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BUSINESS ANALYSIS OF TOTAL REFRACTORY COSTS

Cynthia K. Belt[1]
[1]Fayetteville, AR 72701, USA

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Abstract

Refractory is a critical component of a furnace. Both planned and unplanned downtime due to refractory wear or failure can detrimentally affect production. Refractory materials, design, and maintenance can improve or degrade energy efficiency and melt rate. In addition, the cost of refractory is typically the largest maintenance expense of a melt or hold furnace. Total refractory costs include refractory materials, installation, energy, and downtime. Many attempts have been made by companies to hold down these costs in various ways. This paper compares several methods and gives relative cost savings based on a benchmark furnace.

Introduction

Over the life of the furnace, refractory costs are typically the largest maintenance expense of a melt or hold furnace. The condition of refractory and the downtime due to repairs greatly affects furnace utilization and energy efficiency. Different theories as to the best method to reduce costs abound. Data was collected to model and compare these methods using a standard furnace over the lifetime of the furnace.

The various methods that were compared included: reduction of refractory material costs, reduction of installation costs, reduction of installation time, energy efficient insulation, repair versus total reline, and extension of the life of the refractory.

Total Refractory Cost Model

For the purposes of this paper, the first standard furnace is an 180,000-pound [82 metric tons] reverberatory melt furnace that melts 5,000,000 pounds of aluminum per month [2,268 metric tons]. The standard life of the furnace used in this model was 4 years. The second standard furnace is an 85,000-pound [39 metric ton] reverberatory hold furnace with a 15-year life and throughput of 7,000,000 pounds of aluminum per month [3,175 metric ton].

It is expected that operations will damage jambs, lintels, and the sill surrounding the door causing holes to form and reducing energy efficiency. Other damage and/or wear will occur over the lifetime of the furnace that will be major, but not enough to completely reline the furnace. External labor for repairs and reline is assumed, however internal labor is used to plan and oversee the work.

The cost of downtime can widely vary between furnace, plants, companies, and depending on current sales. In some cases, production can be smoothly moved to other furnaces while for others, unplanned downtime may cause the loss of an important customer. For the purpose of this paper, two outcomes were modeled. First was that production could be moved to another furnace but that extra energy would be required to start that furnace. The second is that production and profit were lost. The profit was estimated to be $0.05 per pound aluminum.

Of course, the costs and life of a particular furnace can vary greatly. The results of this modeling will not cover all furnaces or situations. However, the general concepts can be used to understand business results of refractory changes.

Total Refractory Costs

Refractory material costs can be very high. As high as these costs are, other related costs can be equal or higher. Many of these costs are hidden and not necessarily charged to repairs. Figures 1-4 show the relative percentage of these costs for the baseline furnaces. These costs are based on the total life of the furnace. For instance, materials would include the materials used during the total reline of the furnace and smaller repairs done over time.

1) Materials – This includes bricks, castable, gunned, and shotcrete material. It includes materials for direct material contact, insulating materials and anchors. Some of the material is lost during application (Shrinkage). For bricks and blocks, minimal shrinkage or material loss is expected. This type of material has a long shelf life with only a small loss due to bricks being cut or breakage. Castable material will have a higher loss. Material is lost within the mixer and pump system or will be thrown away due to a limited refractory life. Bags can be damaged or can get wet. Finally, gunning typically has the same losses as castable but with extra losses from rebound (material that does not adhere during application).
2) Labor – This is the cost of labor and equipment used to repair or reline refractory within the furnace. Material and labor costs are essentially equal for a melt furnace. Because hold furnaces are smaller but the labor is almost the same, labor costs are a higher percentage than materials costs for these furnaces. Labor costs include:
   a) Tear-out of old refractory materials - For major repairs and relines, equipment must be brought in to break up and haul out the old refractory.
   b) Installation - Installation costs include labor and materials needed to complete the work. Along with labor, costs for both wood and steel needed for the forms can be high.
   c) Dry-out - It is best to use external burners that are controlled with multiple thermocouples instead of using the furnace's burners. This process is critical to a good installation!
3) Furnace steelwork repairs – Frequently steelwork must be repaired during a reline. The damage may be due to excessive heat over the life of the furnace or to damage during the tear-out.
4) Downtime - Downtime can be long during a reline (over 30 days). Even smaller repairs require time to cool down then dry-out the refractory. The importance of downtime greatly

varies. When other furnaces can take the production, heating up a spare furnace is a minor cost. When production is lost, it can become equal to the value of the material or the labor. In the case of a hold furnace, downtime becomes even more important. Many hold furnaces are connected to multiple melt furnaces and are directly tied to a casting machine. Downtime here is critical!

5) Material Storage - Space is needed to store new refractory material on-site. Castable and gunning materials must be kept dry. Depending on the season, it may need to be heated or cooled to keep refractory at the right conditions.
6) Disposal - The costs of old material disposal include hopper rental, transportation, and landfill fees. These costs have risen over the years.
7) Internal labor - Internal time is needed to plan, quote, and manage a job of this size. Material storage, disposal, and internal labor are a relatively small part of total refractory costs.
8) Energy - While most energy in a furnace is used for production, some is directly related to refractory. Within this paper, this term does not include the energy used to melt and hold metal, flue loss, conveyor loss, or most opening losses.
   a) Dry-out - This is the energy used during dry-out for burners and blowers.
   b) End-of-Life – This is the heat loss towards the end of life due to openings occurring in the roof, wear in the walls, or heat lost around the doors.
   c) Wall Heat Loss – These are the heat losses through the walls, floor, and roof during the life of the furnace. Wall heat loss is an especially high component of Energy over the life of the furnace. This is particularly true for hold furnaces given their long life.

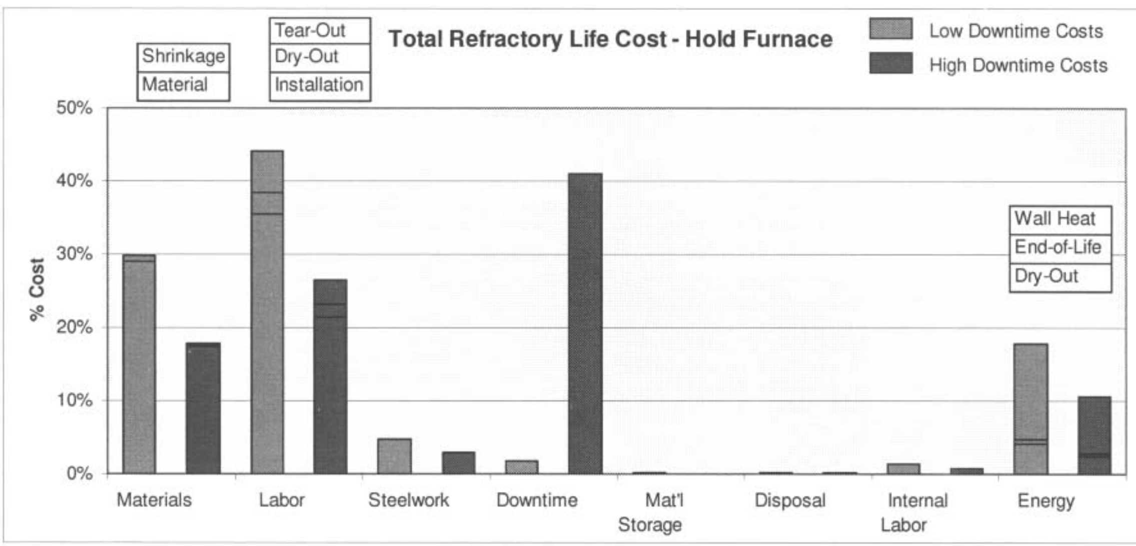

Figure 1. Total Refractory Costs – Melt Furnace

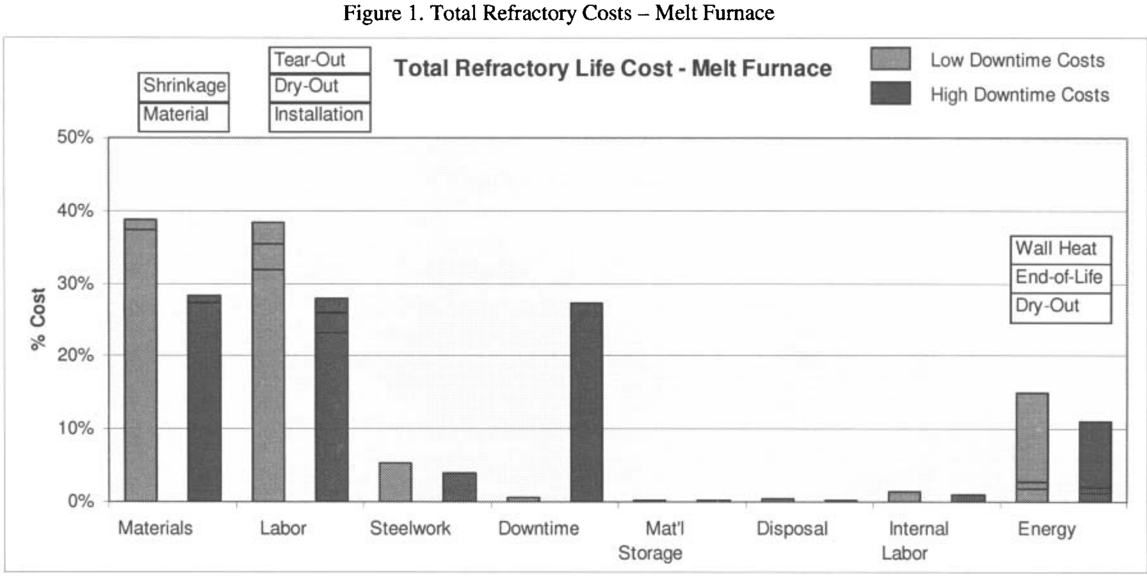

Figure 2. Total Refractory Costs – Hold Furnace

Methods to Reduce Total Refractory Costs

The various methods that were compared are the following.

1. Reduction of refractory material costs

The first method a company typically uses to reduce costs is to negotiate costs of the refractory materials. This works to a limited extent. While there is certainly profit within the sales of these materials, it is not extremely high. Refractories are, in general, a commodity so that a refractory company that demands a higher cost without improved properties will quickly lose business.

More importantly, care must be taken so that low cost and low quality materials do not affect overall performance. Indeed, higher material costs may be preferred if it can reduce installation downtime or extend the life of the furnace with materials with greater strength, wear, or release properties.

As long as critical properties (Hot Modulus of Rupture, Cold Crush Strength, etc.) are understood and maintained, good negotiations can bring down the costs 5 % and perhaps 10 %. However, since lower costs may reduce the quality of the project, it is assumed within this model that life of the furnace stays the same for a 5 % material reduction and is reduced 2 % for a 10 % reduction. While that reduction is a mere one-month for a 4-year life, it has high implications for the total refractory costs.

2. Reduction of installation costs

Similar to material costs, installation costs can be negotiated. However, the low cost installer may not be the best!

Again, since lower costs may reduce the quality of the project, it is assumed within this model that life of the furnace stays the same for a 5 % installation cost reduction and is reduced 2 % for a 10 % reduction.

3. Direct contracts versus turnkey

Installations can be turnkey or separately contracted. This includes materials, tear-out, and dry-out. We know that the installation company profits by marking up sub-contacts. However, there are trade-offs to be understood.

The biggest savings is by purchasing refractory directly. However, additional internal time is needed to estimate the proper quantities and to track usage. Frequently additional material is needed or extra material is left at the end of a job. A contractor is able to stockpile materials to be used on another job but extra material or lack of material will add to costs when purchased directly. In the model it is assumed that normal shrinkage is 5 % while directly purchasing material will increase this to 7 %.

The biggest issue is the question of who is liable if there are problems with the furnace refractory. Did a refractory failure occur due to the material, due to installation problems, or due to dry-out issues? When the job is turnkey, this problem is solved since the contractor is liable. On the other hand, if contracts are carefully written and the work is clearly understood, this issue is less likely to occur. This extra liability is difficult to assess and is not included in the model.

4. Energy efficient insulation

Better insulation can reduce heat loss. Extra insulation or different types of insulation (such as microporous) can increase the cost of insulation and insulation. However, over the life of the furnace, improvements in insulation are typically easily cost justified.

5. Reduction of installation time

Several methods are available to reduce installation time. Material solutions may include big block, pumpable, shotcrete, or quick dry-out materials. Installation methods include longer shifts, weekend, and holiday work. Both the material and the installation method increase costs. For the purposes of the model, it is assumed that installation costs increase by 5 % to shorten downtime by 10 %.

While shorter dry-out schedules are available, it is extremely important to follow material supplier specifications. A 'steam event' (explosion) is far more expensive than the extra time for a proper dry-out! Even without a catastrophic event such as an explosion, shorter dry-out's in some cases may reduce the properties and life of the material.

6. Repair versus total reline

There are two different viewpoints on refractory repairs. To one viewpoint, repairs should be scheduled approximately every year to repair the portions of the refractory showing wear or damage. Over the years, all parts of the furnace will be replaced with some portions replaced more frequently (such as jambs and lintels).

The second point of view is to perform minor repairs and then totally reline the furnace when the majority of the furnace requires repairs. The first method means that good sections of the furnaces are not replaced. It also means that refractory is periodically damaged due to the cool-downs and heat-ups of this process. Energy is used for extra dry-outs. Multiple tear-outs and dry-outs occur over time so that downtime will be higher overall.

The model assumes that the same amount of material is used but that that extra downtime, dry-out energy, and project management time will be needed. Since repairs are down more often, the energy loss toward the end of the furnace life will be reduced. However, since the refractory is susceptible to cracking from thermal shock, the life of the furnace is reduced by 10 % (4.8 months).

7. Extension of the life of the refractory

Much work has been done to extend the life of these types of furnaces. A long-term refractory program should include failure analysis to understand the exact needs in certain areas along with in-furnace trials of refractory. Refractory costs may increase by selecting higher strength materials, but costs can be kept down by using these materials in the most critical areas.

In this model, it is assumed that overall refractory costs increase 4 % for every 10 % increase in refractory life. As an example, for a furnace using $250,000 materials, an increase of $10,000 would increase the life of a furnace 4.8 months. A second model was run assuming 10 % increase in material costs to receive the extra 10 % life.

Modeling Results

Figures 3-6 show the potential savings from the specified changes. Please note that the scaling varies to show the data better.

Reduction of refractory material and installation costs

Hard negotiation is always a good idea on large projects and equipment that is critical to production. Saving 5 % for a $500,000 project on materials and installation is well worth the time.

Key to this is a bid package that details the specific materials and methods to be used. In this way, everyone is bidding on the same thing. The quality of the installation and materials will be maintained. Poor practices include asking for quotes to "Reline the furnace" without details and bidding using only the contactor you used the last time!

A warranty is needed of at least one year. The bid package should detail who will be supplying each item (ex. refractory disposal, water, compressed air, etc.). If possible, important installation details should be specified. For instance, this may include keyed sections or whether pumpable materials are acceptable. Of course, a refractory print is important!

However, if cutting costs reduces the life of the furnace, there is little benefit. Cheap materials or cutting corners during installation saves the company no money over time. Based on this modeling, it is better to receive only a 5 % discount then a 10 % reduction that reduces the life of the furnace by 2 %, particularly when downtime costs more.

Direct contracts versus turnkey

Directly purchasing the materials will save money as long as care is taken to calculate the right amount of materials. However, it is important to keep in mind that liability needs to be discussed and documented in purchase orders. It is best to have someone from the refractory company present during as many pours as possible. They can ensure that proper practices are being followed.

There are fewer savings by directly contracting the tear-out and dry-out, but it will save some money. Again, liability for problems must be decided before the job starts.

Energy efficient insulation

While payback is over a year, installing better insulation will save money over the life of the furnace. This is especially true for hold furnace given their long life. Short-term savings with less insulation will lose the company money with increased heat loss. Invest in insulation!

Reduction of installation time

If downtime causes a loss in production, extra costs can be easily justified. However, there is no purpose in reducing installation time for furnaces where production can be moved to another furnace. Extra costs to reduce installation time will end up costing more for the project. Sometimes management pushes for reduced installation time based on previous experience when plant production or profit per pound was higher. Current conditions must be evaluated.

Repair versus total reline

Based on this analysis, it does not make sense to take a furnace cold multiple times to repair sections of a furnace. Each cycle shortens the furnace life by thermal shocking the refractory. While multiple smaller repairs will give short-term savings, it costs more over the life of the furnace. Instead, a scheduled total reline is best for total refractory costs.

Note that thermal shocking can also occur when cold cleaning a furnace. Cleaning is best done hot. When possible, minor repairs should be done hot or 'warm'.

The analysis was done assuming a 10 % shorter life (4.8 months). It was also rerun (results are not shown) using an assumption that refractory life remains the same. While the total lifetime cost was better, it still was more expensive to repair sections. This was due to extra costs from multiple tear-outs, dry-outs, and internal labor in managing the jobs.

The analysis was not completed for hold furnaces. Most companies will do the total reline and not do patches. This may be due to the long life of the furnace, the difficulty in scheduling downtime on hold furnaces, or that without heavy wear from charging most sections of the hold furnace wear at an equal rate.

Extension of the life of the refractory

The best method to save total refractory costs is by extending the life of the furnace. And, the more that downtime is worth to the company, the more important longer furnace life becomes.

Two different assumptions were made. In one, each 4 % increase in material costs resulted in 10 % increase in life. Understanding the critical areas and refractory properties can make this possible. For example, stainless steel needles can be added to the jamb and lintel section or silicon carbide can be used in ramps and ledges. Adding radii while forming may help. Upgrades in areas such as the roof, upper sidewalls, or sub-hearth rarely are needed. To get a feel for this, on a $250,000 project (material only) we are assuming material costs would increase by roughly $50,000 resulting in a furnace that lasts 6 years instead of 4 year. This takes work, but can be done.

In the second assumption, each 10 % increase in material costs increases the life by 10 %. Even this scenario shows much higher savings then just reducing the material costs by proper bidding. For the same assumptions as above material costs would increase by roughly $125,000 resulting in a furnace that lasts 6 years instead of 4 year. This type of results is very possible.

Another point is that many companies will save money by reducing the quality of refractory on hold furnace since wear is less. In fact, using high quality material is very important since downtime tends to be more critical in these applications.

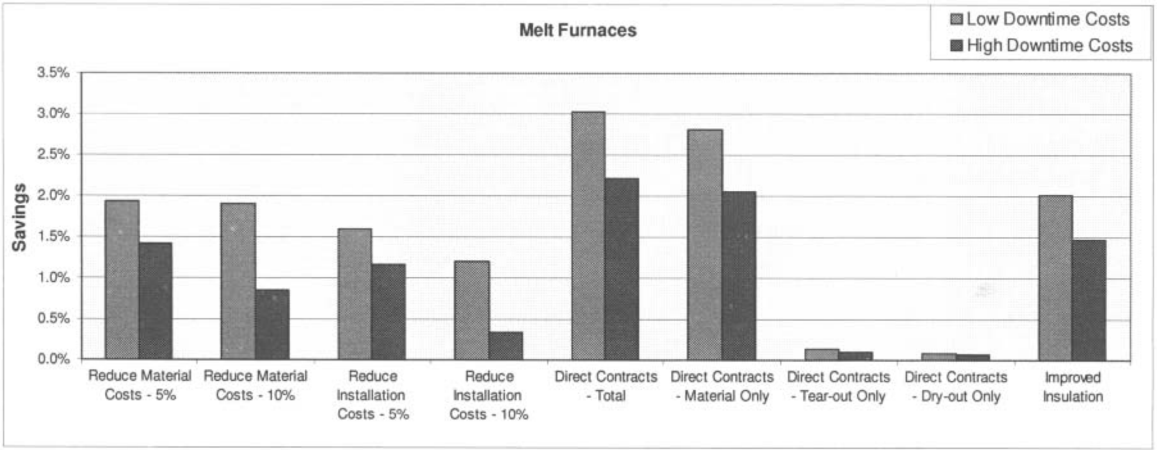

Figure 3. Total Refractory Savings – Melt Furnace

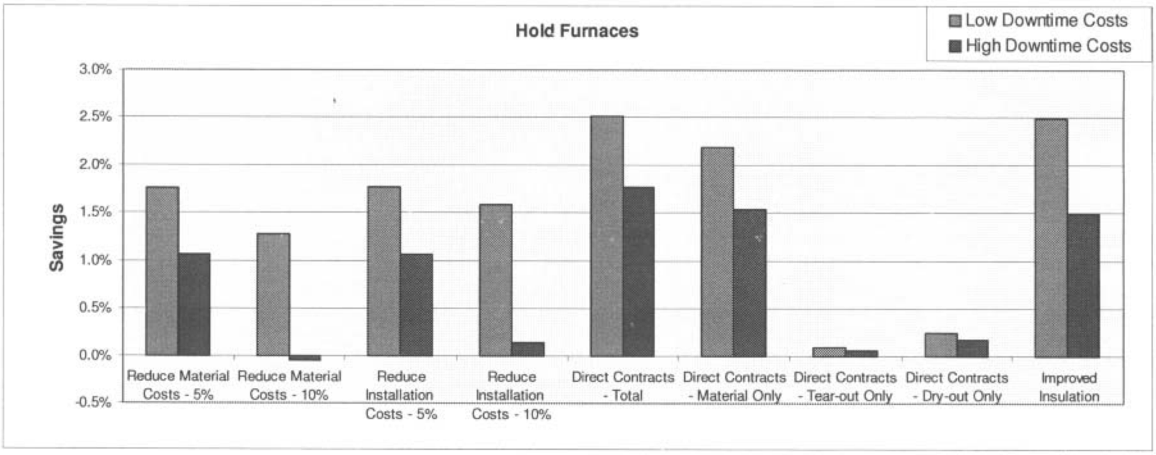

Figure 4. Total Refractory Savings – Hold Furnace

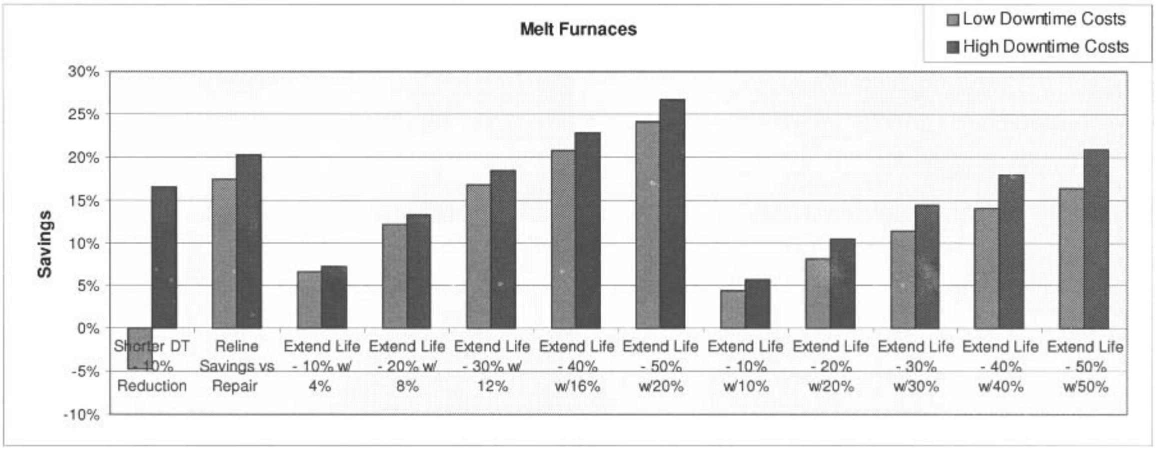

Figure 5. Total Refractory Savings – Melt Furnace

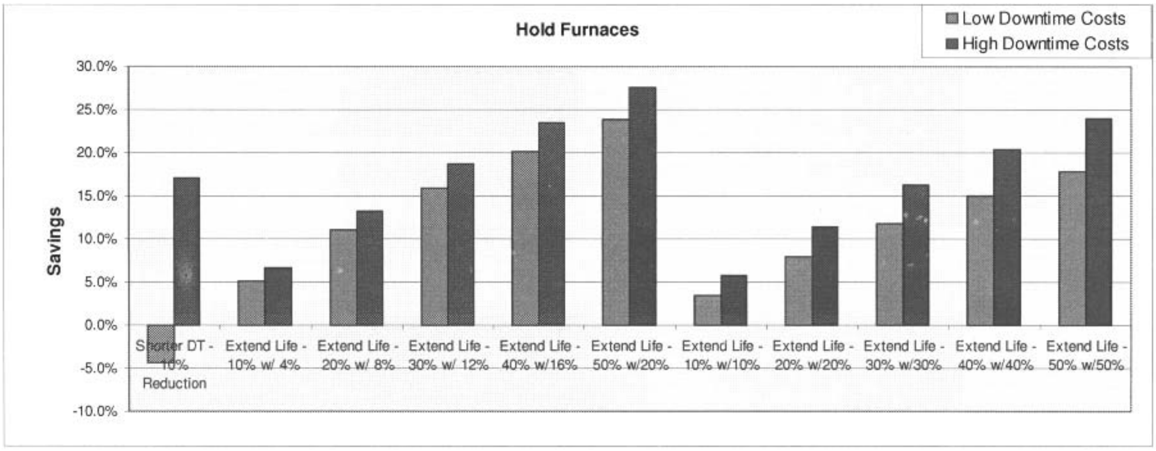

Figure 6. Total Refractory Savings – Hold Furnace

Conclusions

Costs related to refractory in a furnace are high. While material and labor costs for a specific repair may seem high, it is important to keep in mind all costs associated with the furnace and the total life of the furnace. Based on the results from this study, the most attention should be spent in extending the life of refractory versus reducing the cost of refractory. Higher cost repairs may be the best business decision to improve energy efficiency, reduce downtime, and reduce overall costs for the life of a furnace.