Melting Modified 4330 Steel

by Ralph Carlson

The requirements for higher quality steels will continue to challenge the metal producing industry. Steels with properties or combinations of properties that exceed usual catalog figures are frequently specified for certain applications.

A modified 4330 steel was such a steel melted at the American Cast Iron Pipe Co. This steel represented a combination of chemical analyses and physical properties designed to meet a specific need by a digital computer. Data processing was by Northeastern University, and the castings were purchased by American Science and Engineering, Inc., of Cambridge, Mass. Desired and actual chemical analyses are shown in Table I.

The castings were centrifugally spun tubes approximatelly 9-11 in. in diam and 2½-3 in. thick. It is recognized that mechanical properties are lower in heavier sections, and that tests from the actual wall are somewhat lower than familiar keel block tests.

The objective in this project was to obtain from the actual tube wall a high combination of strength and impact resistance. A minimum Charpy V impact resistance of 16 ft-lb at —40°F was the first requirement. Highest possible yield (over 150,000 psi) was desired.

The metal was heat treated as follows: (1) 1750° for 8 hr and air cool; (2) 1650° for 6 hr and furnace cool to 1450°F. Hold at 1450°F for 2 hr and water quench, and (3) Double temper at 1000°F for 6 hr each.

PHYSICAL TEST DATA

Keel block specimens from 16 heats were physically tested along with 94 specimens from actual castings. The average values of these tests were as follows:

	T. S.	Y. S.	El-%	RA-%	V-40°F Impact Charpy
Keel Blocks	171.2	160.1	12.4	31.6	
Actual Castings	169.6	158.7	8.0	16.3	19.0

These castings were required to pass a vacuum test in which the tubes were pumped down to as low as 1 micron with acetone as an indicator. The purchaser conducted these tests and results were satisfactory within the capability of the pumping equipment.

MELTING PRACTICE

Raw materials were not available to meet the low phosphorus and sulfur levels with acid practice, and the time required for basic practices reported in the literature for obtaining such low levels was too long for us, with hazards to fluidity and hydrogen absorption. Other means had to be devised.

The general plan was to start with a highly oxidized heat and drain the melt down slag when cold to remove phosphorus; then build a basic slag capable of removing and holding sulfur from the metal without prolonging the heat too much.

Prior to charging the furnace with metal, 10% limestone, 4% iron ore and 1% fluorspar were placed on the furnace bottom. The plate scrap was then charged. When melted and thoroughly rabbled, and with metal temperature at 2750°F, the oxidizing slag was drained completely for phosphorus removal, and a new slag built of 2% floor sand, 5% lime, 0.25% fluorspar and 0.4% aluminum per ton of charge. Temperature was quickly raised to 3000°F and electrodes were dipped for approximately 5 min., rabbling the bath frequently. Preliminary samples for analyses were poured and the heat blocked. While waiting for analytical results, the following slag and reducing materials were added: 2% lime, 0.5% aluminum shot, 0.1% silicon fines and 0.2% fluorspar. Final alloy and carbon additions were made and the heat tapped at 3200°F, adding 2 lb per ton of aluminum in the tapping ladle and 1 lb per ton in the casting machine ladle.

This practice resulted in slag compositions during the finishing stages of the heat as follows:

SiO_2	MnO	MgO	CaO	FeO	TiO_2	Al_2O_3
16.7	0.6	15.0	44.0	0.6	0.2	22.9

This composition was calculated to fall in the desired location on the liquidus diagram for the 25% Al_2O_3 plane in the CaO, MgO, Al_2O_3, SiO_2 quaternary system as developed by Osborn, DeVries, Gee, and Kraner.[1] This slag is highly fluid, is essentially all liquid at the operating temperature, and has high sulfur removal potential. There are no adverse effects on the furnace lining.

PRACTICAL APPLICATION OF SLAG PRACTICE

Our present slag practice has been altered to suit our usual production basic heats where extreme oxidation is not required, and results are most gratifying as we now average about 0.01% sulfur on all our basic heats. A recent change in patch material has lowered our Al_2O_3 level to about 20%, but results are still the same.

The slag materials added on melt down now consist of 7.5% Limestone, 1% Floor Sand, 1% Iron Ore, and 0.5% Fluorspar

After the oxygen blow and while waiting for carbon analyses, the following materials are added to the slag: 0.15% Silicon Fines (75%); 0.2% Fluorspar; 1.75% Lime; and 0.15% Aluminum Shot

RESULTS

Reports following installation of the castings described in this report indicate the performance surpassed expectations. The properties of the castings were reportedly within 5% of the desired values as set forth by the computer, even though casting thickness was not conducive to attaining expected properties.

Finally, by accepting the challenge to melt and produce this rather unusual steel, we found a slag practice which will yield low phos and sulfur levels with a practical 2-slag practice, and will yield a sulfur level of about 0.01% with a single slag practice.

REFERENCES

[1] E. F. Osborn, R. C. DeVries, K. H. Gee, and H. M. Kraner: Journal of Metals, 1954, vol. 6, no. 1, p. 33.

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Table I. Desired and Chemical Analyses

	C	Si	Mn	S	P	Cr	Mo	Ni	Al
Target	0.32	0.35	0.75	0.01/Max	0.01/Max	0.90	0.45	3.0	0.10
Desired Limits	0.28/0.36	0.20/0.50	0.60/0.90	0.01/Max	0.01/Max	0.75/1.00	0.35/0.55	2.75/3.25	0.06/0.14
Avg 16 Heats	0.33	0.37	0.81	0.010	0.014	0.92	0.50	2.92	0.076