THE TECHNOLOGY, BENEFITS, AND MEASUREMENT OF THE ELBY™ LADLE BOTTOM[1]

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Abstract

The ELBY™ (Enhanced Ladle Bottom Yield) system is a novel technology for a steel teeming ladle precast bottom that uses specifically designed channels, terraces, and impact zones to alter the phenomenon of vortexing at the end of the ladle draining sequence. By delaying the vortex, more steel is allowed to exit the ladle into the tundish without slag carryover. In actual operations, the ELBY™ system can potentially achieve large yield savings which impact the operating cost of the steel plant. Significant technical benefits are also gained by insuring less slag carryover into the tundish, resulting in lower tundish maintenance costs and improved steel quality. The ELBY™ system is made possible through three proprietary technologies: Computational Fluid Dynamics (CFD): After a detailed audit is conducted on the ladle practice, a CFD is utilized to study and simulate the ladles draining pattern, vortex characteristics, and surface collapse. CFD analysis will detail the specific design of the ELBY™ bottom and estimate the yield savings.NUMAX^{TM} Refractory Castable: Cement free refractory, ultra low water castable. Designed with optimal particle packing, Numax™ castable allows ELBY^{TM} ladle bottoms to maintain their engineered profile to maximize flow characteristics and yield savings.Infrared Thermal Imaging (ITI): The measurement of yield savings is very important to the steelmaker. Using a proprietary infrared measurement system, videos are taken of individual ladle dumps after casting. Specialized software distinguishes slag steel, labeling each with a unique color. A program specifically designed for the ELBY™ system counts the total number of pixels in both the slag and steel to give a percentage of each component.In summary, the combination of bottom design, Numax™ castable performance, and infrared yield measurement make the ELBY™ system an important innovation with the potential to impact shop yield around the world.

Key words: Ladle; Yield; Technology; Caster; Refractory.

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1 INTRODUCTION

The ELBY™ (Enhanced Ladle Bottom Yield) system is a novel technology for a steel teeming ladle precast bottom that uses specifically designed channels, terraces, and impact zones to alter the phenomenon of vortexing at the end of the ladle draining sequence. By delaying the vortex, more steel is allowed to exit the ladle into the tundish without slag carry over. In actual operations, the ELBY system can potentially achieve large yield savings which impact the operating cost of the steel plant. Significant technical benefits are also gained by insuring less slag carryover into the tundish, resulting in lower tundish maintenance costs and improved steel quality.

2 MATERIAL AND METHODS

2.1 Technology: Computational Fluid Dynamics

The first step in the process is to conduct a detailed audit on each melt shop's operation. Based on previous water model characterization studies,(1) computational fluid dynamics (CFD) is used to analyze the ladle's draining characteristics and study the timing of the weak vortex formation, strong vortex, and surface collapse. This allows for a prediction of how much residual steel is left in the ladle at each of the three phases of vortexing (Table 1).

After validating and duplicating the results, the amount of steel left in the ladle is calculated during normal operating conditions using a standard bottom. Using CFD, a solution is proposed which will optimally delay the vortexing phenomenon (Figure 1). Once the design is optimized, a comparison of the residual amount of steel left in the ladle at weak vortex, strong vortex, and surface collapse is made between the standard bottom and ELBY system. Based on actual ELBY bottom use in operating steel plants, the CFD predictions have been shown to correlate closely to actual results in the melt shop.

Table 1. Example CFD results

Tons of Steel Left in Ladle			
	Conventional Bottom	ELBY Bottom	Yield Savings per Heat
Weak Vortex	~3.7 Tons	~1.1 Tons	~2.6 Tons
Strong Vortex	~2.5 Tons	~.6 Tons	~1.9 Tons
Surface Collapse	~1.3 Tons	~.4 Tons	~.9 Tons

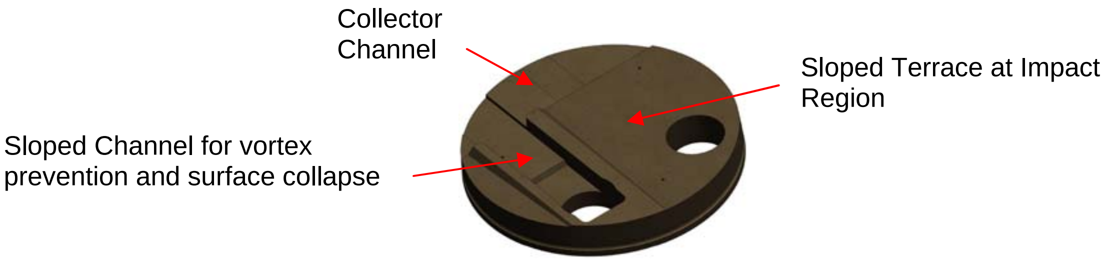
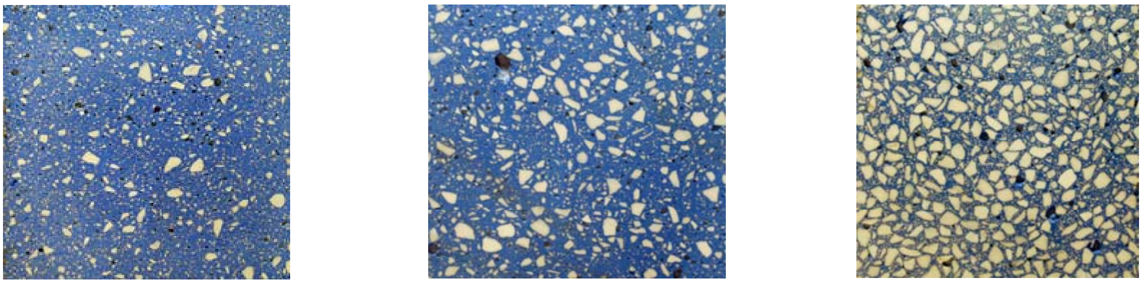


Figure 1. Example of an ELBY ladle bottom.

2.2 Precast Refractory

In order for the ELBY system to be commercially viable in service, the refractory must be engineered to withstand the harsh conditions inside the ladle while maintaining the profile shape of the engineered ELBY bottom design. After trialing the best low cement castables available, a new precast composition called Numax™ was developed. Numax formulations are advancements in precasting materials and technology. Proprietary refractory design formulation has allowed the manufacture of precast shapes with unprecedented low levels of casting water. This has allowed for refractory designs with enhanced properties such as hot strength, thermal shock resistance, and erosion/corrosion resistance that maintain the ELBY bottom design, thus allowing for maximum yield savings throughout the ladle campaign.



Conventional

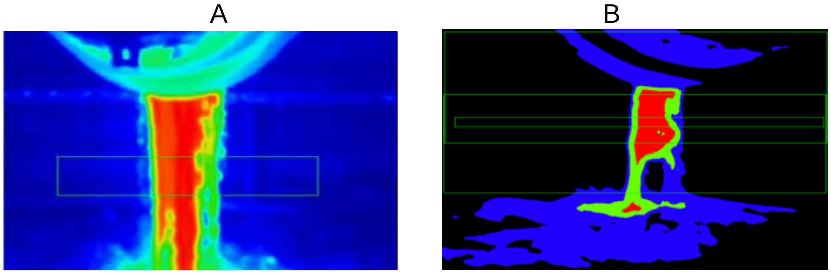
Low Cement Castable

NUMAX Technology

Figure 2. Numax Refractory utilizes optimal particle packing.

2.3 Yield Measurement

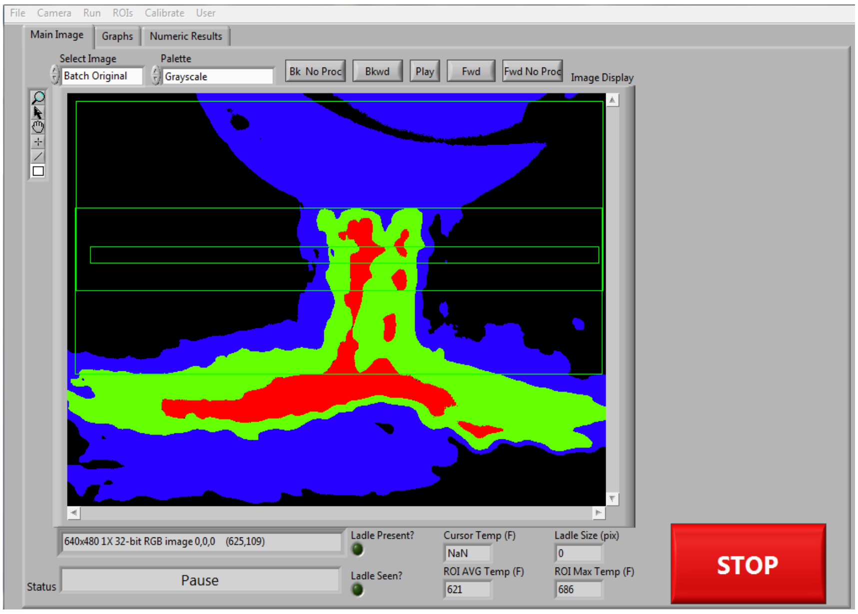
A key aspect of the ELBY system performance is having the ability to measure the yield savings. Common methods used to measure yield include slag pot studies, scale weights, and overall shop yield. In some operations, these methods prove to be difficult due to steel plant conditions. To help alleviate this issue, Infrared Thermal Imaging (referred to as ITI from here on out), a process commonly used in high temperature applications, was adopted. An infrared camera is specially calibrated to detect temperatures up to 2,000°C and is combined with a novel software technology which can differentiate steel from slag. When optical images are first taken, the steel and slag are indistinguishable from one another. However, the software manipulates the raw optical data and allows for the steel and slag to be differentiated into two separate, distinct, colors (Slag = Green/Darker Color, Steel = Red/Lighter Color in Figure 3b) (Figure 4).



Raw Thermal Image of a Ladle being dumped after Casting

Proprietary Computer Software can isolate Steel from slag

Figure 3. Thermal image and image showing steel and slag isolate.

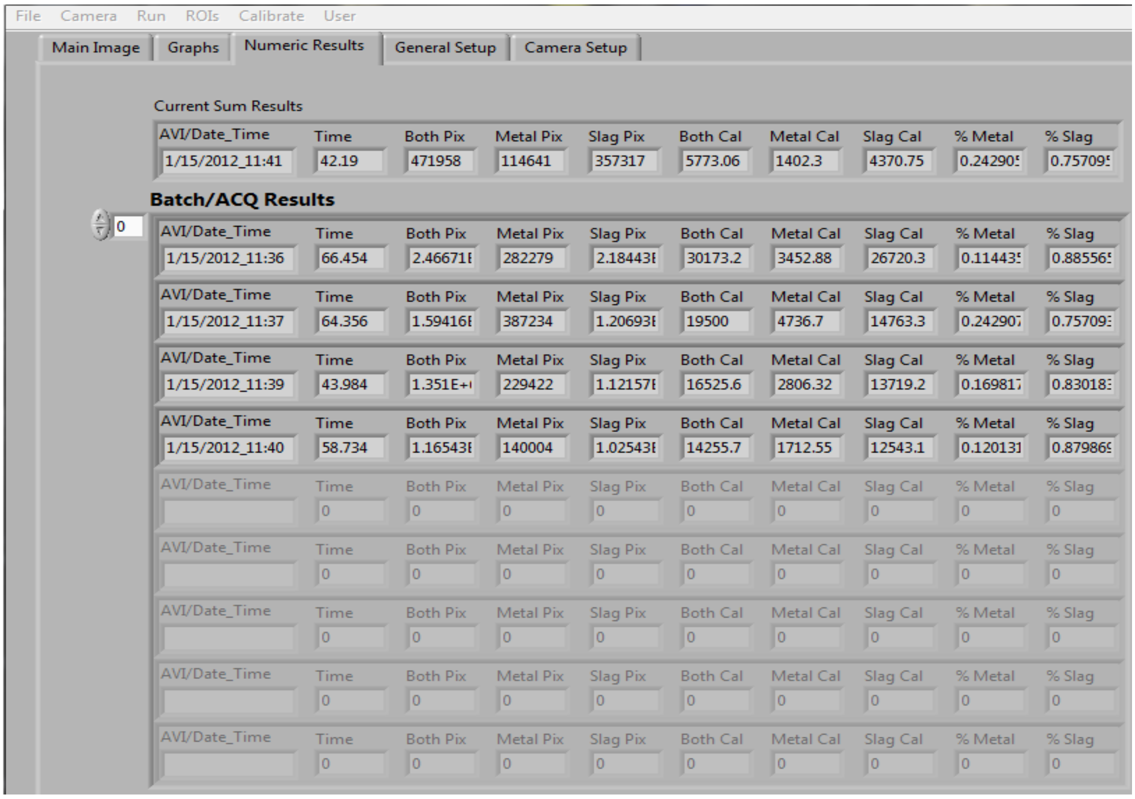


Select Image: Batch Original
Palette: Grayscale
640x480 1X 32-bit RGB image 0,0,0 (625,109)
Status: Pause
Ladle Present? ●
Ladle Seen? ●
Cursor Temp (F): NaN
ROI AVG Temp (F): 621
Ladle Size (pix): 0
ROI Max Temp (F): 686

Figure 4. Screenshot of program that calculates percentage of steel vs. slag.

This program is designed to automatically start recording once it sees the ladle in its view. It will continue to record until the temperature range inputted by the user is not longer there, at which point it will stop recording and be ready for the next ladle.

As the program is recording the ladle dump, it is also calculating the amount of metal, slag, percentage of each, and time and date of the dump (Figure 5). The program automatically creates a folder for each day and all of the data from that day is stored in that folder. All of the data is stored in a Microsoft Excel File (Figure 6).



Current Sum Results

AVI/Date_Time	Time	Both Pix	Metal Pix	Slag Pix	Both Cal	Metal Cal	Slag Cal	% Metal	% Slag
1/15/2012_11:41	42.19	471958	114641	357317	5773.06	1402.3	4370.75	0.24290	0.75709

Batch/ACQ Results

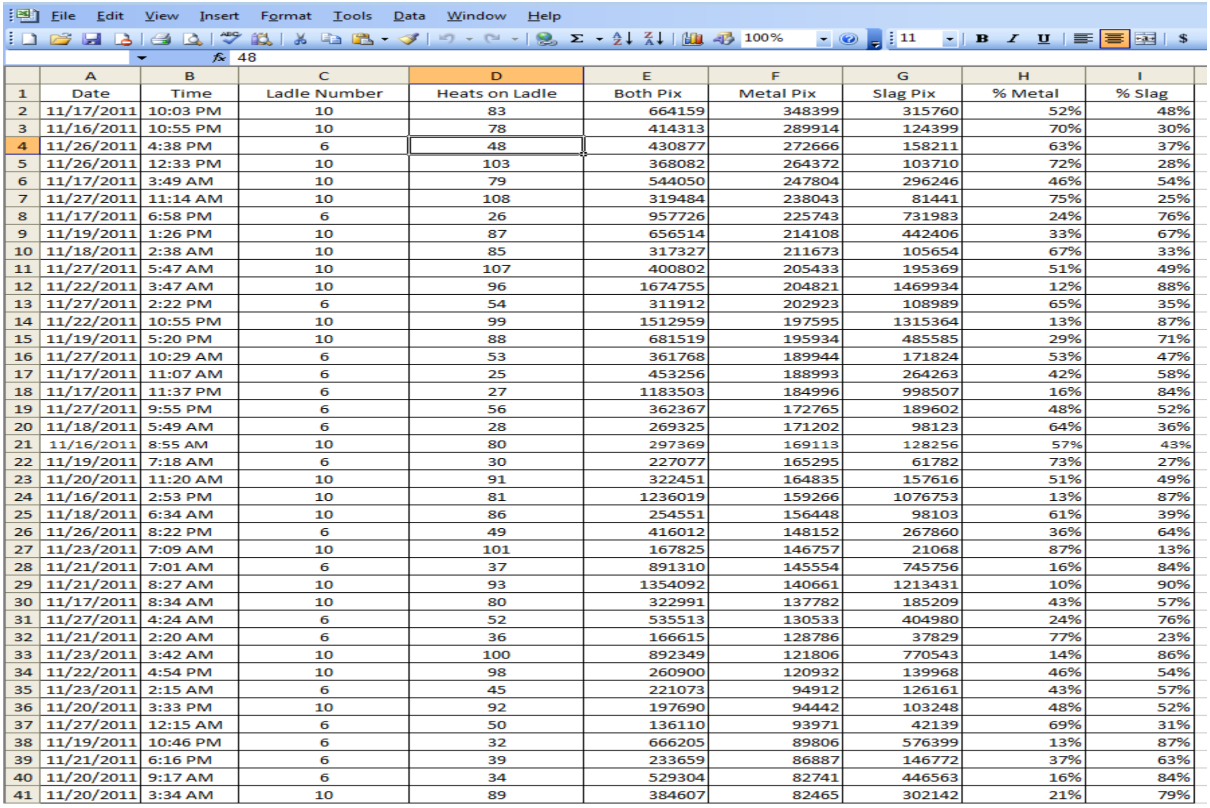
0

AVI/Date_Time	Time	Both Pix	Metal Pix	Slag Pix	Both Cal	Metal Cal	Slag Cal	% Metal	% Slag
1/15/2012_11:36	66.454	2.46671E	282279	2.18443E	30173.2	3452.88	26720.3	0.11443	0.88556
1/15/2012_11:37	64.356	1.59416E	387234	1.20693E	19500	4736.7	14763.3	0.24290	0.75709
1/15/2012_11:39	43.984	1.351E+	229422	1.12157E	16525.6	2806.32	13719.2	0.16981	0.83018
1/15/2012_11:40	58.734	1.16543E	140004	1.02543E	14255.7	1712.55	12543.1	0.12013	0.87986
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0

Figure 5. Screenshot of live, numerical data.

By comparing the times and dates of each video to the time of the caster shut off, one is able to match each ladle dump to a specific ladle number, heat number, or anything other type of information they may be looking for.

This compilation is completed manually, and when done allows for a graphical analysis of the average amount of steel left in the ladle after casting as the ladle life increases.



	A	B	C	D	E	F	G	H	I
1	Date	Time	Ladle Number	Heats on Ladle	Both Pix	Metal Pix	Slag Pix	% Metal	% Slag
2	11/17/2011	10:03 PM	10	83	664159	348399	315760	52%	48%
3	11/16/2011	10:55 PM	10	78	414313	289914	124399	70%	30%
4	11/26/2011	4:38 PM	6	48	430877	272666	158211	63%	37%
5	11/26/2011	12:33 PM	10	103	368082	264372	103710	72%	28%
6	11/17/2011	3:49 AM	10	79	544050	247804	296246	46%	54%
7	11/27/2011	11:14 AM	10	108	319484	238043	81441	75%	25%
8	11/17/2011	6:58 PM	6	26	957726	225743	731983	24%	76%
9	11/19/2011	1:26 PM	10	87	656514	214108	442406	33%	67%
10	11/18/2011	2:38 AM	10	85	317327	211673	105654	67%	33%
11	11/27/2011	5:47 AM	10	107	400802	205433	195369	51%	49%
12	11/22/2011	3:47 AM	10	96	1674755	204821	1469934	12%	88%
13	11/27/2011	2:22 PM	6	54	311912	202923	108989	65%	35%
14	11/22/2011	10:55 PM	10	99	1512959	197595	1315364	13%	87%
15	11/19/2011	5:20 PM	10	88	681519	195934	485585	29%	71%
16	11/27/2011	10:29 AM	6	53	361768	189944	171824	53%	47%
17	11/17/2011	11:07 AM	6	25	453256	188993	264263	42%	58%
18	11/17/2011	11:37 PM	6	27	1183503	184996	998507	16%	84%
19	11/27/2011	9:55 PM	6	56	362367	172765	189602	48%	52%
20	11/18/2011	5:49 AM	6	28	269325	171202	98123	64%	36%
21	11/16/2011	8:55 AM	10	80	297369	169113	128256	57%	43%
22	11/19/2011	7:18 AM	6	30	227077	165295	61782	73%	27%
23	11/20/2011	11:20 AM	10	91	322451	164835	157616	51%	49%
24	11/16/2011	2:53 PM	10	81	1236019	159266	1076753	13%	87%
25	11/18/2011	6:34 AM	10	86	254551	156448	98103	61%	39%
26	11/26/2011	8:22 PM	6	49	416012	148152	267860	36%	64%
27	11/23/2011	7:09 AM	10	101	167825	146757	21068	87%	13%
28	11/21/2011	7:01 AM	6	37	891310	145554	745756	16%	84%
29	11/21/2011	8:27 AM	10	93	1354092	140661	1213431	10%	90%
30	11/17/2011	8:34 AM	10	80	322991	137782	185209	43%	57%
31	11/27/2011	4:24 AM	6	52	535513	130533	404980	24%	76%
32	11/21/2011	2:20 AM	6	36	166615	128786	37829	77%	23%
33	11/23/2011	3:42 AM	10	100	892349	121806	770543	14%	86%
34	11/22/2011	4:54 PM	10	98	260900	120932	139968	46%	54%
35	11/23/2011	2:15 AM	6	45	221073	94912	126161	43%	57%
36	11/20/2011	3:33 PM	10	92	197690	94442	103248	48%	52%
37	11/27/2011	12:15 AM	6	50	136110	93971	42139	69%	31%
38	11/19/2011	10:46 PM	6	32	666205	89806	576399	13%	87%
39	11/21/2011	6:16 PM	6	39	233659	86887	146772	37%	63%
40	11/20/2011	9:17 AM	6	34	529304	82741	446563	16%	84%
41	11/20/2011	3:34 AM	10	89	384607	82465	302142	21%	79%

Figure 6. Screenshot data from program exported to Microsoft Excel.

After separating the data into your control ladle bottom and ELBY ladle bottoms, plot Column F, “Metal” on the y-axis and Column C, “Heats on Ladle” on the x-axis. This shows the comparison of a flat bottom (no yield savings effect) vs. an ELBY Bottom (early in the ladle campaign, when the ELBY Bottom profile is intact, less steel is left in the ladle. As the profile wears, the positive yield savings becomes less (Figure 7).

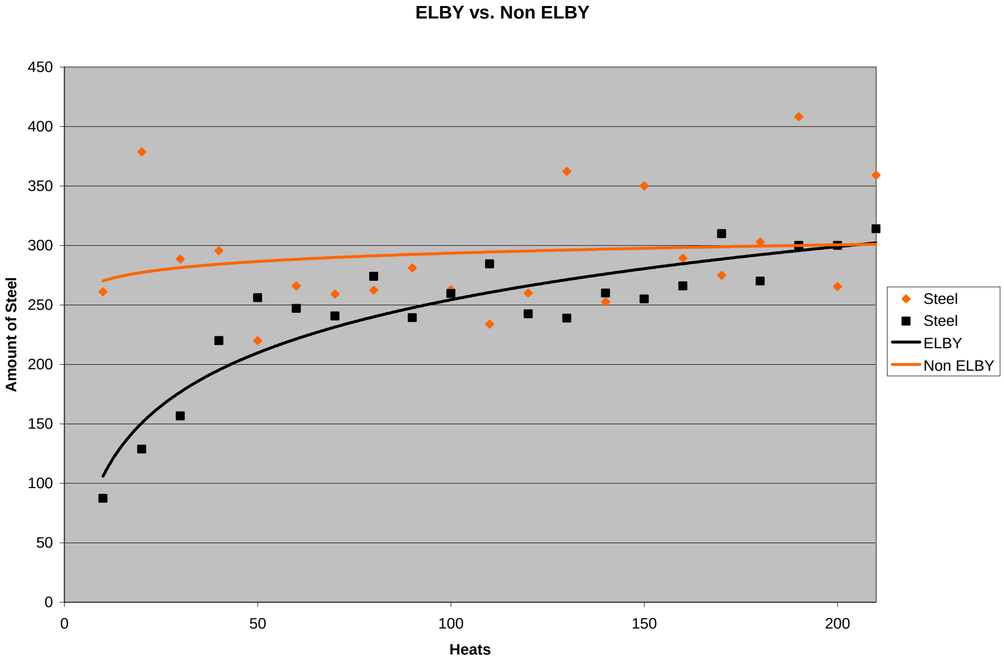


Figure 7. Graph showing the positive yield effects of an ELBY Bottom vs. a flat bottom.

ITI (Infrared Thermal Imaging) is best utilized when combined with a measurement system from the steel mill itself. This may include slag pot studies, crane scale weights, turret weights etc. By combining ITI with another method, it is possible to come up with an average amount of steel left in a ladle after casting.

3 RESULTS

More than a dozen steel plants are using or evaluating ELBY bottoms globally. Steel plants using ELBY bottoms are realizing unprecedented yield savings and quality improvements. Below (Table 3) are examples of real steel plant yield savings and the approximate commercial impact:

Table 3. Real steel shop yield savings

	Tons Saved/Heat	$$$ Saved/Year
Shop 1	.35 Tons	$ 1,663,200.00
Shop 2	1 Ton	$ 3,808,000.00
Shop 3	.706 Tons	$ 3,388,800.00
Shop 4	.85 Tons	$ 5,666,100.00

In addition to yield savings, other benefits have been exhibited at specific locations including outstanding overall refractory life and quantifiable efficiency in plug usage and wear.

4 DISCUSSION

The results of the three proprietary technologies can be seen in Graph of the Figure 7. First the results from ITI Camera measurements collected in the meltshop. The profile made by Numax™ Refractory Technology has resisted up to 80 heats to 100 heats. The CFD savings prediction was obtained in the 1st part of the curve and affected in the 2nd part, after 80 heats to 100 heats, so the CFD has allowed analysis and optimization of ladle bottom design.

5 CONCLUSION

The combination of steel flow analysis, bottom design, novel refractory development, and infrared yield measurement make the ELBY system a groundbreaking technology that can improve financial performance in steel plant operations and impact shop yield.

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