A Melt Performance Comparison: Stack Melter vs. Reverberatory Furnace

As aluminum foundries expand their operations, the choice of furnace is vital to the efficiency and quality of the melting operation.

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One of the most important decisions in the start-up or expansion of a foundry is the choice of melting equipment. It also is one of the most difficult.

The decision first must be based on quantitative reasons such as cost, fuel usage and environmental issues. Then, the decision must incorporate intangibles such as melt quality requirements, charge stock available, maintenance requirements, required flexibility of melt rates, availability of parts and field service, and even worker attitudes.

A recent expansion of the casting capacity at a large Midwestern foundry presented an opportunity to compare two of the more popular aluminum melting furnaces—stack melters and reverberatory furnaces. After expanding with a casting line supplied by an older reverberatory furnace (delivering quality A356 aluminum castings), the customer demanded further capacity, enabling the foundry to install a second new casting line. This line, however, would be fed by a stack melter. The result was two parallel production lines—one featuring the conventional reverberatory melter with a wet bath charge into an intermittently sealed hearth (Fig. 1 left) and the other featuring a stack melter (Fig. 1 right). Both furnaces were rated at 3000 lb/hr, were used to melt A356 for an identical product line, and were fed the same melt stock at the same ratios of new metal to returns. Further, the units were operated by the same staff and maintained with procedures and techniques recommended by the individual manufacturers.

Melt Quality Tests

After the installation of the stack melter, notable differences existed in the quality of melt produced by the two units. As a result, a decision was made to quantify each furnace's melt quality using the reduced pressure test (RPT) and K-mold test (an examination of multiple fractures in permanent mold test castings). Both test methods offer visual evidence of changes in melt quality, and, therefore, may be quantified to measure differences in performance.

Since the two melters served parallel casting systems in the plant, samples first were taken during day-shift production from the molten hearth of each furnace and then from the delivery systems to the casting stations. As a final check, a second group of samples then was taken from the hearths of each of the melting furnaces.

This time period was chosen to remove any bias that might exist in favor of either furnace, with special concern for the reverberatory unit, which accepted a direct charge of both ingot and returns to the wet bath. This charging method was considered to be a source of both gas and inclusions, and, as the production day continued, these levels were expected to increase.

The following samples were collected at each of the survey points:

RPT—Using a preheated stainless steel sampling cup, a single molten sample of approximately 80 g of A356 aluminum was collected and solidified under a vacuum of 27 in. of mercury. If the molten metal contains dissolved hydrogen, the sample will expand upon solidification and produce a shape that can be quantified by specific gravity measurements or cross-sectioned and compared to standards.

K-mold—Using a special permanent mold, a total of five K-bar shapes were poured at each test site. The bars contain four notches on the cope surface that form eddies to trap inclusions as the samples are cast. When the bars are broken on the fracture planes, the surfaces may be examined and quantified for any inclusions (two fractures containing 20 inclusions would produce a K-mold value of 2/20 or

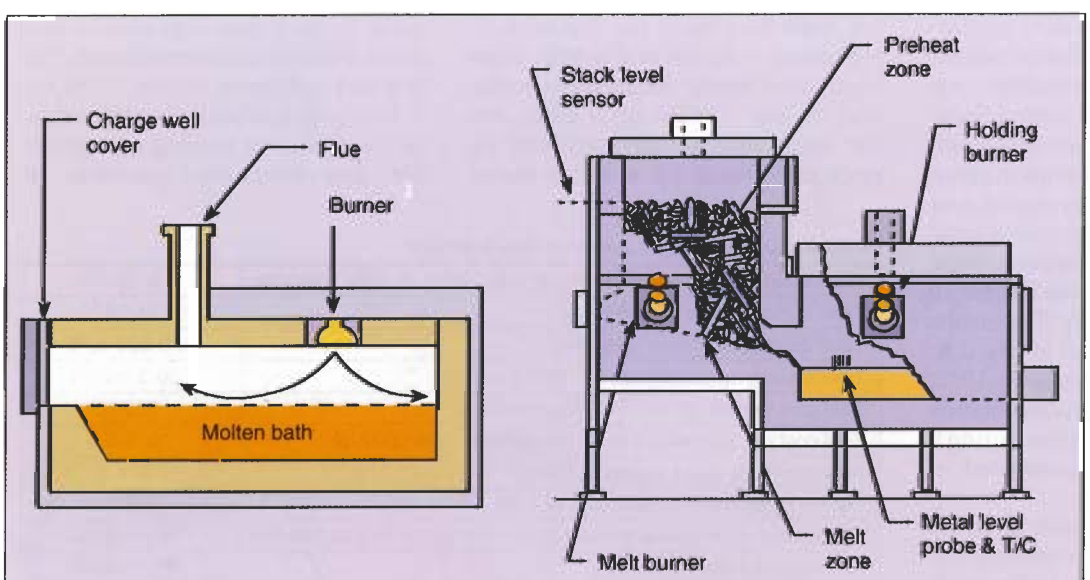

Fig. 1. A reverberatory furnace (l) was compared to a stack melter (r) in parallel production runs. The results of the comparison show, among other things, that: melt loss was reduced from 5.5% on the reverberatory furnace to 0.9% on the stack melter; and energy consumption to melt and superheat to 1350F (732C) was reduced from 1975 Btu/lb with the reverberatory furnace to 955 Btu/lb with the stack melter.

0.10). Normal levels of acceptance vary with the final cast product, but parts that are stressed in service or have significant machining are normally produced to melt quality levels of a 0.05 K-value.

The results of the melt quality assessments are presented in Fig. 2. Three sample points are shown for each system: from inside the hearth of each style of melter; from the exit point where metal is transferred to the delivery system; and from the ladling point where metal is collected for delivery to the casting system.

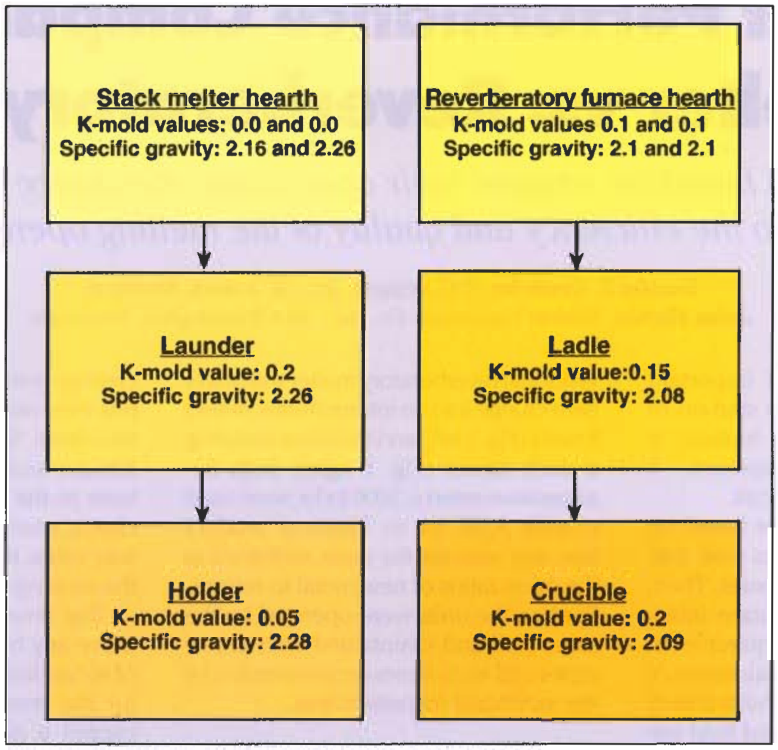

Fig. 2. The melt quality analysis of the two furnaces illustrates the higher quality of the stack melter metal bath. This flow diagram shows the measurements taken at each stage of metal flow.

The initial and final metal samples collected from the stack melter hearth had K-mold values of 0.0, were fine-grained and exhibited moderate ductility. Specific gravity measurements on RPT samples collected at the same time were 2.16 and 2.26. When the metal was subsequently tapped from the stack melter into the launder, oxides were generated and are reflected by the elevated K-value of 0.2 and specific gravity of 2.26. Transport through the launder to the casting station removed a portion of the oxides (0.05 K-value) and raised the specific gravity to 2.28.

Samples collected from the hearth of the reverberatory furnace had K-mold values of 0.1 and specific gravity of 2.1, reflecting the pick-up of both gas and inclusions in the wet-bath charge. The higher gas level and inclusions also appeared to negatively affect ductility and strength, as estimated by the reduced breaking load required to fracture the K-bars. The tap into the transfer ladle was measured to generate an additional level of both oxides and gas (K-mold value of 0.15 and specific gravity of 2.08). Also, the transfer of metal into the holding crucible and filter vessel caused more problems, resulting in metal with a K-mold value of 0.2 and a specific gravity of 2.09.

Melt Performance

Side-by-side furnace comparisons were made on the basis of total pounds of material charged, the weight of dross and skimmings generated, the weight of makeup alloy additions, and the energy consumed in a day's production. The results are shown in Table 1.

There are a number of differences in construction and operation that influence the performance of the two furnace

A Stack Melter Case Study

The technical literature on aluminum melting is filled with conflicting claims on melter performance because most foundries do not perform assessments of the costs associated with volume operations. It does require careful process monitoring, with full consideration given to material and energy inputs and the products and weights of materials taken out of the furnace. Most references agree that stack melting improves melt recovery. The results of one study performed by the U.K. Energy Efficiency Bureau in 1992, which summarizes the performance of a 4000lb/hr stack melter during 9 hr of operation, are presented in the table below.

It is significant to note that the melt loss has more economic impact than the fuel costs in the study cited. For example, in the worst case scenario, where the 273 lb of waste material removed from the furnace is primarily aluminum alloy valued at $0.75/ lb, the economic loss is $204.75 (or more than twice the cost of melting energy). In the real world, dross units have some recoverable value and do not contain pure alloy, but the economic penalty imposed by poor melt recovery is still a major cost to any production operation. This is significant when the reductions in melt loss reported in the comparative trial are considered. The five-fold difference in loss (0.9% vs. 5.5%) could be a major consideration in the choice of melting equipment for a new or expanded operation. ▼

Performance Results of a 4000 lb Stack Melter

Production hours (start of melting to completion of stack cleaning)	9 hr 23 min
Total lb melted and superheated	31,097
Total quantity of natural gas used	30,300 cu ft
Total Btus used (30,300 cu ft x 1000 Btu/cu ft)	30.3 million
Fuel cost to melt (30.3 DTH x $3.068/DTH)	$92.96
Fuel cost per lb to melt and superheat ($92.96/31,097 lb)	$0.0029
Average Btu/lb (30.3 million/31,097lb)	974.4
Peak melting capacity (average of 2 hr)	4600 lb/hr
Energy use during peak melting (2 hr: 10.9 million Btu/12,338 lb)	883.4 Btu/lb
Average melt rate for total hr	3315 lb/hr
Total material removed from furnace bath	273 lb
Maximum theoretical melt loss (273 lb/31,097 lb)	0.88%
Stack temperature range	700-950F (371-510C)

designs. The reverberatory furnace carries a larger bath of molten metal in the hearth, has more surface area exposed to oxidation and melt loss, operates at a higher temperature in the melting chamber, and is charged with a bulk addition of ingot and potentially wet shop returns. Thus, many factors have the potential to contribute to the differences in metal quality.

Table 1. Melt Comparison of Reverberatory vs. Stack Furnaces

Melting Characteristics	Reverb. furnace	Stack melter
Melt loss	5.5%	0.9%
Energy consumption (1350F)	1975Btu/lb	955Btu/lb
Makeup alloy additions:		
Strontium	—	64% less than reverb.
Magnesium	—	43% less than reverb.
Tap temperature ranges	± 32F	± 5F

A stack melter (or even a dry hearth furnace) offers the potential to remove all moisture and organic material from the charge before it can react with molten aluminum to generate oxides (melting loss). The smaller volume of metal in the stack melter hearth reduces both the exposure time and surface area exposed to gas pick-up, while further benefiting melt losses for the same reason. Also, since a significant portion of the energy required to superheat the melt to target temperatures already has been transferred to the charge with heat units that would otherwise be lost in the flue gases, the total energy requirement for the process is dramatically reduced and permits lower hearth flame temperatures.

Environment and Safety

While the economic benefits from low melt losses and efficient utilization of energy are important management issues, the melt room staff will be concerned with the environmental and safety features of the stack melters. With the absence of open charging wells, minimal flue gas emissions and excellent side wall insulation, the units offer a more benign working environment than that typically associated with either wet well or dry hearth melters. The smaller hearth volumes in stack furnaces (typically equal to or twice the hourly production rate) further simplify the cleaning tasks by making all internal surfaces more accessible and maintainable.

Metal charging is another concern of the melt room staff. Since all furnace additions of melt stocks are made by automated charging systems delivering material to the charging stack, there is virtually no exposure of the charging crew to the risks of metal explosions created by the addition of wet materials to a molten bath. Over the years, molten metal explosions have been the source of numerous injuries in aluminum melting shops. While the source of tramp moisture in charge materials cannot be eliminated, the addition of those same materials to a partially filled charging stack ensures that all traces of moisture will be gone by the time the materials reach a molten state. ▼

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