COMPARING FURNACES USING A DETAILED OPERATING COST MODEL

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ABSTRACT

A decision as to what furnace to buy is usually decided on a number of factors but price is typically the most dominant. However, an examination of the total operating costs for a furnace shows that the initial purchase price is, in fact, one of the least important elements. More important factors include the costs for utilities and atmospheres as well as uptime (furnace utilization) and quality costs associated with the ability of a furnace to make good parts.

A detailed operating cost model has been developed into which appropriate furnace operating cost assumptions can be inserted. These include equipment purchase, depreciation and space occupancy costs, utility and atmosphere usage rates and prices, operator, inspection and rework costs, as well as replacement parts usage. The model calculates the impact of these costs on total annual operating cost in total dollars, $/lb (or Kg) and/or $/piece.

This paper will highlight experience with the model and provide examples and insights as to the most critical factors affecting the real costs of purchasing and operating a furnace.

INTRODUCTION

You're thinking of buying a new furnace and your boss has just asked you what it's going to cost. What answer do you give?

Typically, your response will be given in the context of the purchase price plus costs for delivery, installation and warranty coverage. After all that is what will be on the Purchase Order. But suppose the furnace will actually save you money by replacing older less efficient equipment, or bring in new revenue and operating margin from a new account. In either case the purchase cost is likely to be less than 10% of the total operating costs of the furnace over the next 5 years. It's even less if you take a 10 year horizon which is hardly unreasonable for a piece of equipment that can last 20 years or more. So what, then, is the real 'cost'?

To try to better answer these questions, a detailed, multi-year, user-interactive, cost of ownership model has been developed into which appropriate furnace operating cost assumptions can be inserted. In addition to the capital costs, the model includes line items for space, utility, atmosphere and spare part costs, as well as costs for operating labor, maintenance, inspection and rework. The model calculates the impact of these costs on total annual operating cost in total dollars, $/lb (or Kg) and/or $/piece.

BACKGROUND

The purchase of an industrial furnace represents a significant capital investment. During the acquisition process, a prospective customer needs to answer such questions as:

- What is the best type of furnace to buy?
- Will a new furnace be financially justified?
- Which vendor can best supply my needs?

It is not unusual for a furnace manufacturer to be asked by prospective customers to provide information that will help them answer these questions. Questions about such things as atmosphere consumption, utility usage and the replacement of belts and muffles are common.

In addition to helping prospective customers resolve their process needs, an acute understanding of the major cost components of operating a furnace can be really helpful in shaping future furnace design.

It was for all these reasons that the operating cost model was built. From the outset it was designed to be comprehensive, financially focused and interactive. The latter was particularly important since there are few, if any, ‘standard’ furnace specifications and process requirements. Much depends on the parts or material being processed, the operating constraints within the manufacturing organization and the associated labor costs. The intent was to build a model that would not only provide good solid cost estimates but also answer “what if” kinds of questions.

This paper highlights some of our early takeaways from using the model and, in particular, provides a cost based rationale for some operating best practices.

COST ELEMENTS

The model includes all the costs associated with operating and maintaining a furnace. As much as possible, inputs are based on units of activity … e.g. hours of labor, volume / hr of gases, kw-hrs of electricity, etc. Appropriate costs/unit then create the dollar cost of the activities.

Fig 1. outlines the cost factors in the model.

The size shape and weight of the product can all be factored into the throughput of the model. This is essential when comparing furnaces. Simply specifying the operation and weight/hr of product is not enough. Similarly, it is important to specify the desired time, temperature and atmosphere requirements and translate that into power requirements and atmosphere consumption.

Inputs	Calculated Annual Operating Cost
Capital Cost Installation Cost Economic Life	Depreciation
Footprint	Facility Cost
Available Hours Required Operating Hours Downtime / Maintenance Hours	

Part Characteristics
    Weight
    Loading (pcs / area)
Furnace Belt Width
Furnace Belt Speed	

Atmosphere Consumption Volume & Price (each gas)	Atmosphere Expense

Utilities
    Electricity
    Gas
    Compressed Air
    Water
    Other
	Utilities

Replacement Parts By critical part	Parts Expense
Operator Labor (hrs, rate & overhead)	Operating Labor
Maintenance Labor (hrs, rate & overhead)	Maintenance Labor
Inspection Labor (hrs, rate & overhead)	Inspection Cost
Pass / Fail Percentage Rework & Re-inspection Cost	Rework Costs
	Total Operating Cost

Figure 1. Operating Cost Model Inputs

SINTERING FURNACE ILLUSTRATION

By way of example, Fig 2 is an operating cost profile for an electrically heated, continuous belt sintering furnace. This is a condensed version of the final summary page of the model. For simplicity, the other, detailed cost construction, sheets within the model have been omitted.

The key operating parameters are as follows:

- Sintering is at 1120°C (2050°F)
- 2,000,000 parts per year. Each part weighs 0.9Kg (2 lbs). Output 325Kg/hr (720 lbs/hr).
- Furnace utilization is 3 shifts a year, 5 days / week, 48 weeks / year and maintenance is planned at 100 hrs a year, during the two shifts
- Atmosphere is 90% N_2, 10% H_2 and overall consumption is 23,600 cm^3/sec (3,000 CFH)
- The furnace has a full time operator and sample inspection. Labor rates are assumed to be $15.00 / hr for operators $18.00 / hr for maintenance and inspection. Direct labor overhead rate is 30%.
- Yield is assumed at 100%. (i.e there are no rework / re-inspection costs)
- The furnace consists of a Pre-Heat section with a Stainless Steel muffle and a High Heat section with a Silicon Carbide muffle
- Spare parts use is driven by the belt and the muffles.

OPERATING COST COMPARISON

Continuous Belt Sintering Furnace

(All figures in US$)

Item					Unit	Annual Cost	Cost / Part ($ / pc)	Cost / lb ($ / lb)
Capital Cost				500,000	$			
Installation Cost				30,000	$			
Anticipated Life				20	Yrs			
Gross footprint (incl. aisles)				900	Sq Ft			
Depreciation (straight line)					$	26,500		
Facility Space costs ($/sq ft/yr)				10.00	$ / sq ft	9,000		
Total Available Hrs/Week			3x5x8	120	Hrs			
Total Weeks Available				48	Wks			
Total Available Hours				5,760	Hrs			
Est. Downtime (Repairs / Mtce)				100	Hrs			
Est. Operating Hrs				5,556	Hrs			
Effective Utilization				98.2%				
Part Description								
Weight			lbs / pc	2.00				
Furnace speed			ins / min	6.0				
Throughput		Pcs /Hr		360				
		Lbs / Hr		720	Lbs			
Atmosphere Consumption								
	%	cf / h	$ / 100cf	hrs / yr				
N_2	90.0%	2,700	0.33	8,064	$	71,850		
H_2	10.0%	300	1.10	8,064	$	26,611		
Tot	100.0%	3,000						
Utilities								
Electricity			Full Load kw	$ / kwhr				
			150	0.08	$	96,768		
Natural Gas			Cu Ft / Hr	$ / 100cf				
			10	1.30		1,048		
Comp Air			0	0.00		0		
Other Furnace Reqts (e.g. Water)				10,000	$ / yr	10,000		
Replacement Parts (First 5 yrs)								
Belts				150,000	$	30,000		
Muffles				70,000	$	14,000		
Other				40,000	$	8,000		
Operator Labor		Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		5,556	15.00	4.50	$	108,333		
Maintenance Labor		Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		100	18.00	5.40	$	2,340		
Gross Output (pcs)			pcs	2,000,000				
Inspection Labor								
	Pcs/hr	Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
	4	556	18.00	5.40	$	12,999		
Yield (%)				100.0%	%			
Total Output (pcs)			pcs	2,000,000				
Annual Furnace Operating Cost						417,450	0.2087	0.1044

Note:

- All numbers are approximate and for directional purposes only
- Operations are 3 Shifts, 5 Days/wk
- Utilization is calculated based on Operating Hrs + Downtime
- Consumption of atmosphere and utilities in idle mode is assumed to be the same as operating consumption
- Sample inspection only (sample rate is approximately 1%)

Figure 2. Operating Cost Comparison – Sintering Furnace Example

As is evident, the model covers all the key costs associated with owning and operating the furnace. Altering the input variables provides the opportunity to test different furnace options or operating assumptions.

In this example, the three dominant operating costs are:

- Atmosphere consumption
- Utilities
- Operator, Inspection and Maintenance costs

Each represents approximately 25% of the total operating cost, which is typical.

Although the purchase price for the furnace is frequently a subject of much discussion, its impact on operating cost, through depreciation, is actually quite small; in this case just 6% of the total.

Clearly, then, it makes sense to carefully match the choice of furnace to your process needs. Whilst the purchase price of a new furnace is important, estimating and validating the impact on atmosphere, utility and labor costs is even more important. The reliability and predictability of the furnace, which has a major impact on these costs, is far more important than purchase price.

OPERATING COST PROFILE

Based on the various PM examples compiled to date, total operating costs break down approximately as follows:

RELATIVE IMPORTANCE OF TYPICAL ANNUAL OPERATING COSTS

Operating Cost	**Range** (% of Total)	**Guideline** (% of Total)
Furnace Depreciation	5% - 15%	10%
Facility Space Costs	5% - 15%	10%
Atmosphere & Utilities	40% - 55%	50%
Operator & Maintenance Labor Costs	5% - 15%	10%
Inspection & Rework	5% - 20%	8%
Replacement Parts	10% - 15%	12%
		100%

Figure 3. Relative Importance of Typical Annual Operating Costs

Looking at this profile, it is no surprise that atmosphere and utilities are frequently the focus of productivity efforts.

COST SENSITIVITY

In addition to understanding the key cost drivers, it is also important to understand how those cost factors change across a range of operating conditions. The following table provides a guideline:

HOW SENSITIVE ARE THE COSTS?

Operating Cost	Predictability	Typical Source of Data
Furnace Depreciation	High	PO + Installation
Facility Space Costs	High	Budgeted Overhead
Atmosphere & Utilities	Med - High	Similar Processes & Parts
Operator & Maintenance Labor Costs	Med	Similar Processes
Inspection & Rework	Low - Med	
Replacement Parts	Med	Other Furnaces

For new processes, inspection & rework costs can be both significant and uncertain.
It is critical to have a furnace that can consistently deliver high quality.

Figure 4. Cost Sensitivity

Once the process parameters and furnace specifications are set, the cost of the furnace and its related depreciation are typically predictable and relatively fixed. So are the footprint of the furnace and the related facility space costs. Although there can be a wide variation amongst companies in the cost per square foot for facility space costs, within the same building or accounting structure the cost per square foot will likely be very consistent.

Atmosphere and utility costs are also reasonably predictable once a stable time, temperature and atmosphere profile is established for a part and the furnace. Atmosphere flows and heat still need to be maintained at some level even when the furnace is idling. Productivity initiatives can help optimize the flow rates but the metallurgy of the part and the need to adhere to critical part dimensions and specs impose limits on the extent to which changes can be made.

On the other hand, operator labor, inspection labor and associated rework costs can vary significantly depending on operating practice. For instance, depending on the type and quantities of a part, loading can be automated or an operator positioned to handle more than one furnace. The degree to which inspection and rework is needed is a function not only of the predictability of the furnace and furnace process but also the quality of upstream operations and, in PM applications, of the powder itself. Whatever the source, the cost of poor quality can be very significant, as a later table will illustrate.

Estimates for replacement parts will depend on the parts, loading, temperature and degree of cycling that the furnace is subjected to. If they are available, other like furnaces can be used for the basis of estimates. Otherwise the furnace manufacturer can provide an estimate.

The model can also be used to estimate how costs change under different operating assumptions. Estimating the benefit of reducing atmosphere consumption is straightforward assuming, of course, that part quality is not compromised.

But, what about increasing throughput?
The tables in Appendix 1 use the example in Fig 2, but increases the throughput rate from 15cm / min (6" / min) to 20cm / min (8" / min), a 33% increase.
A couple of key assumptions were made:

- Atmosphere and utility usage remains unchanged. This is because, for the examples in this paper, it is assumed that atmosphere and utility usage would be the same in idle mode as in production mode. Obviously this is conservative.
- Operator labor is assumed to be completely flexible and so labor hours are reduced commensurate with the lower furnace production hours.
- There is no change in part quality.

The overall impact is to reduce the cost per part by only 6%; from 20.87c per part to 19.52c. However the available unused furnace capacity increases from 2% to 26%. Appendix 2 shows that if the increase in available capacity is fully utilized for production, (i.e. total utilization is increased back to approximately 98%), then the furnace output increases to 2,650,000 parts (from 2,000,000) and the cost per part drops to 15.73c, a 25% reduction. Clearly the greatest benefit in increasing belt speed is when capacity is constrained or when total plant output can be rationalized over fewer furnaces.

The impact of poor part quality or an unreliable furnace is even more significant, increasing the cost per part and reducing furnace capacity, sometimes very significantly. Appendix 3 shows the effect on operating cost in a situation where parts need to be 100% inspected and, subsequently, 15% of the output needs to be re-worked. Inspection time is assumed to be 6 seconds / part, and inspection is for 48 minutes / hr. Rework takes 20 seconds per part and is 100% effective.

The result is an increase in total operating cost per part of 20%; from 20.87c to 25.10c. This increase is driven by the inspection / rework time. Obviously, depending on the part and the problem, this inspection and rework time can vary very widely, but it is a potential cost killer. Furnace capacity is unchanged since it is assumed that all reworked parts pass inspection and no extra production is required.

An inferior furnace, or one poorly tuned to the required process, has a similar impact. In addition to poor part quality the furnace may experience higher downtime, higher maintenance costs and higher costs for replacement parts. Appendix 4 shows the cost for a furnace which incurs significantly higher downtime and maintenance hours; in this instance, 400 hours vs. 100hrs in the base case. Because of the higher repair time, replacement parts expense is also assumed to increase 20%. In this scenario, total operating cost increases by $10,400, or just under 3%, vs. the base case in Fig.2. In comparison, a $100,000 increase in the cost of the furnace increases the annual cost of depreciation by only $5,000. The conclusion; choosing the least expensive furnace makes sense, but only if the furnace can perform reliably, consistently and with minimum downtime.

Similarly it makes sense to consider replacing older furnaces particularly if they incur high downtime, maintenance charges and are less fuel or atmosphere efficient. The added depreciation of a new furnace is likely to be more than offset by other operating cost savings.

TAKEAWAYS

There are a number of insights and operating guidelines that fall out of the analyses that have been done. Some are well understood and the model serves merely to provide numerical support. Other takeaways may be less obvious but all can be verified and tested using the model:

- When it comes to operating cost, the purchase cost of a furnace and its associated installation cost are second order effects. Atmosphere, utility and operating labor costs matter much more.
- Buying a furnace that can consistently deliver the correct time, temp & atmosphere profile is critical for minimizing operating cost.
- 100% inspection is very expensive. Investing in a furnace that will consistently deliver quality parts is a huge cost saver and justifies a significant premium on purchase cost.
- The incoming quality of the parts or material being processed is very important. The furnace can't be expected to fix powder or press issues, for example.
- Three quarters of the costs are affected by process design and management, i.e. the process requirements for the part and the way in which the furnace is run. So it pays to carefully match the furnace to the process you need and to learn how to run it effectively.
- Operator costs are very significant. They can be as large as the atmosphere or utility costs. This makes it worthwhile to really think about how you will load and unload the furnace.
- Replacement belts and muffles have the largest impact on the overall replacement parts cost so it pays not to overheat the furnace and it also pays to minimize thermal cycling.
- In terms of cost / lb or Kg, bigger is better provided you have the need for the capacity. A 36" furnace is more cost effective than two 18" furnaces.

From a furnace manufacturer's point of view, John Ruskin, the noted 19th century critic and philosopher aptly said;

> "It's unwise to pay too much, but it's unwise to pay too little.
> When you pay too much you lose a little money; that is all.
> When you pay too little, you sometimes lose everything, because the thing you bought was incapable of doing the thing you bought it to do."

SUMMARY

This cost model was developed in an attempt to portray, in hard financial terms, the differences between various furnace and operating conditions. It has already proved valuable in helping customers better specify their furnace needs. Rather than just relying on 'experience' it provides a solid numerical footing for the identification of critical success factors and the discussion of equipment alternatives.

For operating and engineering management it provides a vehicle to communicate the cost and benefits of alternative courses of actions. Whether adding capacity for new business, pulling back business from a vendor or offshore location, or merely helping select the right size, type and make of furnace, the operating cost model can be a valuable aid.

Appendix 1

OPERATING COST COMPARISON

Continuous Belt Sintering Furnace

Higher Belt Speed

					Unit	Annual Cost	Cost / Part	Cost / lb
(All figures in US$)							($ / pc)	($ / lb)
Capital Cost				500,000	$			
Installation Cost				30,000	$			
Anticipated Life				20	Yrs			
Gross footprint (incl. aisles)				900	Sq Ft			
Depreciation (straight line)					$	26,500		
Facility Space costs ($/sq ft/yr)				10.00	$ / sq ft	9,000		
Total Available Hrs/Week			3x5x8	120	Hrs			
Total Weeks Available				48	Wks			
Total Available Hours				5,760	Hrs			
Est. Downtime (Repairs / Mtce)				100	Hrs			
Est. Operating Hrs				4,167	Hrs			
Effective Utilization				74.1%				
Part Description								
Weight			lbs / pc	2.00				
Furnace speed			ins / min	8.0				
Throughput		Pcs /Hr		480				
		Lbs / Hr		960	Lbs			
Atmosphere Consumption								
	%	cf / h	$ / 100cf	hrs / yr				
N_2	90.0%	2,700	0.33	8,064	$	71,850		
H_2	10.0%	300	1.10	8,064	$	26,611		
Tot	100.0%	3,000						
Utilities								
Electricity		Full Load kw		$ / kwhr				
		150		0.08	$	96,768		
Natural Gas		Cu Ft / Hr		$ / 100cf				
		10		1.30		1,048		
Comp Air		0		0.00		0		
Other Furnace Reqts (e.g. Water)				10,000	$ / yr	10,000		
Replacement Parts (First 5 yrs)								
Belts				150,000	$	30,000		
Muffles				70,000	$	14,000		
Other				40,000	$	8,000		
Operator Labor		Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		4,167	15.00	4.50	$	81,250		
Maintenance Labor		Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		100	18.00	5.40	$	2,340		
Gross Output (pcs)			pcs	2,000,000				
Inspection Labor								
	Pcs/hr	Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
	4	556	18.00	5.40	$	12,999		
Yield (%)				100.0%	%			
Total Output (pcs)			pcs	2,000,000				
Annual Furnace Operating Cost						390,366	0.1952	0.0976

Note:

All numbers are approximate and for directional purposes only

Operations are 3 Shifts, 5 Days/wk

Utilization is calculated based on Operating Hrs + Downtime

Consumption of atmosphere and utilities in idle mode is assumed to be the same as operating consumption

Sample inspection only (sample rate is approximately 1%)

Appendix 2

OPERATING COST COMPARISON

Continuous Belt Sintering Furnace

Belt Speed Increased, Additional Capacity Utilized

					Unit	Annual Cost	Cost / Part	Cost / lb
(All figures in US$)							($ / pc)	($ / lb)
Capital Cost				500,000	$			
Installation Cost				30,000	$			
Anticipated Life				20	Yrs			
Gross footprint (incl. aisles)				900	Sq Ft			
Depreciation (straight line)					$	26,500		
Facility Space costs ($/sq ft/yr)				10.00	$ / sq ft	9,000		
Total Available Hrs/Week			3x5x8	120	Hrs			
Total Weeks Available				48	Wks			
Total Available Hours				5,760	Hrs			
Est. Downtime (Repairs / Mtce)				100	Hrs			
Est. Operating Hrs				5,521	Hrs			
Effective Utilization				97.6%				
Part Description								
Weight			lbs / pc	2.00				
Furnace speed			ins / min	8.0				
Throughput		Pcs /Hr		480				
		Lbs / Hr		960	Lbs			
Atmosphere Consumption								
	%	cf / h	$ / 100cf	hrs / yr				
N_2	90.0%	2,700	0.33	8,064	$	71,850		
H_2	10.0%	300	1.10	8,064	$	26,611		
Tot	100.0%	3,000						
Utilities								
Electricity		Full Load kw		$ / kwhr				
		150		0.08	$	96,768		
Natural Gas		Cu Ft / Hr		$ / 100cf				
		10		1.30		1,048		
Comp Air		0		0.00		0		
Other Furnace Reqts (e.g. Water)				10,000	$ / yr	10,000		
Replacement Parts (First 5 yrs)								
Belts				150,000	$	30,000		
Muffles				70,000	$	14,000		
Other				40,000	$	8,000		
Operator Labor		Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		5,521	15.00	4.50	$	107,656		
Maintenance Labor		Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		100	18.00	5.40	$	2,340		
Gross Output (pcs)			pcs	2,650,000				
Inspection Labor								
	Pcs/hr	Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
	4	556	18.00	5.40	$	12,999		
Yield (%)				100.0%	%			
Total Output (pcs)			pcs	2,650,000				
Annual Furnace Operating Cost						416,773	0.1573	0.0786

Note:

All numbers are approximate and for directional purposes only

Operations are 3 Shifts, 5 Days/wk

Utilization is calculated based on Operating Hrs + Downtime

Consumption of atmosphere and utilities in idle mode is assumed to be the same as operating consumption

Sample inspection only (sample rate is approximately 1%)

Appendix 3

OPERATING COST COMPARISON

Continuous Belt Sintering Furnace

Poor Quality; 100% Inspection, 15% Rejected & Reworked

						Unit	Annual Cost	Cost / Part	Cost / lb
(All figures in US$)								($ / pc)	($ / lb)
Capital Cost					500,000	$			
Installation Cost					30,000	$			
	Anticipated Life				20	Yrs			
	Gross footprint (incl. aisles)				900	Sq Ft			
Depreciation (straight line)						$	26,500		
Facility Space costs ($/sq ft/yr)					10.00	$ / sq ft	9,000		
Total Available Hrs/Week				3x5x8	120	Hrs			
Total Weeks Available					48	Wks			
Total Available Hours					5,760	Hrs			
Est. Downtime (Repairs / Mtce)					100	Hrs			
Est. Operating Hrs					5,556	Hrs			
Effective Utilization					98.2%				
Part Description									
	Weight			lbs / pc	2.00				
	Furnace speed			ins / min	6.0				
Throughput			Pcs /Hr		360				
			Lbs / Hr		720	Lbs			
Atmosphere Consumption									
		%	cf / h	$ / 100cf	hrs / yr				
	N_2	90.0%	2,700	0.33	8,064	$	71,850		
	H_2	10.0%	300	1.10	8,064	$	26,611		
	Tot	100.0%	3,000						
Utilities									
	Electricity		Full Load kw		$ / kwhr				
				150	0.08	$	96,768		
	Natural Gas		Cu Ft / Hr		$ / 100cf				
				10	1.30		1,048		
	Comp Air			0	0.00		0		
Other Furnace Reqts (e.g. Water)					10,000	$ / yr	10,000		
Replacement Parts (First 5 yrs)									
	Belts				150,000	$	30,000		
	Muffles				70,000	$	14,000		
	Other				40,000	$	8,000		
Operator Labor			Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
			5,556	15.00	4.50	$	108,333		
Maintenance Labor			Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
			100	18.00	5.40	$	2,340		
Gross Output (pcs)				pcs	2,000,000				
Inspection Labor									
		Pcs/hr	Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		480	4,167	18.00	5.40	$	97,500		
Yield (%)					100.0%	%			
Total Output (pcs)				pcs	2,000,000				
Annual Furnace Operating Cost							501,951	0.2510	0.1255

Note:

All numbers are approximate and for directional purposes only

Operations are 3 Shifts, 5 Days/wk

Utilization is calculated based on Operating Hrs + Downtime

Consumption of atmosphere and utilities in idle mode is assumed to be the same as operating consumption

100% inspection

Appendix 4

OPERATING COST COMPARISON

Continuous Belt Sintering Furnace

Higher Downtime & Higher Replacement Parts Usage

						Unit	Annual Cost	Cost / Part	Cost / lb
(All figures in US$)								($ / pc)	($ / lb)
Capital Cost					500,000	$			
Installation Cost					30,000	$			
	Anticipated Life				20	Yrs			
	Gross footprint (incl. aisles)				900	Sq Ft			
Depreciation (straight line)						$	26,500		
Facility Space costs ($/sq ft/yr)					10.00	$ / sq ft	9,000		
Total Available Hrs/Week				3x5x8	120	Hrs			
Total Weeks Available					48	Wks			
Total Available Hours					5,760	Hrs			
Est. Downtime (Repairs / Mtce)					400	Hrs			
Est. Operating Hrs					5,556	Hrs			
Effective Utilization					103.4%				
Part Description									
	Weight			lbs / pc	2.00				
	Furnace speed			ins / min	6.0				
Throughput			Pcs /Hr		360				
			Lbs / Hr		720	Lbs			
Atmosphere Consumption									
		%	cf / h	$ / 100cf	hrs / yr				
	N_2	90.0%	2,700	0.33	8,064	$	71,850		
	H_2	10.0%	300	1.10	8,064	$	26,611		
	Tot	100.0%	3,000						
Utilities									
	Electricity		Full Load kw		$ / kwhr				
				150	0.08	$	96,768		
	Natural Gas		Cu Ft / Hr		$ / 100cf				
				10	1.30		1,048		
	Comp Air			0	0.00		0		
Other Furnace Reqts (e.g. Water)					10,000	$ / yr	10,000		
Replacement Parts (First 5 yrs)									
	Belts				180,000	$	36,000		
	Muffles				84,000	$	16,800		
	Other				48,000	$	9,600		
Operator Labor			Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
			5,556	15.00	4.50	$	108,333		
Maintenance Labor			Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
			400	18.00	5.40	$	9,360		
Gross Output (pcs)				pcs	2,000,000				
Inspection Labor									
		Pcs/hr	Hrs/Furn/Yr	$ / Hr	Ohd $ / Hr				
		4	556	18.00	5.40	$	12,999		
Yield (%)					100.0%	%			
Total Output (pcs)				pcs	2,000,000				
Annual Furnace Operating Cost							434,870	0.2174	0.1087

Note:

All numbers are approximate and for directional purposes only

Operations are 3 Shifts, 5 Days/wk

Utilization is calculated based on Operating Hrs + Downtime

Consumption of atmosphere and utilities in idle mode is assumed to be the same as operating consumption

100% inspection