A treatise on the use of insulating refractory brick in malleable annealing ovens

James Joseph Offutt

Follow this and additional works at: http://scholarsmine.mst.edu/professional_theses

Part of the Ceramic Materials Commons

Recommended Citation
A TREATISE ON THE USE OF INSULATING REFRACTORY
BRICK IN MALLEABLE ANNEALING OVENS

by

J. J. Offutt

A
THESIS

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the
DEGREE OF
CERAMIC ENGINEER
Rolla, Mo.
1936

Approved by

Professor of Ceramics

R44-300-6-29
# TABLE OF CONTENTS

List of Illustrations--------------------------Page A
Introduction----------------------------------Page 1
Properties of Insulating Fire Brick----------Page 1
A Typical Malleable Annealing Oven-----------Page 3
Heat Balance--------------------------------Page 4
Discussion of Heat Balance-------------------Page 5
Effect of Insulating Refractories on Operating Conditions-------------------------Page 6
Recommended Construction with Insulating Fire Brick-----------------------------Page 8
Selecting an Insulating Fire Brick---------Page 10
Conclusion-------------------------------Page 10
Bibliography-------------------------------Page B
Index---------------------------------------Page C
LIST OF ILLUSTRATIONS

Malleable Annealing Oven------------------------Page 3A
A typical malleable annealing oven fired with powdered coal: This furnace has the side walls and a 11-foot section of the arch lined with insulating fire brick.

Quick Annealing Furnace-----------------------Page 6A
A small furnace for quick annealing: This is an oil fired oven - the lining of which was changed from regular heavy fire brick to insulating refractories. A 50% saving in fuel was effected.

Stress Relieving Furnace-----------------------Page 9A
A large stress relieving furnace lined with insulating refractories: Most outstanding results are obtained in such furnaces with light weight fire brick as the only lining.
INTRODUCTION

At frequent intervals, there is developed in the refractory field some product which serves to keep this branch of industry in line in the fast moving modern era. The advent of such materials as high temperature mortars and high alumina, super refractories provided a definite mark of progress. One of the most recent and far reaching developments was made possible by the perfection of light weight, insulating fire brick.

This product filled a gap which had long been an aching void to all who had made a careful study of furnaces in an effort to obtain higher efficiency. Formerly, it had been necessary to resort to heavy, thick fire brick linings, plus low temperature insulation to obtain anything like maximum efficiency in the operation of even the smallest industrial furnace. Always looking for some means of reducing the large amount of heat absorbed by the usual heavy refractory lining, furnace men promptly approved insulating fire brick. It remained only to establish the lasting qualities of this feather weight product.

PROPERTIES OF INSULATING FIRE BRICK

The conductivity of this type of brick is about one-fourth that of heavy fire brick and approaches
very closely that of some insulating materials used only when protected by an inner lining of fire brick. Since this light weight brick can be used in direct contact with furnace flames and gases, it is a substitute for both the heavy refractory lining and the low temperature insulation. Naturally, such a product will make a thinner, lighter, and more efficient lining.

The results from installations in virtually all types of furnaces have justified to the fullest extent the use of insulating fire brick. Fuel savings by actual measurement in large industrial units have been as much as 60%. The actual reduction in fuel consumption is influenced by the design, the maximum temperatures attained, and by the length of cycle of operation of each individual furnace.

In order to indicate the relative value of two types of linings in a furnace, it is necessary to calculate a heat balance showing the various sources of heat dispensation. Even though it is impossible to figure actual fuel consumptions accurately on a theoretical basis, the respective merits of the two types of lining can be easily determined.
A TYPICAL MALLEABLE ANNEALING OVEN

Since every company engaged in manufacturing malleable castings has a battery of annealing ovens, a heat balance worked up on one of these furnaces should serve as a good typical example. With this in mind all of the available information pertaining to the operation of one malleable oven was obtained and a heat balance was made. The figures thus obtained were compared with another heat balance worked out on the basis of substituting 3 inches of insulating fire brick in the side walls and in the arch of the same furnace.

Actually this insulating fire brick has a conductivity of 1.96 at mean temperatures of 1000 degrees F. and a conductivity of 2.3 at mean temperatures of 1600 degrees F. The brick weighs $2\frac{1}{2}$ pounds per 9 inch equivalent and has a crushing strength of 350 pounds per square inch. The fusion point is Cone 32, but the brick is recommended for use in direct contact with furnace gases at temperatures not exceeding 2500 degrees F.

The following data was calculated for a furnace 14 feet, 6 inches wide, 18 feet long, and 8 feet, 6 inches high to the bottom of the arch. The arch has a spring of 2 feet. The original arch consisted of
9 inches of fire brick backed up with 2½ inches of Silocel. The side walls and the end walls consisted of 13½ inches fire brick. The hearth of the furnace is of regular fire brick backed up with insulation.

The data below shows the theoretical difference in heat requirement with the original lining and an effective lining of 9 inches insulating fire brick in the walls and arch.

The furnace carries an average charge of 18 tons. The metal stands holding this charge weigh 81,000 pounds while 6,000 pounds of sand are required for packing the castings. The furnace operates at an average temperature of 1600 degrees F. It is brought up to working temperatures in thirty hours, held for fifty-five hours, and then cooled at the rate of ten degrees per hour down to 1000 degrees F. The unit is hand fired by means of a Dutch Oven located outside of the furnace proper.

A HEAT BALANCE

<table>
<thead>
<tr>
<th>FIRE BRICK</th>
<th>G-25 BRICK*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEAT STORAGE</td>
<td>HEAT STORAGE</td>
</tr>
<tr>
<td>8,136,260 B.t.u.</td>
<td>Arch</td>
</tr>
</tbody>
</table>

* G-25 Brick -- the brand of insulating fire brick used as the basis of the accompanying heat balance,
<table>
<thead>
<tr>
<th>FIRE BRICK</th>
<th>G-25 BRICK</th>
</tr>
</thead>
<tbody>
<tr>
<td>21,301,699 B.t.u. Side Walls</td>
<td>4,311,216 B.t.u.</td>
</tr>
<tr>
<td>9,724,400 B.t.u. Floor</td>
<td>9,794,400 B.t.u.</td>
</tr>
<tr>
<td>7,488,000 B.t.u. Charge</td>
<td>7,488,000 B.t.u.</td>
</tr>
<tr>
<td>16,712,000 B.t.u. Stands &amp; Sand</td>
<td>16,712,000 B.t.u.</td>
</tr>
<tr>
<td>CONDUCTION LOSS</td>
<td></td>
</tr>
<tr>
<td>9,450,000 B.t.u. Arch</td>
<td>7,844,000 B.t.u.</td>
</tr>
<tr>
<td>44,908,500 B.t.u. Side Walls</td>
<td>17,841,200 B.t.u.</td>
</tr>
<tr>
<td>5,803,500 B.t.u. Floor</td>
<td>5,803,500 B.t.u.</td>
</tr>
<tr>
<td>23,380,400 B.t.u. HEAT CARRIED OUT</td>
<td>13,570,200 B.t.u.</td>
</tr>
<tr>
<td>WITH EXHAUST GASES</td>
<td></td>
</tr>
<tr>
<td>143,054,759 B.t.u. TOTAL</td>
<td>85,509,636 B.t.u.</td>
</tr>
</tbody>
</table>

**DISCUSSION OF THE HEAT BALANCE**

The total number of B.t.u. required to operate this furnace with either lining will be much greater than that shown on the theoretical heat balance. This is due to the fact that in firing by hand much of the actual heat generated by the combustion of the coal is never introduced into the oven proper. Furthermore, there is quite a high percentage of heat losses which are unaccounted for in the operation of such furnaces. It is logical to assume that the same number of B.t.u. per pound of coal will be introduced into the oven with either type of lining. The unaccounted-for heat losses will be in proportion to the total
amount of heat required to operate the furnace during one complete cycle. Seven tons of 15,500 B.t.u. per pound coal were required per cycle of operation with a lining of fire brick. Taking these facts into consideration it can be seen that the saving with a lining of G-25 Brick would be 28% or approximately 3,030 pounds of coal per cycle.

As is evident from the heat balance, this saving is brought about by reducing the amount of heat lost by conduction through the furnace lining, and by reducing the total amount of heat stored in the refractory lining. The heat stored in the fire brick becomes waste heat when the furnace is shut down. The amount of heat carried out with the exhaust gases is in direct proportion to the total heat required for operation. By reducing the heat losses by conduction and by reducing the heat storage of the lining, a still further saving is made by automatically reducing the amount of heat carried out with the exhaust gases.

**EFFECT OF INSULATING REFRACTORIES ON OPERATING CONDITIONS**

Recognized authorities on furnace construction, in general, agree that much of the useful heat in any furnace comes by radiation from the hot refractory walls. This is of particular importance when the furnace in
question has a large volume and is heated by only one or two burners. Early in the development of insulating refractories it became quite obvious that such brick would have much better radiant properties than any regular fire brick. This feature has provided for another unmeasurable but quite important factor favoring higher efficiencies with the use of insulating refractory linings.

Of interest is the fact that in one plant the temperatures on the outer wall surface of a furnace lined with 13½ inches of fire brick and backed up with 4½ inches of low temperature insulation were found to be 120 degrees. In a furnace operation on a similar cycle with a lining of 9 inches of 6-25 brick backed up with ¼ inch insulating board, the temperatures were 100 degrees.

The rate of heating and of cooling a furnace is determined by the total amount of heat which will be absorbed by the charge, the furnace fittings, and the refractory lining. From the heat balance given above, the respective heating and cooling rates of these two linings can be quite accurately determined. In one plant, an annealing oven lined with fire brick was found to cool at the rate of 40 degrees per hour with the furnace tightly closed. A 6-25 lined furnace in the same plant cooled at the rate of 100
degrees per hour under the same conditions. These cooling ratios will not apply to all furnaces, but there is definite proof that the cooling cycle will be faster if the lining is of insulating fire brick. This fact is not apparent at a glance because the lower conductivity of the insulating refractory brick. A thorough study will reveal that even more important in determining the cooling rate is the total amount of heat stored inside the furnace shell.

**RECOMMENDED CONSTRUCTION WITH INSULATING FIRE BRICK**

The furnace which is the basis of the foregoing heat balance is of typical fire brick design, details of which have been given previously. The comparison has been drawn between this lining and an effective lining of 9 inches of insulating fire brick. Actually in a large furnace it is not always practical to use 9 inches of insulating fire brick in the side walls and the arch without revising the steel reinforcement. If a new furnace is to be built, then an ideal lining would consist of 5 inches insulating fire brick backed up with one inch low temperature insulation and the entire furnace enclosed in a steel shell. In such furnaces it is generally well to have an angle iron in back of the skews to take the thrust of the arch off the side walls.
If an old furnace is to be rebuilt without any radical changes, then a 9 inch lining of insulating fire brick can be quite satisfactorily backed up with either 4\(\frac{1}{2}\) inches or 6 inches of regular fire brick. The usual number of buck stays and tie rods should be used. The fire brick back of the insulating refractory lining will serve as a brace for the entire structure. The heat balance of the furnace will not be materially affected by superimposing a fire brick lining back of the light weight brick. The temporary expansion of insulating refractories is virtually the same as that of the average heavy fire brick. Therefore, there is little danger of any shearing of the header courses which are used to tie the light brick to the heavy brick.

In some particular since only one or two burners are used, there is quite a severe flame impingement on that section of the arch just above the burners. This applies for the most part to hand fired or oil fired ovens. If such flame impingement is found to be sufficient to build up temperatures in excess of 2500 degrees, then it is well to use regular heavy fire brick for that section of the arch which must stand such abuse. A normal powdered coal burner will not cause any deterioration of the good insulating refractories. This is demonstrated
quite clearly in the picture showing insulating fire brick in a malleable annealing oven after the furnace has been operating normally for several months.

Fire brick should be used to line the first course of the arch and the side walls to take care of the abrasive action which results from placing, sealing, and removing the oven door.

SELECTING AN INSULATING FIRE BRICK

As is always the case when some products is accorded a warm welcome, the market rapidly becomes flooded with brands of all types and descriptions. It then becomes the problem of the consumer to select that particular material which is best suited for his needs. In the order of their importance the following features should be given due consideration: The brick must have sufficient strength to provide a proper safety in construction and to stand normal operating conditions over a period of years. The composition of the brick must be such that it will resist any tendency to disintegrate or to lose any of its strength or insulating value. With these properties confirmed, then the lightest brick with the best insulating value will provide for the highest efficiency.

CONCLUSION

Over a period of five years the truly exceptional
service records on the better grades of insulating refractory brick have given ample assurance that this type of material has been and can be used as a most important aid in providing for excellent efficiencies in furnace operation. It is necessary that a careful study of each individual furnace be made before the best lining for a particular unit be selected. Such items as heat capacity and heat loss by conduction through the walls will not be of the same relative importance in every case. Such a study is not complicated and the improvement in the operation of a furnace more than justifies the time and effort involved in this preliminary work.

This new product has carved a permanent niche for itself. The development of insulating refractory brick is a definite mark of progress in the refractory field.
BIBLIOGRAPHY


A - Construction Recommended -- with insulating refractories alone - using backing-up insulation - light weight brick combined with heavy refractories - precautions to take care of unusual furnace conditions. Page 8


C - Malleable Annealing Oven -- construction and cycle of operation. Page 3

D - Operating Conditions as Influenced by a Lining of Insulating Refractories -- discussion of phases of improvement made possible with light weight brick in lining. Page 6

E - Properties of Insulating Fire Brick -- variation in brands - comparison with heavy fire brick and low temperature insulation. Page 1

F - Selecting an Insulating Fire Brick -- properties desirable discussed in the order of their importance from the users point of view. Page 10