Light Metals 2011 *Edited by: Stephen J. Lindsay*
TMS (The Minerals, Metals & Materials Society), 2011

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FURNACE EFFICIENCY – ENERGY AND THROUGHPUT

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Session I

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Furnaces Designed For Fuel Efficiency

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Furnace efficiency, energy saving furnaces, aluminum melting and holding furnaces

Introduction

The purpose of this paper is to enlighten you about the various designs of aluminum melting and holding furnaces and how they relate to energy efficiency. The word efficiency is thrown around with little regard to its true meaning. There are three types of efficiencies in every furnace. There are burner efficiencies, furnace efficiencies and melting and holding efficiencies. They are not the same and cannot be looked at as individual items when making a decision on a new furnace, they are equally important. The first one that should be looked at is furnace efficiency. It is the only one we will talk about today. Does the furnace design make sense from an overall melting and holding standpoint? You can buy four different radiant roof melting furnaces and end up with three different actual BTU's/# of metal melted. Does it take more net BTU's in one gas fired furnace than the other to melt a pound of aluminum? No! But the amount of Gross BTU's required to maintain that net BTU's has to do with furnace efficiency. Adding pre heat hearths and circulation to the furnace will increase BTU's/# melted efficiencies but not combustion efficiencies. In breaking these down one by one we can better understand the importance of each type of efficiency.

Furnace Efficiency

Three different furnaces all rated at 7,000#/hr natural gas fired can be designed differently to effect efficiency of the melter. In the first two examples the furnace design is a radiant roof melter with 6 flat flame burners in the roof about 24" off the bath. Total connected capacity 14,000,000 BTU's/hr. These units have a standard 3 component refractory lining with good insulating qualities. They all have standard cold air combustion systems and operate very close to this Sankey Diagram, (Fig 1)

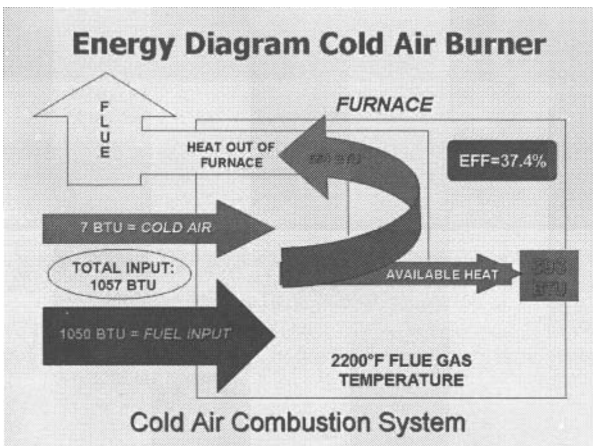


Fig 1 Slide courtesy of Bloom Engineering

Furnace #1

This is a 7,000#/hr radiant roof furnace with a charge well and a preheat hearth and no circulation of the metal. You can preheat sows or ingots on the hearth to save about 15% in fuel. You can melt about 45% of the total load in scrap. This melter will hit about 1400BTU's/# of metal melted depending upon the mix of scrap and new material. This furnace will lose about 3% in metal melt loss.

Furnace #2

This is a 7,000#/hr radiant roof furnace with a charge well and a preheat hearth and circulation of the metal by mechanical means with a pump in the charge well.

This furnace will melt for about 1250 BTU's/# of metal melted due to the increase in efficiency form the circulation process. This circulation actually helps pull the BTU's from the hottest metal on the surface to the middle of the bath and heat up anything being melted under the bath much faster. Metal melt loss will be between 2 and 2.5%

Furnace #3

This is a 7,000#/hr high headroom furnace with two sidewall fired burners @ 7,000,000 BTU/hr each. It has a preheat hearth and a circulation pump in the charge well. It will melt for between 1400-1500 BTU's/# of metal melted. Because of the higher sidewalls required to place the burners up out of the metal this furnace requires more BTU's/# to melt because its fixed heat losses are greater. Also since transfer of heat in this case is mainly convection instead of radiant the transfer of BTU's is slower. If this did not have circulation the BTU's/# of metal melted would be about 1700BTU's/#.

Radiant heat is the fastest transfer of available heat into aluminum. Stephan-Boltzmann law of radiant heat transfer stated that the closer the heat source is to the object being heated the faster the transfer of BTU's. Also the greater the temperature differential between the heat source and what you are heating the faster the transfer of BTU's. By running a low headroom with a thermal head of 1950 degrees F you can transfer the BTU's into the metal at a faster rate than in a higher headroom furnace. In doing so you do create more dross and that is why the circulation is so important. The flowing metal under the surface strips away the BTU's at a faster rate than the stagnant pool of metal.

Kirchhoff's law explains why this works and is really just common sense: When radiant energy hits any particular material it has to do one of three things:

1) Be absorbed (a perfect black body with emissivity of 1 absorbs all the radiant energy)

2) Be reflected (the opposite of a perfect black body - a material with low emissivity)

3) Pass through the material (transparency) the energy is being pulled through the reflective metal by the flow.

The energy of the radiation absorbed, reflected and transmitted through the material must equal the energy hitting the material. This is why the larger surface area and bath capacity are so important in radiant roof fired aluminum melting furnaces.

Energy Saving Options:

In addition to these relatively inexpensive options to furnaces there are a few other ways to save more energy when buying a new furnace.

1. Refractory Linings: Buy the most energy efficient lining you can buy. You can control fixed heat loss. The insulating materials available now will reduce casing temperatures to 145 degrees F under the metal level at the casing and about 170 degrees F above the metal line at the casing. This is significantly cooler than furnaces built just ten years ago. This represents a payback on the higher insulating material costs of less than one year in energy saved. Not to mention the cooler building and less make up air required to cool down the melt room.

2. **H**eat **E**xchangers:

Look at putting heat exchangers on the flue of the large furnaces. This can save you on average about 23% in fuel (fig 2) and represent a payback of less than 2 years. If you have a series of large furnaces then waste heat recovery becomes a very viable option to see a great return on your investment. While this will be much more capital intensive and depending upon current utility rates for recoverable energy purchased, the payback is swift and very beneficial

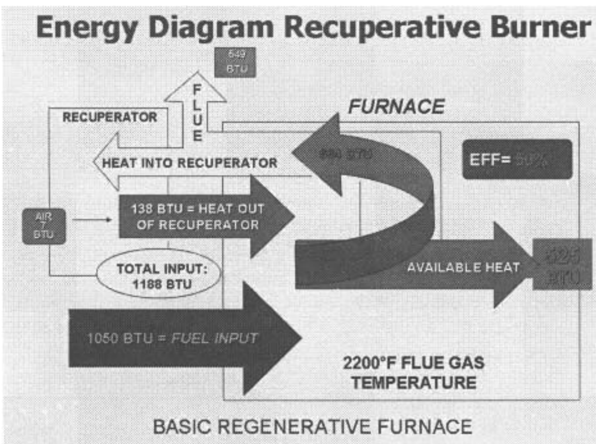


Fig 2 Slide courtesy of Bloom Engineering

3. **R**egenerative **B**urners

In very large high headroom melters, regenerative burners are still saving metal casters about 40% in fuel usage over conventional burners. The ROI payback this year is extensive because of the low fuel costs but we all know the price of natural gas is only going to go up so an investment in regenerative burners today that has an ROI of 50 months might actually end up being 30 months if the gas prices hit double digits again soon.

Fig 3 Regenerative Combustion

4. Well Covers: Covering up open wells will reduce heat loss substantially. An open well of 1300 degrees F aluminum with a .5 emissivity of the bath surface in the well will lose 8,214 BTUs/square foot/hr. If the average charge well is 8' long by 3 feet wide that is 24 sq. ft. or 197,136 BTUs per hour being lost off that well. That is 197 cubic feet per hour or 4,731 cubic feet a day x 340 days a year is 1,608,540 cubic feet lost.

5. Preheat Hearths: By ordering a furnace with a preheat hearth designed into the unit you can save enough money to pay for it in less than two years. By placing two 1,000# sows on the hearth and letting them pre-heat to a sweat, the internal temperature of that sow will be 900 degrees F.

This step uses the heat that normally goes up the flue and some radiant absorption from the burners to pre-heat these sows. When placed into the bath as the next two sows are loaded, the stored BTUs in the bath help finish the melting process, taking the sows very quickly from 900 degrees to melting temperature.

This will save 15 percent in fuel for that 2000# of aluminum. If you were melting at 1800 BTUs/# and you now pre-heat, you are at 1530 BTUs for every # you melt through the pre-heat hearth.

If we use that same 7,000 #/hr unit as in other studies above, that will save you 21,600,000 BTUs per day. So the net savings is 7,344,000 cubic feet of gas per year saved. That alone saves $47,736/year.[1]

> Especially in the case of tilting or barrel type furnaces you need to do what ever you can to improve their efficiencies. These will typically melt for 1600-2,000 BTU's/# and have extreme heat losses. Many are lined with brick which is one of the most inefficient linings available and is 40 year old technology. Flat roofs are more efficient that rounded roofs in these furnaces because of the law of radiant heat. Flat roofs allow the heat to be more evenly transferred into the bath of metal.
> Electric tilting furnaces (fig 3) are much more efficient that gas melting for less than 900BTU's/#

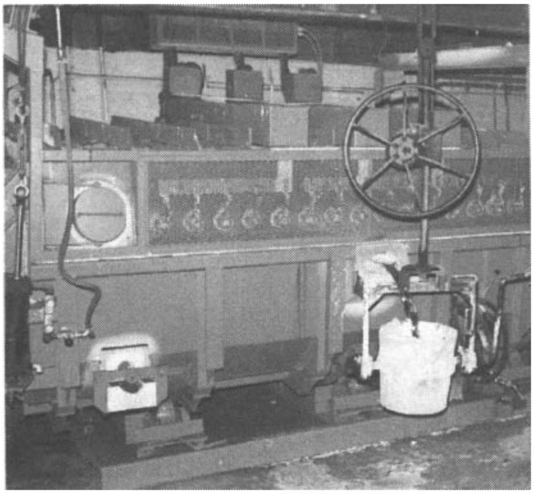


Fig 4 Electric flat roof tilting furnace

Furnace #4. The Stack Melter:

The most energy efficient gas fired aluminum melting furnace is still the Tower or Shaft melter. From a strictly BTU's/# of metal melted there is nothing in gas that can come close without auxiliary equipment like heat exchangers or regenerative equipment installed on the basic units. Stack melters can melt as low as 950BTU's per pound of metal melted if you keep the stack completely full and the burners are in ratio. But if you let the stack empty then it is no better than a dry hearth furnace and that melts at about 1700-1800BTU's/#. However, things like up front costs and higher metal melt loss and maintenance can affect the ROI for these furnaces.

Furnace #5 The Radiant Roof Electric Melter:

The absolute best and most efficient furnace from a BTU's/# of metal melted standpoint is still the radiant roof electric melting furnace. This unit will melt for less than 790 BTU's/# of metal melted. Electric melters melt at .21KW/# simple math says that .21 x 3,412 (BTU's/KWH) = 750.76 BTU's/#. If you add circulation and Micro porous super insulated lining to this electric melting furnace you will be down to about 687 BTU's/# of metal melted. No one can even come close to that. Now move the elements under the bath with immersion electric melting and you get almost 77% efficiency at 655 BTU's/# melted. With the uncertainty of what will happen here in the U.S. on carbon footprint and cap and trade more and more die casters are looking at in cell electric melting and holding at the die cast machine as an alternative to gas fired central melting.

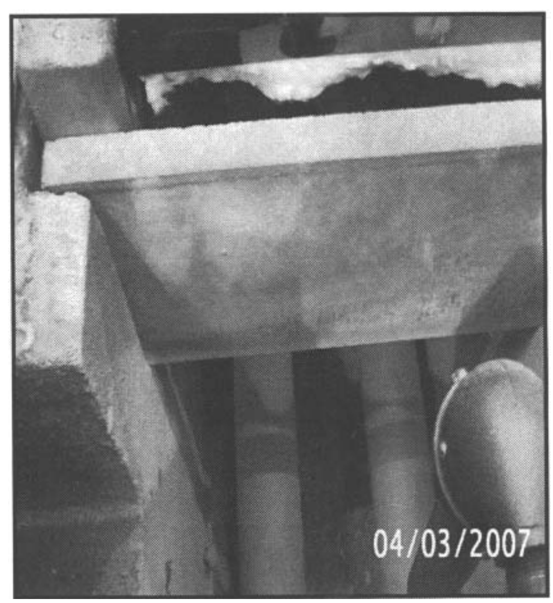
Holding Furnaces:

Holding furnace at die cast machines or at foundry casting lines are designed to do one thing...hold the metal at casting temperature. They are still being designed with the lowest possible BTUs or KW connected to do the job. This is such a dis-service to the industry. It does not cost that much more to connect a passing gear to these units to allow them to make up some drop in temperature if cold metal is delivered to them or if they are being drawn down to low before refilling them. Remember once you make this furnace have to raise metal temperature you have turned it into a mini melter and if it does not have the power connected to raise the metal temperature quickly then you will shut down the casting process waiting on the holder to catch up.

Aluminum holding furnaces whether gas or electric should have highly insulated linings in them. Four component linings are the most efficient; this can either be an all insulating non wetting board lining or a dense castable with non-wetting back up calcium silicate boards, micro porous silica board and block insulated linings. Lids that seal and the capability of repairing that seal easily (anytime it is needed) will also conserve energy. They should have well covers and possibly automated well covers if the cycle times are greater than 1.5 minutes.

Electric Immersion Holding Furnaces

The Electric Immersion furnaces are being designed today with casing temperature at or below 105 degrees F. They are much more efficient than the radiant electric holders since the heat source is under the bath of metal the heat can radiate off all sides of the protection tube and distribute more heat where it is needed most in the metal. Because the heat is generated under the bath of aluminum there is very little dross created. The lack of high thermal head temperatures virtually eliminated the need to clean these furnaces more than twice a week.



The bottom line is yours. Do everything you can to enhance it by buying the most energy efficient furnace that fits your needs and has the best ROI. None of these energy saving ideas are free. They all cost money to do. However your return on investment over the next 3 years could make the difference in "being in a profitable business" or going through a "going out of business" sale of all the old gas guzzling furnaces you kept.