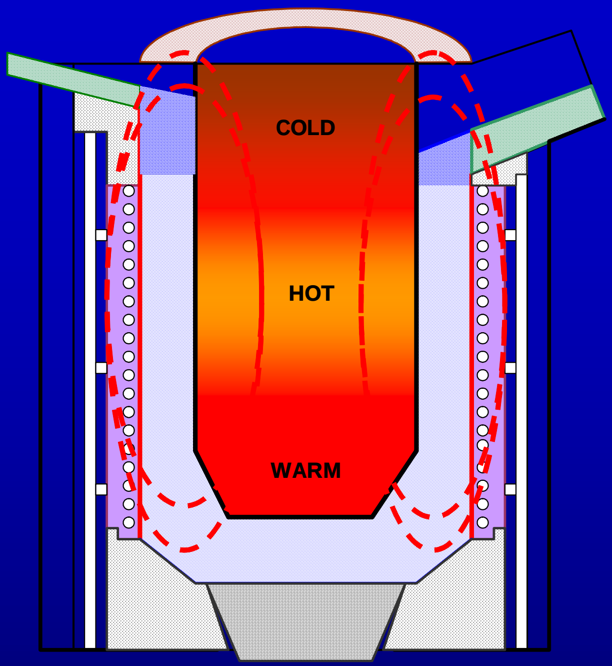
Possible Sources of Slag and Build-Up in Ductile Iron Melting

Severe Build-Up in Ductile Iron Coreless Furnaces



Loss of Effective Melt Power, slower melting rate.

Loss of Capacity, less Production.

Localized superheating of Refractory.

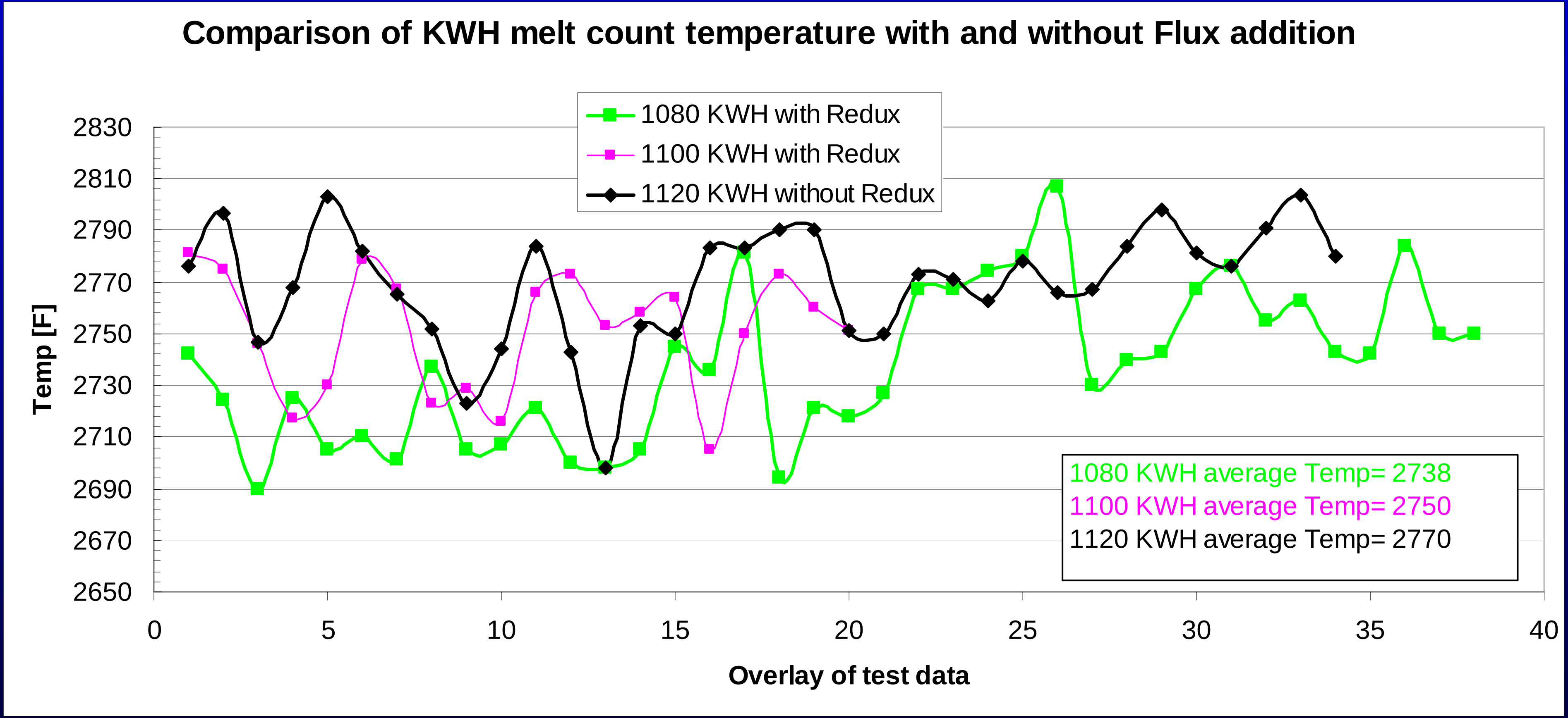
Increased metallic saturation in the Refractory

Severe Build-Up in Ductile-base Iron Coreless Melting

Continuous Flux treatment: use 1-2 lbs of Flux per ton of metallic charge entering the furnace

Never ADD ANY FLUX TO AN EMPTY FURNACE. ALWAYS 50% MOLTEN METAL BATH INSIDE OF THE FURNACE BEFORE FLUXING.

An Example of Controlling Build-Up in Coreless Melters and Improving Energy Loss



2.5 ton medium frequency Coreless Melter

Controlling Severe Ductile–Base Build-Up in Coreless Induction Furnaces

Foundry D1 operates **12 M Ton Coreless** furnaces in a 100% batch melting Ductile-base melt operation

Two 12 M Ton 9000 Kws 180 Hz Coreless furnaces lined with domestic silica dry vibratable refractory / boron oxide

Each charge consisted of ductile "pig iron," carbon steel, and ductile returns. Typical tap temperature 2750-2825 F

Build-Up would occur in the "freeboard" area above the active power coil. After a 24 hour period, serious downtime was experienced due to delays in charging, Each melt cycle required an extra 5 to 15 minutes for each heat daily.

Controlling Severe Ductile–Base Build-Up in Coreless Induction Furnaces

Foundry D1

Adding 6 lbs of Flux to each heat, the build-up was eliminated.

Lining life increased from 4500 tons to 7500 tons per campaign.

Foundry D continues to realize the following benefits:

Furnace capacity remains consistent at 12 M tons
Normal melt cycle of 40-50 minutes is uninterrupted
Less frequent top cap cleaning
Delays at the mold line for molten metal from holding furnace, fed by the coreless melters, was reduced by 50%
Reduced mechanical damaged to the top cap refractory

Controlling Severe Ductile–Base Build-Up in Coreless Induction Furnaces

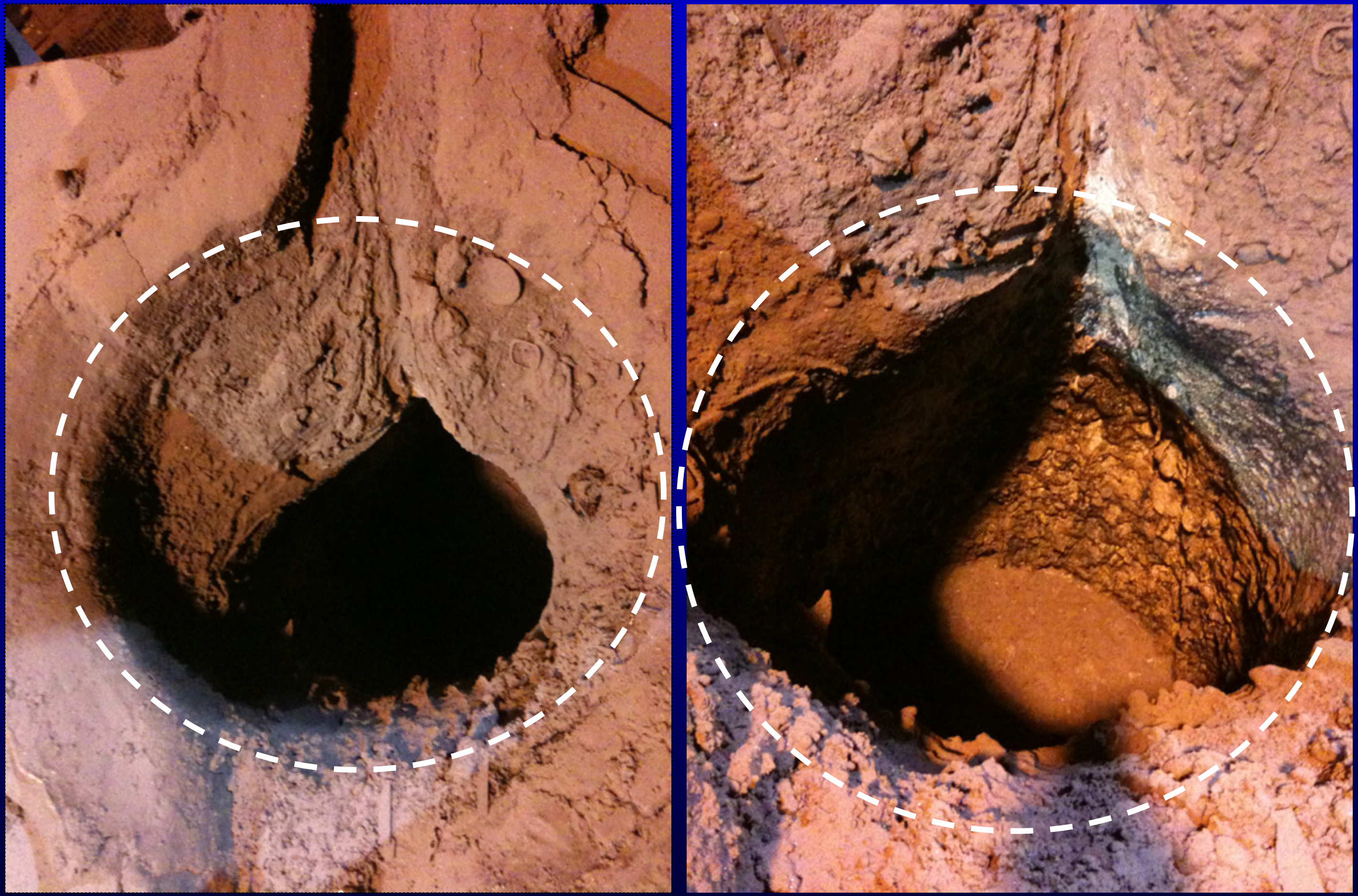
Foundry D2 operates 7 Ton Coreless furnaces in a 100% batch melting Ductile-base

Three 7 Ton 6000 Kws 180 Hz Coreless furnaces lined with domestic silica dry vibratable refractory / boron oxide

Each charge consisted of ductile "pig iron," carbon steel, Machined turnings and ductile returns. Typical tap temperature 2775-2850F

Build-Up occurred along the front wall area in the active power coil. After a 72 hour period, serious downtime was experienced due to delays in charging, Each melt cycle required an extra 30-45 minutes for each heat daily.

Controlling Severe Ductile–Base Build-Up in Coreless Induction Furnaces



Controlling Severe Ductile–Base Build-Up in Coreless Induction Furnaces

Compound	Wt. (%)
SiO_2	60.1
Al_2O_3	16.5
Mn_3O_4	9.0
Fe_2O_3	7.2
CaO	3.9
MgO	0.9
Na_2O	0.8
TiO_2	0.7
BaO	0.2
Cr_2O_3	0.2
SO_3	0.2
K_2O	0.1
CeO_2	0.1
ZrO_2	0.1
P_2O_5	0.1
SrO	0.1
F	0.1

Typical Daily Slag

	12/30/09	12/30/09
	X2438a	X2438b
	Slag A	Slag B
Compound	Wt. (%)	Wt. (%)
SiO_2	69.1	69.6
FeO	10.3	5.9
Al_2O_3	8.1	8.9
CaO	5.1	5.8
MnO	4.1	5.0
MgO	1.1	1.2
TiO_2	0.6	0.8
Na_2O	0.5	1.9
S	0.2	0.2
K_2O	0.2	0.2
BaO	0.2	0.2
Ce_2O_3	0.1	0.1
ZrO_2	0.1	0.1
SrO	0.1	0.1
F	0.1	
Cl	0.1	
Cr_2O_3		0.1

Slag A – 4lbs Flux/ Ht
Slag B – 10lbs Flux/Ht

Controlling Severe Ductile–Base Build-Up in Coreless Induction Furnaces

Foundry D2 operates 7 Ton Coreless furnaces in a 100% batch melting Ductile-base

Adding 10 lbs of Flux per 7 ton heat, build-up eliminated.

Refractory lining was unaffected by the flux. Current Flux addition of 4 lbs per heat per campaign.

Foundry D2 continues to realize the following benefits:

- Furnace capacity remains consistent at 7 tons while recycling machined turnings in the melt
- Normal melt cycle of 40-50 minutes is uninterrupted
- Less frequent top cap cleaning
- Delays for molten metal from the coreless melters to the holding channel furnace was reduced

Controlling Severe Build-Up in Coreless Induction Furnaces

Foundry G a medium sized captive foundry casting grey iron

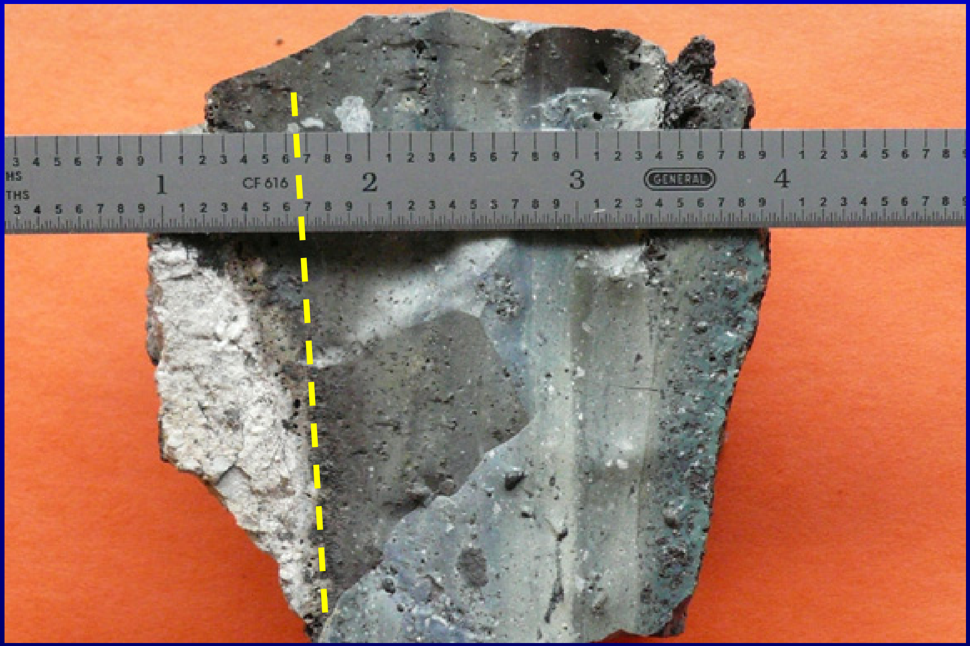
Four **3 ton medium frequency Coreless** furnaces lined with European silica dry vibratable Boron Oxide bonded

Experienced extensive sidewall build-up in a semi-batch melting operation.

The charge make-up is 100% metallic fines, < 20 mesh.

After 48 hours of operation, 3 inches of build-up occurred along the entire sidewall. This led to increased power consumption due to significant downtime to allow for scraping

Controlling Severe Build-Up in Coreless Induction Furnaces



The Build-Up is approximately 2.5” and dense, Fused glass-like material, (Alumino Silicate phase)

Controlling Severe Build-Up in Coreless Induction Furnaces

Foundry G

Solution was to add 2 lbs of Flux per ton of metallic charge added to every backcharge.

Immediate improvements were observed.

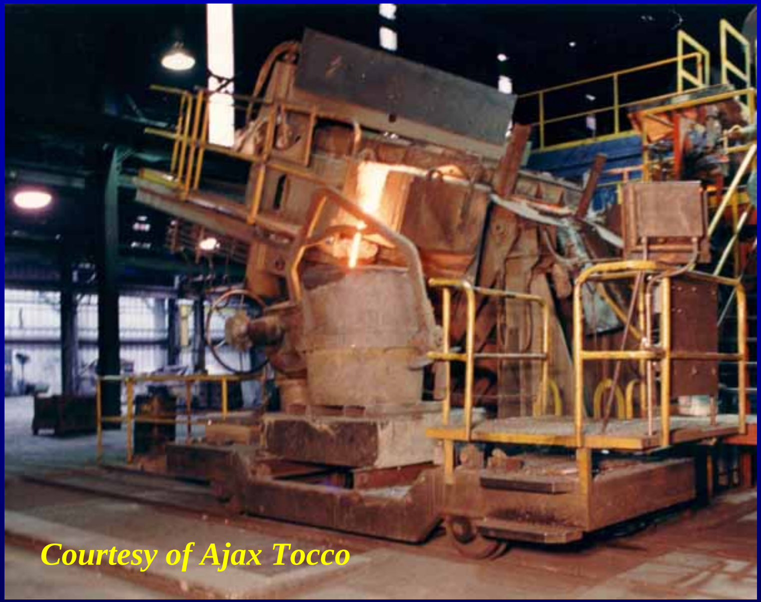
Once build-up was removed, continuous 1 lb flux per ton of backcharge was part of their melt procedure.

Controlling Severe Build-Up in Coreless Induction Furnaces

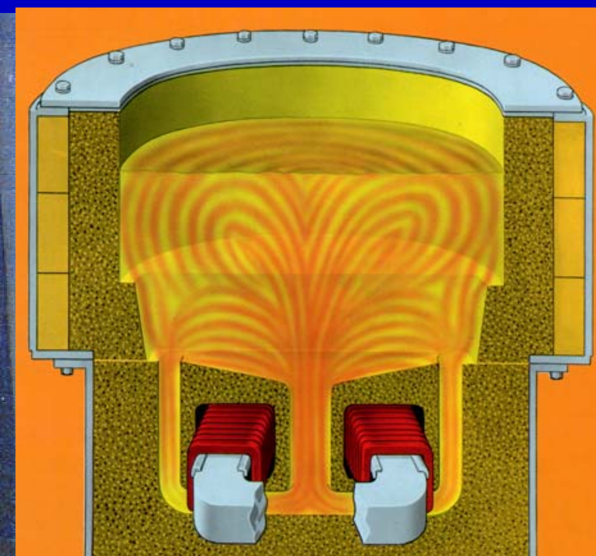
Foundry G observed the following benefits:

Using flux, less tendency for "bridging"
Reduced power consumption during each melt
Hourly maintenance for scraping reduced
Consistent furnace capacities
Improved "electrical coupling" due to improved temperatures
No adverse effects on dry vibratable refractory

Channel Induction Furnaces
Uppercase and Inductor Build-up



Channel Induction Melting furnaces restricted Inductor Melt Power due to Throat or Inductor Build-Up



Courtesy of Ajax Tocco

Severe Restriction of Metal Flow in Throats or Inductor Channels can caused heavy saturation leading to refractory wear or metal leakage. Inability to superheat the molten iron.

Channel Induction Holding furnace Uppercase Build-up, Causing Loss of Capacity, and Service Life

Furnace history will indicate when to flux. Establish the "threshold" indicator such as a minimum/maximum limit to conductance /reactance depending on equipment.

When Do I Flux?

Use "Inductor Condition." This is determined by dividing the new, daily reactance reading by the base line reactance calculation at the beginning of each campaign.

$$\text{Inductor condition} = \frac{\text{Daily reading}}{\text{Base line reading}} \times 100$$

A number greater than 100% is blockage & less than 100% is erosion, saturation or penetration.

When Do I Flux?

A number greater than 100% is blockage & less than 100% is erosion, saturation or penetration.

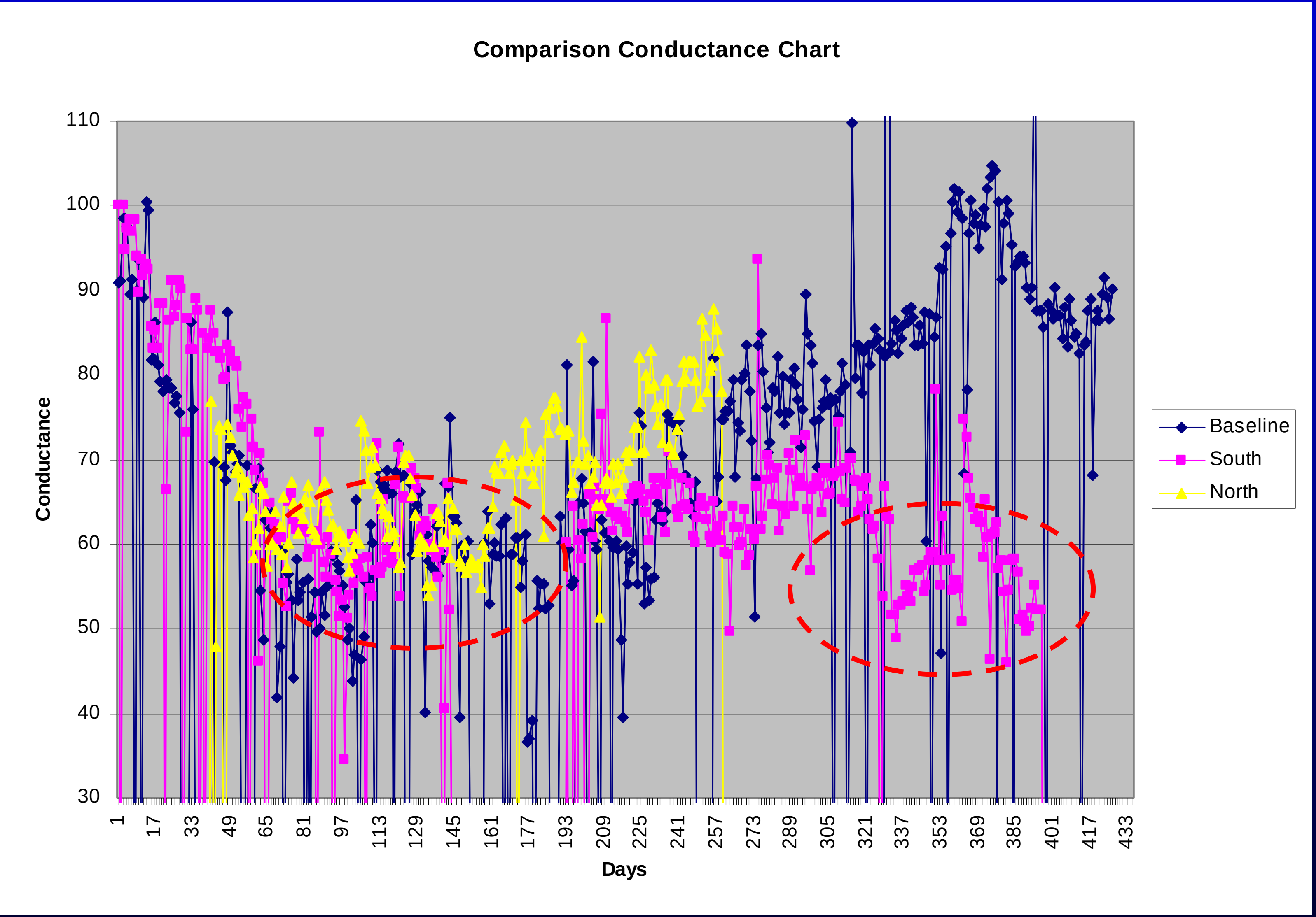
Examples:

107% means 7% blockage

97% would be 3% erosion, saturation or penetration

If a given inductor's "Inductor Condition" is 7% or better blocked for a week or longer, the decision is made to flux the inductor .

Inductor Conductance Ratio for 45 ton Ajax Channel



Treatment 1: Continuous Additions, Daily Maintenance

Continuous Addition of Flux to Uppercase

1) Continuous Flux Addition rate of 1–2 lbs flux per ton of metal entering the furnace

2) This was continued for every day.
3) Furnace continued to operate until daily Deslagging has been performed.

4) Flux addition resumed each consecutive day and the steps were repeated, Deslagged every day.

The quantity of the Flux will vary depending on the build-up.

Restoring Original Furnace Capacity in Holding Channel Furnace holding Ductile-base Iron

Two 65 ton Vertical Channel Holders

Capacity was less than 35 tons after 11 months of operation.

Courtesy of ABP Induction

0.05% flux was added continuously to transfer ladles feeding the channel holders for 3 weeks.

The buildup removed AND capacity was restored.

Restoring Original Furnace Capacity in Holding Channel Furnace holding Ductile-base Iron

3 months later, each furnace was taken off line for its yearly reline and carefully examined. No sign of refractory erosion.

These furnaces now last 24 months instead of 12 months!

Approximate savings of $100, 000 for each furnace.

Build-Up in 110 ton *Vertical* Channel Furnace Holding Ductile-base Iron at Automotive foundry

Monday – Friday 5 DAY
Continuous Additions

Two 110 ton Vertical Channel Holders

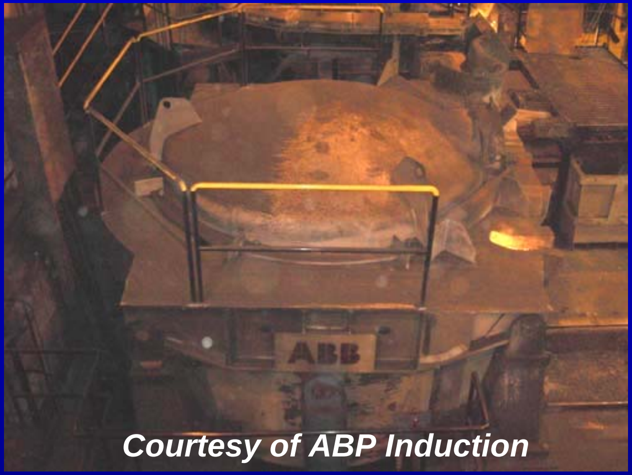
0.4 Kg per ton of molten iron, was added to the cupola launder feeding the channel holder at the collector box of the receiver of the channel furnace for 5 days.

Courtesy of Asea Brown Boveri

Build-Up in 110 ton *Vertical* Channel Furnace Holding Ductile-base Iron at Automotive foundry

The furnace deslagged twice during the five day period. Adding flux created more slag.

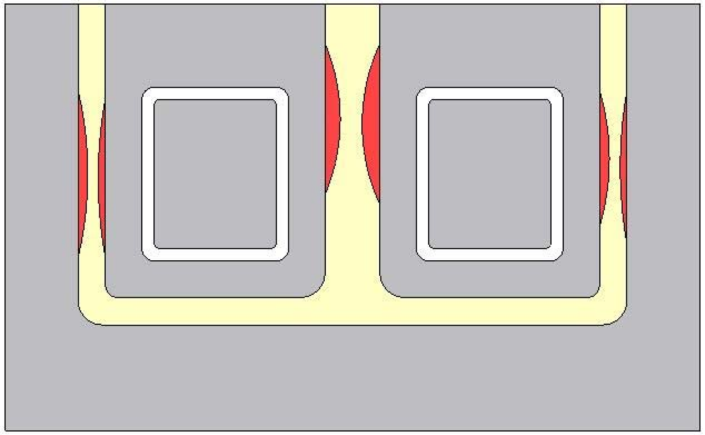
Molten metal temperature should be above 1440C (2624F) for effective fluxing to occur



Courtesy of ABP Induction

Emergency Flux Treatment of Restricted Channel of 45 ton Vertical Melter

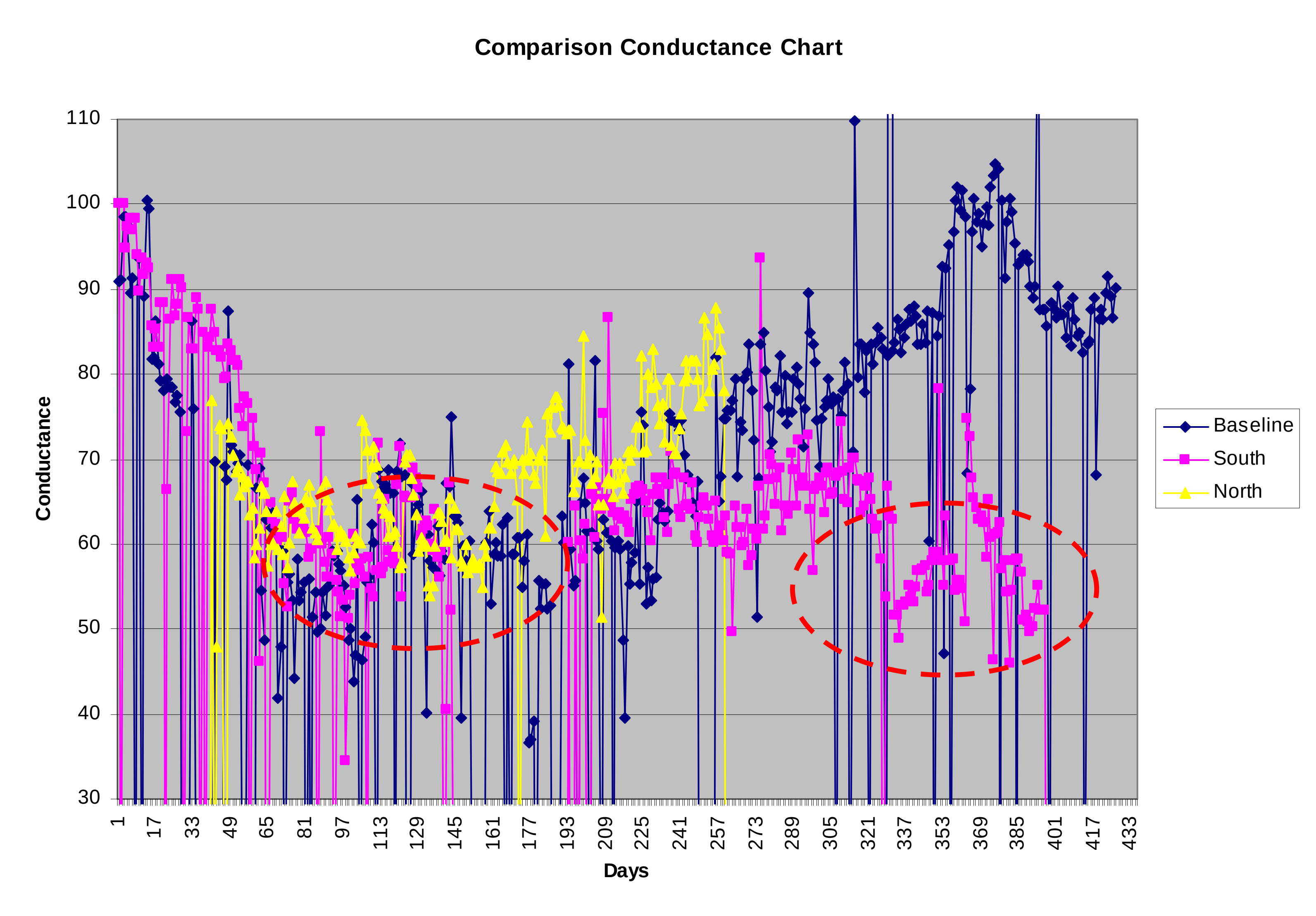
Throat completely 90% Restricted



Twin Loop channel clogging

In 48 hrs, foundry experienced severe Build-Up in throat and each of the channels of a Double-loop inductor.

Inductor Conductance Ratio for 45 ton Ajax Channel



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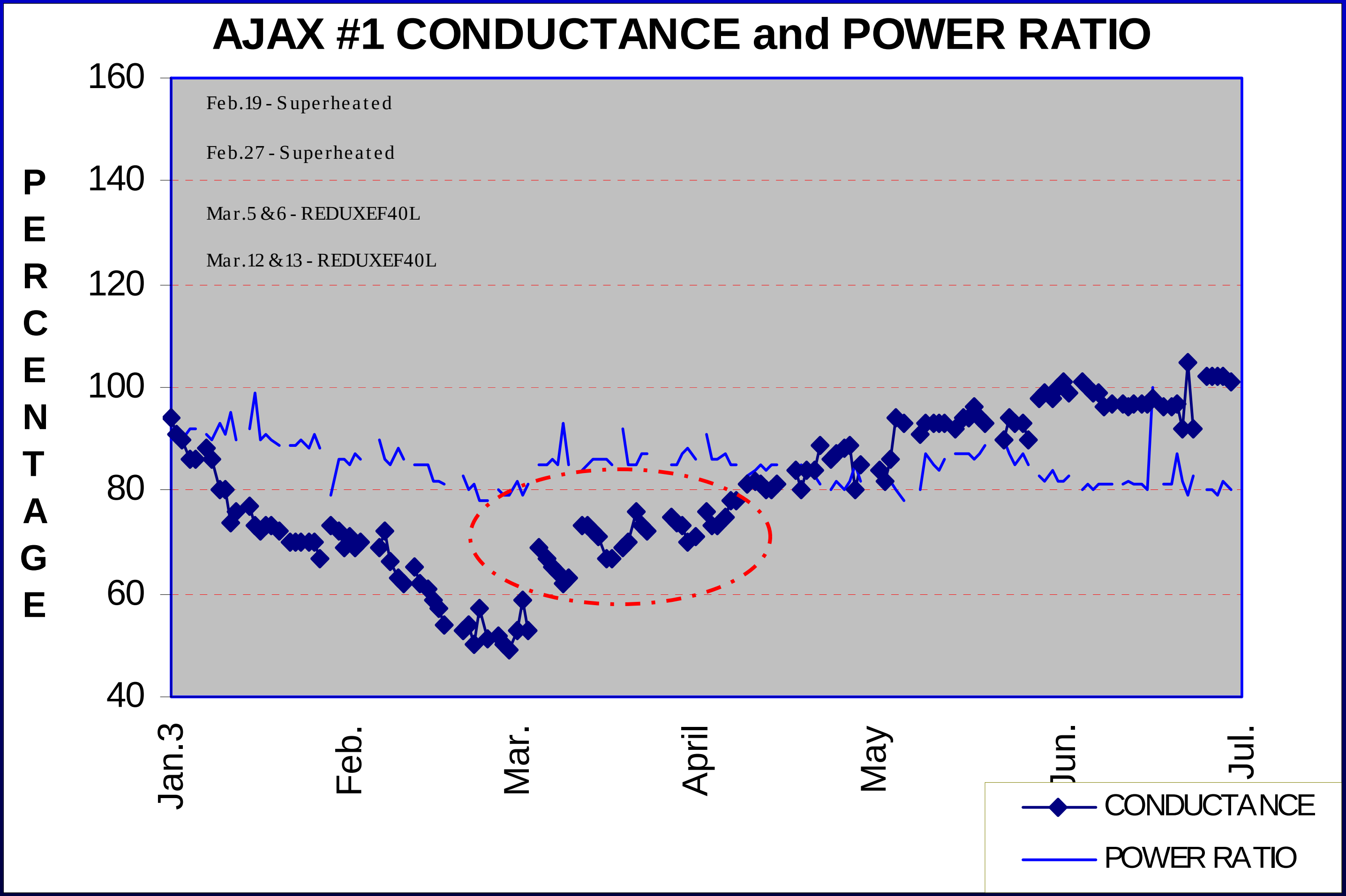
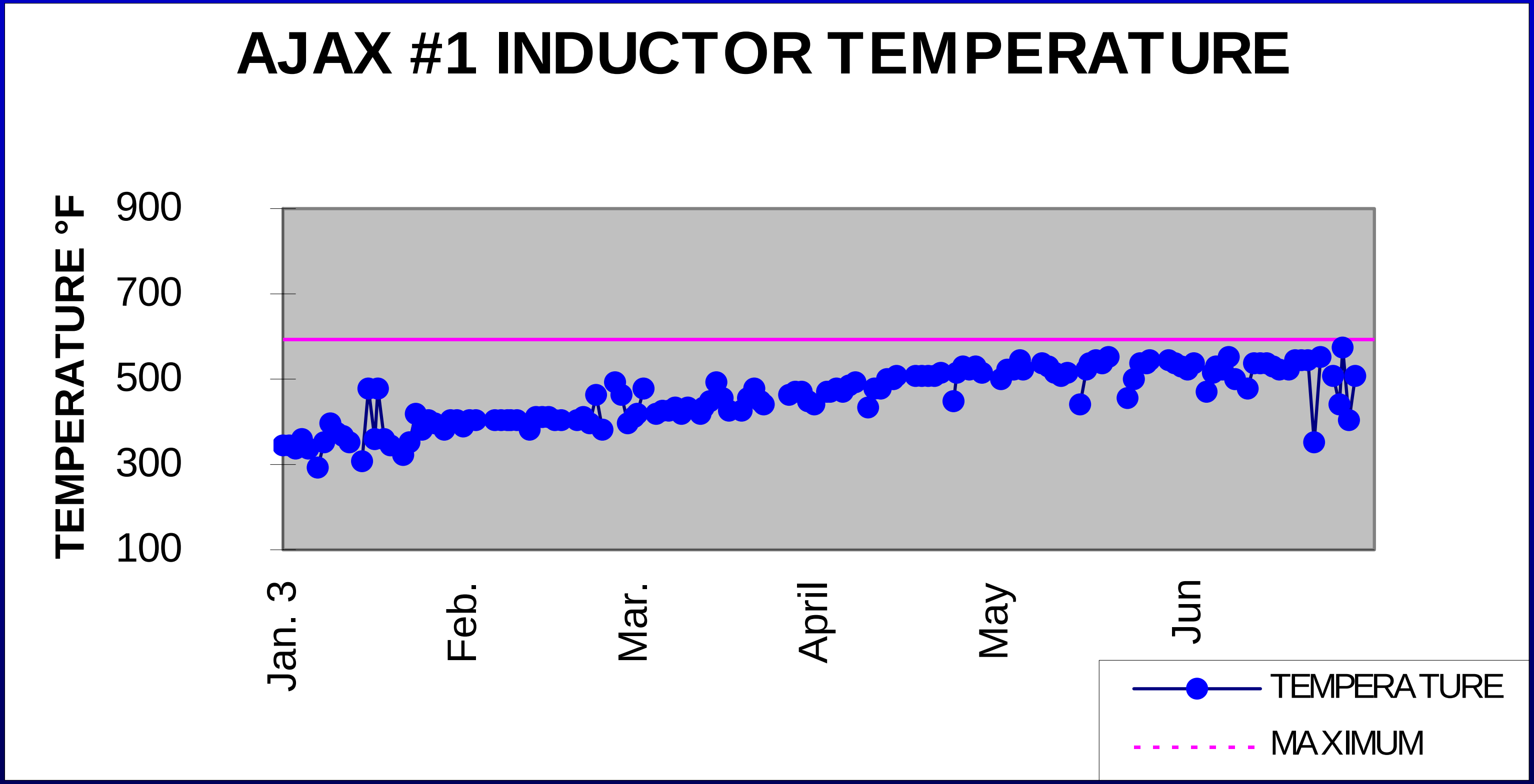
Emergency Flux Treatment of Restricted Channel Melter




AJAX #1 INDUCTOR TEMPERATURE
TEMPERATURE °F
900
700
500
300
100
Jan. 3
Feb.
Mar.
April
May
Jun
TEMPERATURE
MAXIMUM

Method 2: 2-Day, Low Metal Heel Superheat

Treatment (DAY 1)

1) Remove slag from the top of the molten iron.

2) Lower the molten iron level to Minimum Heel.

3) Add 2-4 pounds of Flux per ton of molten iron heel to 2750 F iron. DO NOT ADD ANY FLUX on top of any existing slag. It must be added on top of exposed molten metal.
   Close cover but DO NOT SEAL! Some smoke emissions will occur.

4) Turn inductor power on maximum power.

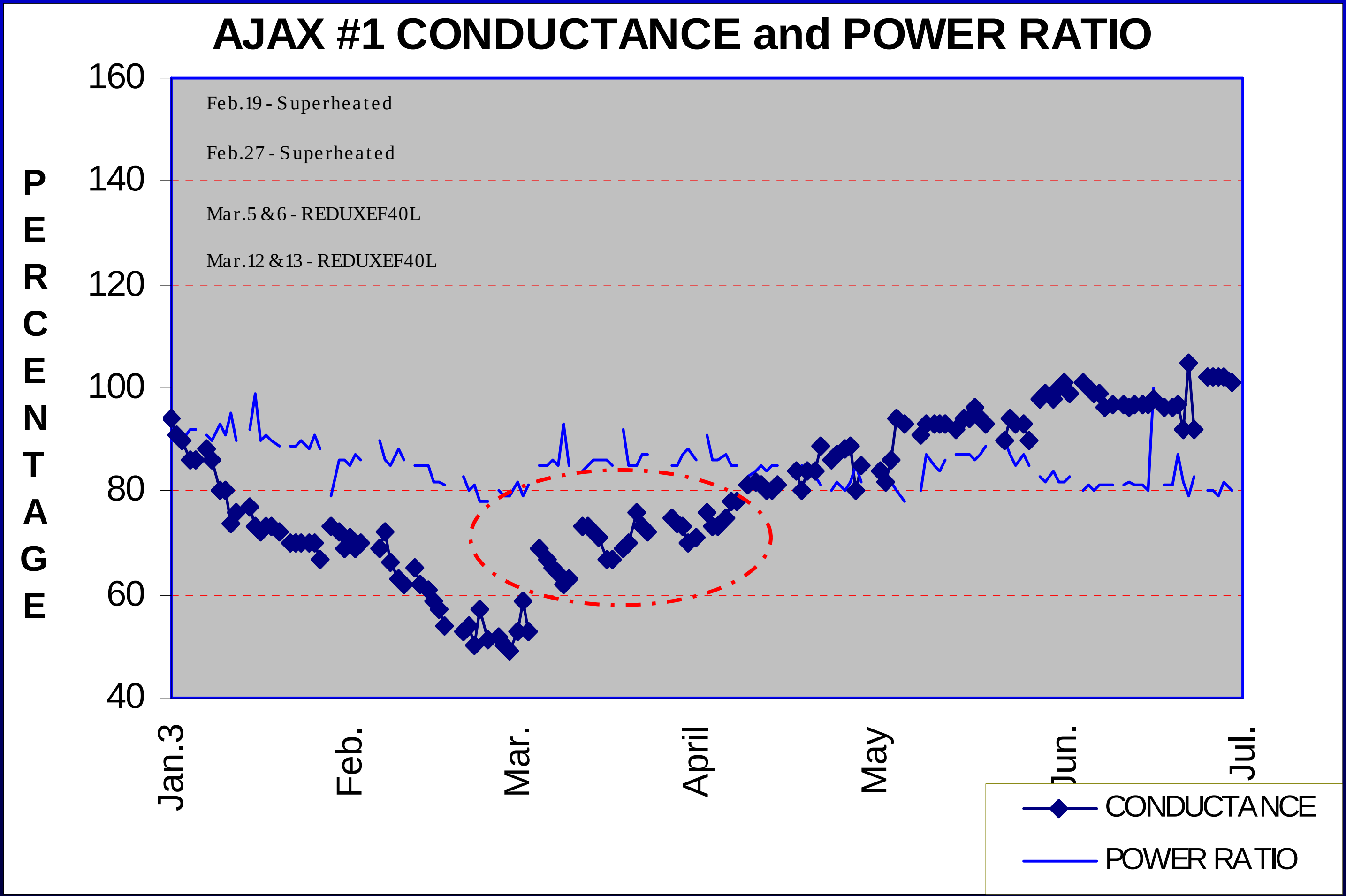
Method 2: 2-Day, Low Metal Heel Superheat

5) Leave inductor on max power for 4 hours. <u>Monitor molten iron temperature so that it NEVER exceeds 2900F(1600C).</u>

6) Depending on the severity of the build-up, it may be necessary to add another 2-3 pounds of Flux per ton of molten iron, after 2 hours of superheating has occurred.

7) After the superheating period has been completed, the molten iron should be cooled to normal holding temperatures. The <u>slag created, SHOULD BE REMOVED.</u> Close cover and check the spout openings.

Emergency Flux Treatment of Restricted Channel Melter



Emergency flux Treatment of Restricted Channel / Treatment 2: 2-Day Additions, Low Metal Heel Superheat; Inductor Max Power

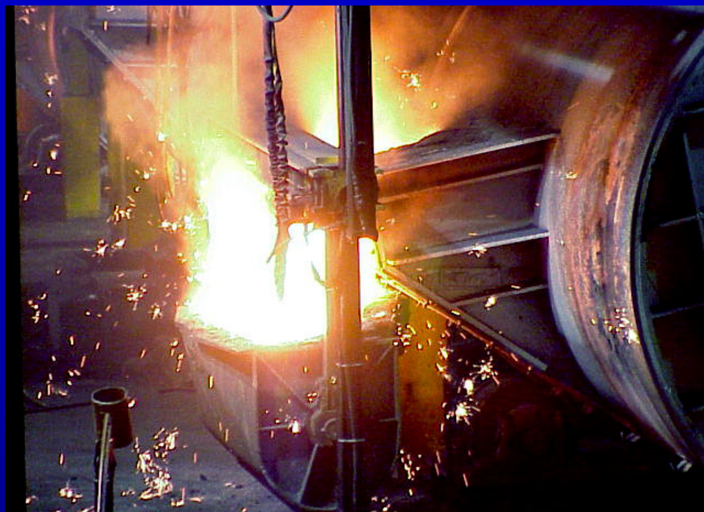
Restoration of Furnace with minimal Downtime

Savings in Loss Production

Savings in Relining the Channel Furnace

Less Chance of Metal Runout

Build-Up in 100 ton ***Drum*** **Channel** Furnace Holding Cast Iron At Large Automotive Foundry



Courtesy of Inductotherm Corp

A Severe Slag Ring.

Estimated loss of capacity 25-33%.

Unable to introduce new molten metal from the cupola, as the thick slag ring could not be penetrated. **Receiver partially open**

A 2-Step Flux Process Used

Build-Up in 100 ton *Drum* Channel Furnace Holding Cast Ductile-based Iron At Large Automotive Foundry

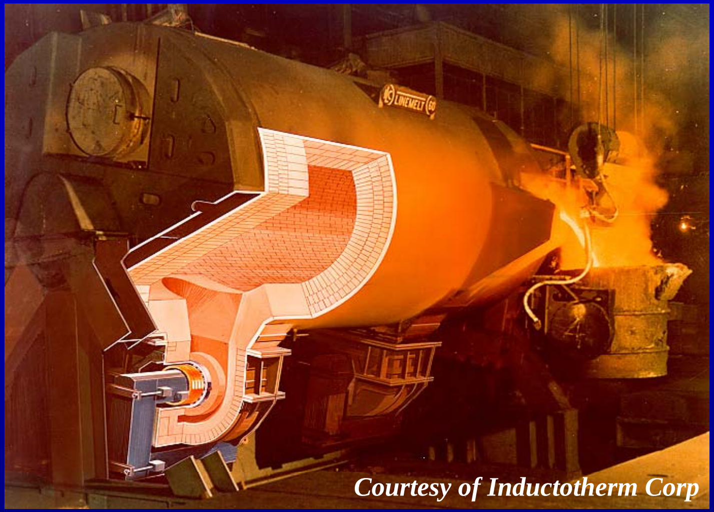
Flux added directly to the Receiver/Fill spout

Continuous Flux Addition rate of 2.0 lbs flux per ton of molten metal entering the furnace, was added at the Receiver / Fill Spout.

For five consecutive days, FLUX was added

Furnace was deslagged continuously, and eventually the furnace was allowed to operate.

Build-Up in 100 ton Drum Channel Furnace Holding Ductile-based Iron At Large Automotive Foundry



Courtesy of Inductotherm Corp

It was necessary to add Flux directly on top of the solidified slag crust, at the rate of 0.1% flux

2.0 lbs per ton of molten metal along the surface area of the bath, through the slag door. It was left on top of the slag for 4 hours.

Build-Up in 100 ton Drum Channel Furnace Holding Ductile-based Iron At Large Automotive Foundry

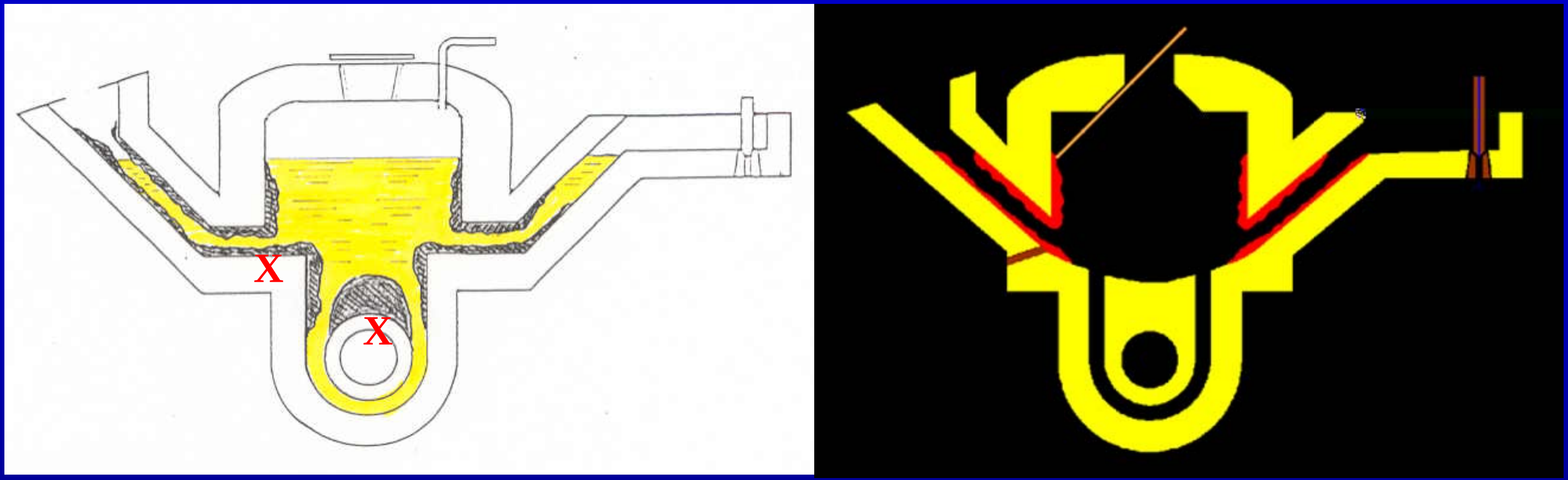
Another similar flux addition was added on top of the slag and allowed to react for another 4 hours.

The slag surface began to soften and the furnace was deslagged through this door appropriately.

(Flux addition will vary depending on the slag ring build-up in the uppercase. Slag removal needed.)

Pressure Pouring Channel Furnaces holding treated Ductile Iron / Severe Build-up occurring daily

Build-Up in Pressure Pour Furnaces



Insoluble build-up can cause:

- energy inefficiencies, diminished heat transfer
- poor temperature control
- superheating in restricted inductor channel
- increased metal saturation within the Inductor
- reduced rate of filling /pouring of furnace

Examples of a Clogged throat and Saturated Inductor

Severe Build-up Consequences occurring daily in Pressure Pouring Channel Furnaces holding treated Ductile Iron

Severe Throat Build-Up in 3 TON Pressure Pour Furnace Holding/Pouring Treated Ductile Iron

Continuous Addition of <u>0.5 lbs per ton of molten metal</u>

Manual Scraping of Receiver every 4 hours

Once a week, <u>1-3 lbs flux per ton of molten metal</u> (low heel) through small cover.

High power on inductor for 2- 4 HRS. Monitor temp.

Courtesies of ABP Induction Corp

Rod out channels / Fill furnace and Deslag. Repeat treatment next 2 days.

Severe Throat Build-Up in 15 ton Pressure Pour Channel Furnace Holding/Pouring Ductile Iron

Treated Ductile Iron at 1426C(2600F)

0. 8 Kg FLUX per 1 ton per each ladle metal entering the Furnace

Mechanical Rodding of Fill and Pour Siphons ONCE EVERY 8 HRS

Courtesy of Inductotherm Corp.

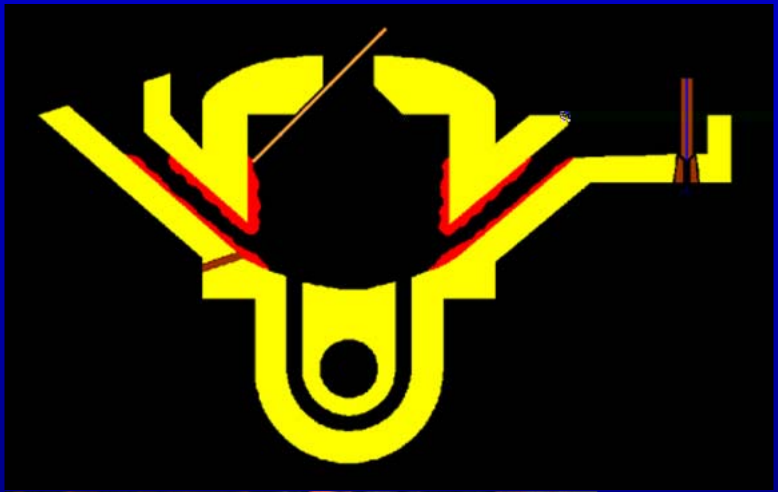
Deslagged twice a week through small cover

Severe Throat Build-Up in 15 ton Pressure Pour Channel Furnace Holding/Pouring Ductile Iron

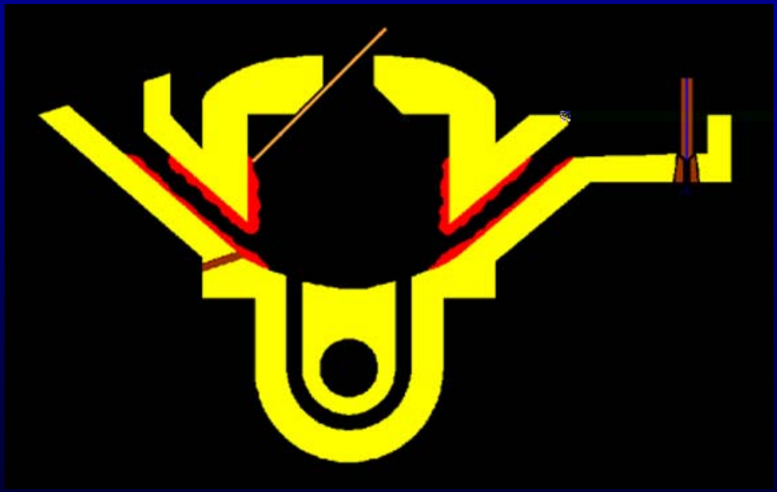
No negative effect on Uppercase, Floor, Throat, Inductor Refractories

Lining Life extended from 4-6 months to 9-12 months

Throat and Uppercase Build-Up Maintenance
15 ton Pressure Pour Channel Furnace
Holding/Pouring Ductile Iron



Throat AND Uppercase Build-Up Maintenance
15 ton Pressure Pour Channel Furnace
Holding/Pouring Ductile Iron

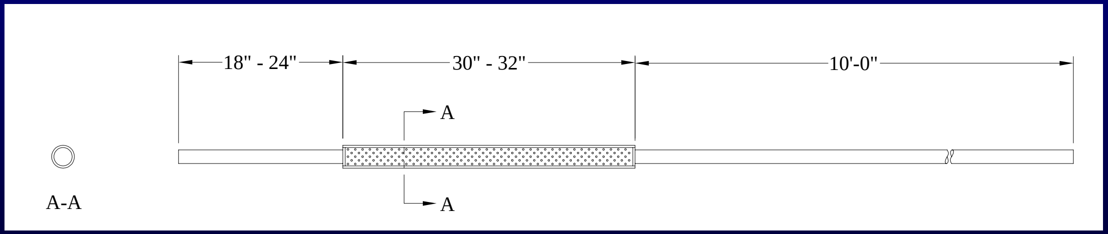


Throat AND Uppercase Build-Up Maintenance
15 ton Pressure Pour Channel Furnace
Holding/Pouring Ductile Iron

Weekly Maintenance of Fluxing and Mechanical Slag removal allows this Press Pour to continue To operate 5-6 days a week, for 1 year campaign

No sudden interruptions midweek for downtime Due to build-up from holding treated ductile iron

Method 3: Periodic Flux Plunging into Throat and Inductor Channels of Press Pour fces



Method 3: Periodic Flux Plunging into Throat and Inductor Channels

Periodic Treatment as determined by Inductor Electrical readings.

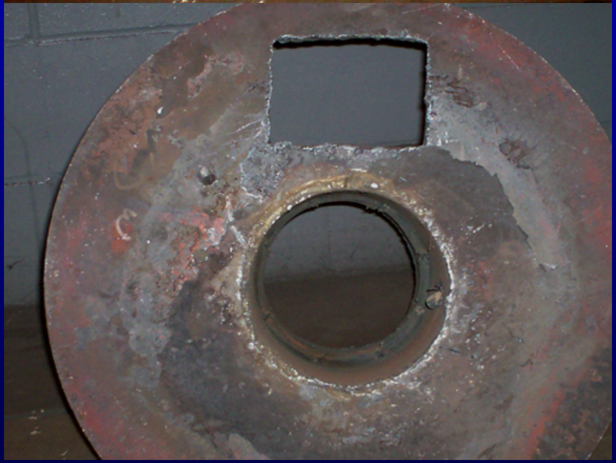
Prolonged operation of Press Pour furnace with Minimal interruption of production.

Safety before Fluxing

Consider the Flux to be used.
Read Material Safety Data Sheet for gas generation and personal protective equipment recommendations.

Consider the Method of Application
There is a good deal of flair / flame off when using this methodology to remove slag. When you think that the amount of PPE is enough, put on some more. Employees should be dressed in full "silver leathers", dark heat reflective face shield with fiberglass helmet, canister type respirator & hot mitts as a minimum requirement

Safety Considerations when Plunging



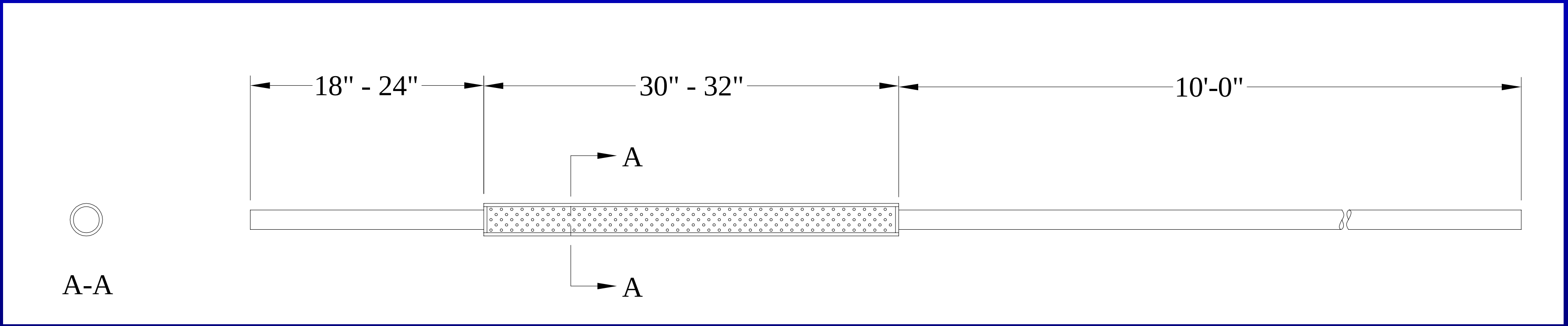
A chimney type device is utilized to redirect the flare and smoke above & away from the team member.

Safety Considerations when Plunging

The chimney is clamped to the furnace hatch & ceramic blanket material is used a compression gasket between the chimney base plate & fce lid.

Flux Plunging Procedure for Channel Inductors and Throats

Flux Plunging Wand (an example is shown below)



Think small when determining the actual size that you will need for your application. One limitation is the size of the chimney and proper venting of the off-gases !!

Method 3: Flux Plunging Procedure for Channel Inductors and Throats

A Mild Fluoride-free Flux, Redux EF40, is packed into the Flux Tube (either a round pipe or square tube can be used). Whether pellets/briquettes or bricks are used, each must be pulverized first before filling the tubes.

Construction Guidelines for the Flux Plunger



Flux is packed into the Flux Tube (either a round pipe or square tube can be used).

The "Feeler Gauge" is attached to the tube.

Prior to filling the tube you ***must*** cut slots or drill holes throughout the flux chamber.

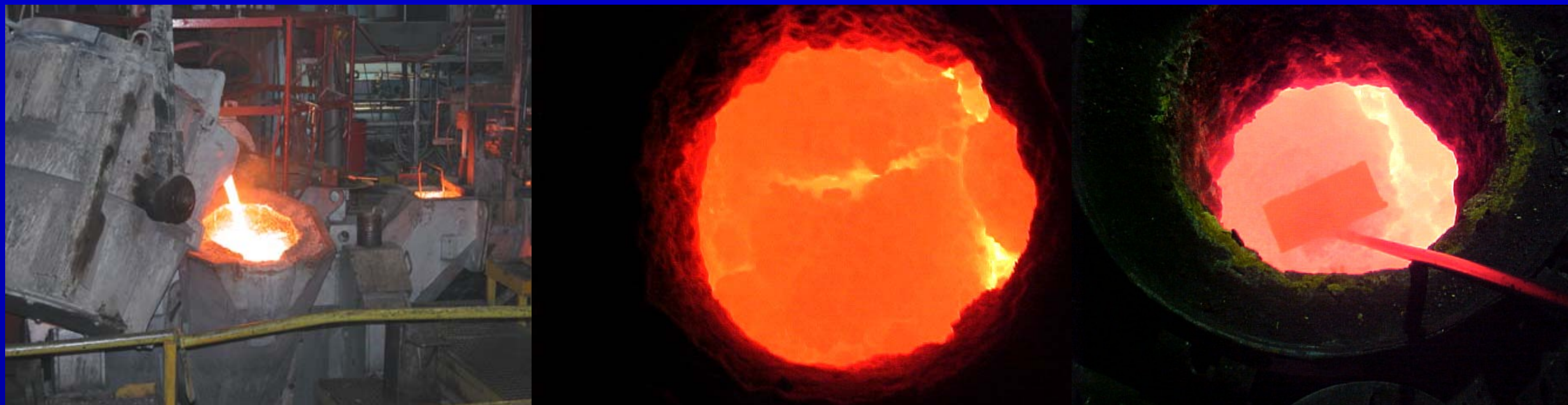
This will allow for OFF-gassing when submerged below the molten metal.

Flux Plunging Procedure

The tube is wrapped with duct tape to keep the flux in the tube.

The solid steel bar Feeler gauge" is attached to end of Flux Pipe. A solid steel bar handle welded on the other end of reaction chamber.

Flux Plunging Procedure



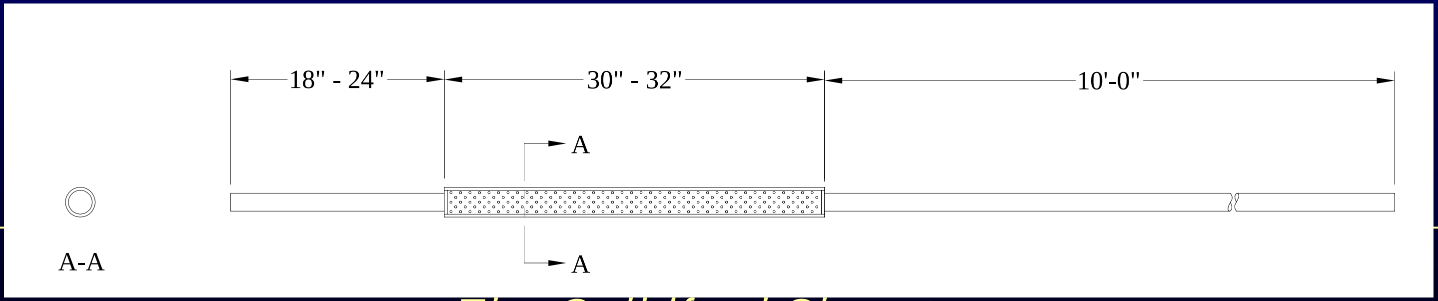
Remove existing slag from the molten metal bath. Record the electrical readings

Lower the bath level to minimum heel level and turn off the power on the inductor & lock out the disconnect. Do not leave the power off for more than 30 minutes maximum.

Flux Plunging Procedure for Channel Inductors and Throats

Lower the first flux plunger using the "Feeler gauge" to locate the channel opening.

Immediately plunge the flux perforated tube/pipe so that the entire length of the pipe is immersed below the molten metal, into the channel opening.



Flux Plunging Procedure for Channel Inductors and Throats

Hold this plunger in place until the flux has completely reacted. The vigorous boiling is similar to "green poling" often used in the past to mechanically disrupt build-up. With Flux Plunging, one can expect a flaring up and must be prepared to take precautions to prevent it reaching the operator such as a chimney.

After the reaction has been completed, there will be more slag generated. This should be removed immediately.

Flux Plunging Procedure for Channel Inductors and Throats

It may be necessary to repeat the plunging with a new flux plunger depending on the severity of the build-up. This application used 1 - 2 plungers. It is not recommend exceed this number in a single treatment episode.

Fill the furnace back to the normal "hold iron" level.

Flux Plunging Procedure for Channel Inductors and Throats

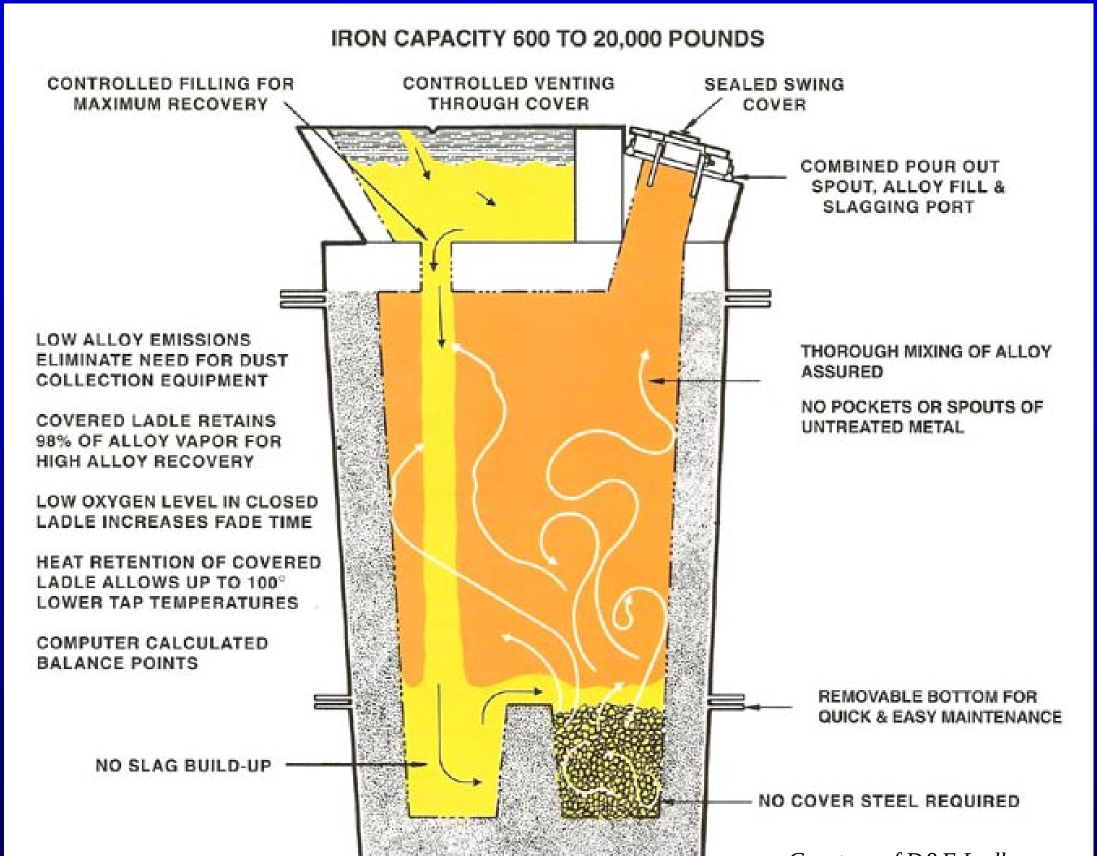
Seal any openings of the furnace to prevent any air from entering into the furnace

Leave the furnace in a holding cycle mode from low Hold to High Hold as needed to maintain the normal hold temperature.

Record all electrical readings of the inductor and compare to previous clogged condition.

Fluxing in Treatment Ladles for Ductile Iron

Treatment Ladles for Ductile Iron

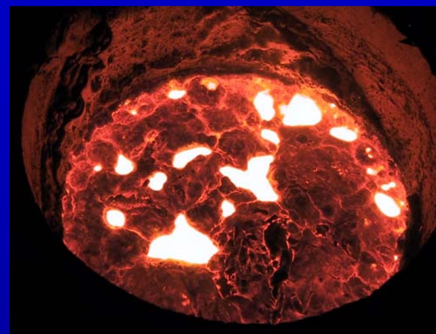


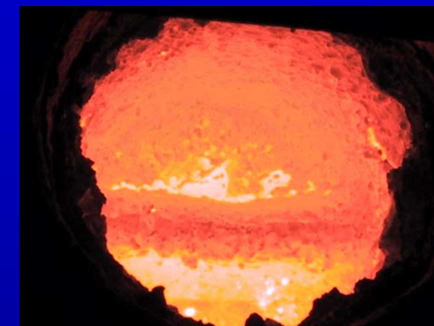
Courtesy of D&E Ladles

Treatment Ladles for Ductile Iron

Treatment Ladles for Ductile Iron

Fluxing 1 ton Treatment Ladle w/ 5 "Wash Heats" one Lb(0.4Kg) Pack /Ladle

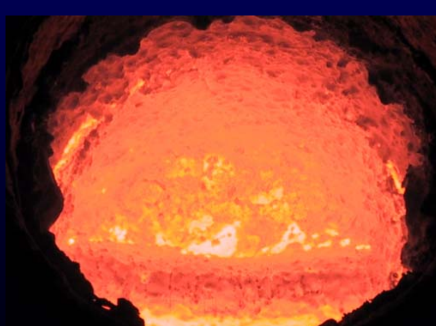



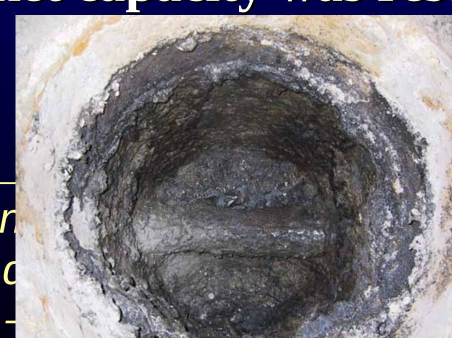


Loss of pocket capacity due to Insoluble Build-Up. After 5 separate Wash heats




After the 5 individual treatments, pocket capacity was restored as shown






Treatment Ladles for Ductile Iron

Before Treatment

After Treatment

This was achieved with minimal scraping, strictly the addition of Flux to 5 different "wash heats." This treatment allowed for 72 hours of service versus 16 hours of service.

Fischer Converter for Ductile Iron Treatment

Pure Magnesium additions lead to MgO and MgS depositing along the sidewalls.

Rock Salt flux is recommended in the chamber, and an 1 lb addition of a mild flux per ton of metal was used inside the body.

Fluxing has been proven beneficial for many Ferrous applications. The three general methods are

Method 1:
Continuous or Semi-Continuous Additions

Method 2:
2-Day Additions, Low Metal Heel Superheat; Inductor Max Power

Method 3:
Periodic Flux Plunging into Throat and Inductor Channels

Other Flux Applications in Ferrous Foundries

Transfer Ladles for Grey, Ductile, Alloyed Iron

Steel Coreless Melting

Cupola Coke Cleansing, Increasing Slag fluidity

Reduction of Sulfur in Furnace Melts

We would like to acknowledge the contribution of Mr Dom Bonacci from Grede St Cloud for his assistance in providing the parameters and safety aspects on Flux Plunging.

Thank you

Any Questions?

David C Williams