EMP ENGINEERING SERVICES INC.

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- #BUSTLE RING HEAT LOSS - (Rev 1)

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The bustle ring is in poor condition and is wasting heat and money due to this condition. A precise determination of how much money is being lost would require a significant level of effort. However, an order of magnitude estimate is fairly straight forward and will serve to make the point. This is that estimate.

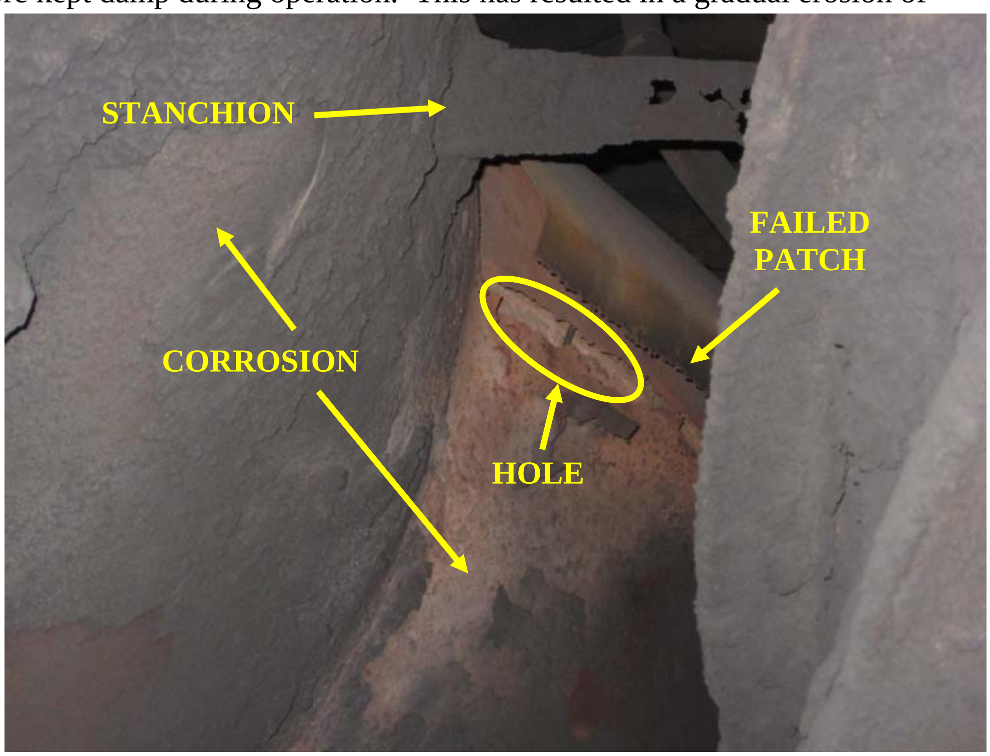
The bustle ring loses heat through three primary means;

1. Through holes in the shell
2. Through convection to the surrounding air
3. Through radiation to surrounding surfaces.

The other element of heat transfer, conduction though materials, is negligible due to the threaded rod suspension of the ring. This mounting system provides flexible support but also minimizes the cross-sectional area through which heat can conduct and provides many discontinuities that resist heat flow.

HOLES

The skin of the bustle ring is in poor condition, primarily due to corrosion. It is constantly exposed to mist from the water jacket and therefore kept damp during operation. This has resulted in a gradual erosion of material and loss of thickness. Patches have been installed however there isn't much material for a weld foundation so the patches don't last long under the differential pressure from the bustle ring air.



There are currently two significant holes in the bustle ring, both on the inside diameter and about 180 degrees apart with one almost directly above the tap and the other on the side towards the Hot Blast. The holes appear to be points where support stanchions for expanded metal decking was once attached. The stress of the stanchions probably contributed to the

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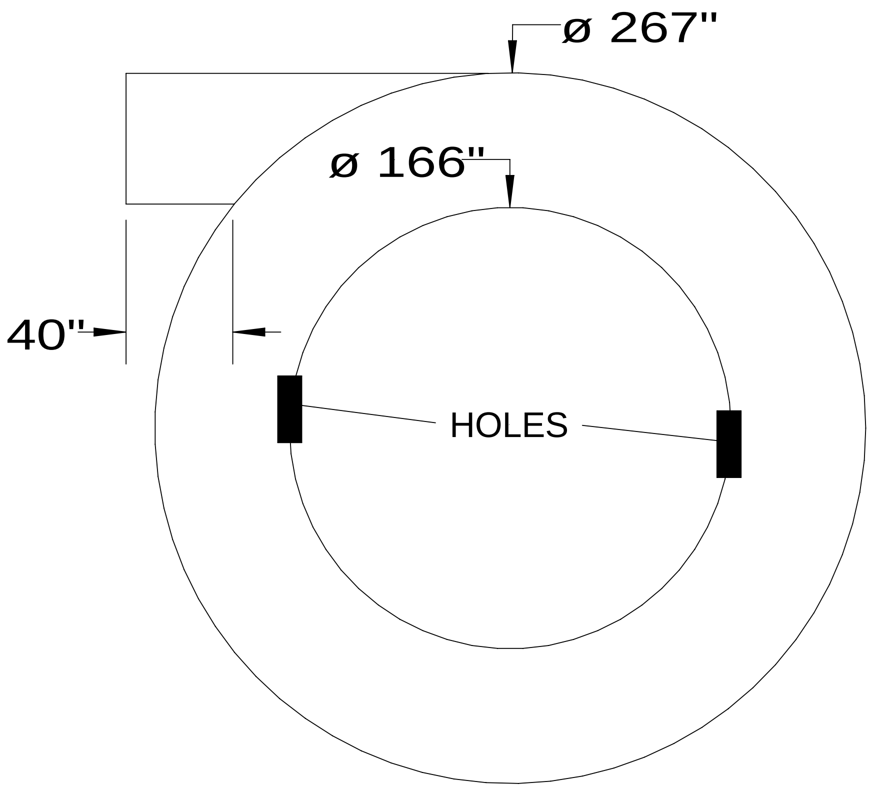
failures. The stanchions do not appear on the original Modern Equipment drawing of the bustle ring and may have been a post installation modification.

These holes are each larger than the openings in the down comers. Although the irregular shape serves to resist the flow more than the smooth down comer openings, the path has less discontinuities so it is fair to assume that the volumetric flow is similar for this gross calculation.

This means that there are actually 12 similar openings through which the heated air inside the bustle ring can pass, 2 of which are simply wasting the heat because it exhausts to the atmosphere. In other words, 16% of the heat content provided by the Hot Blast is wasted.



In typical operation the Hot Blast provides 570,000 cubic feet per hour (cfh) of air. It also uses 34,200 cfh of natural gas. The heat content of natural gas varies from region to region but not by much. West Virginia gas is in the middle of the range and provides about 1,040 BTU/cubic foot. In 2007, Griffin Pipe paid an average rate of $9.59 per million BTU (MBTU). This means that the cost of

$Gas_{hourly} = 34,200 * 1,040 * 9.59 / 1,000,000 = 341$ This is $341/hour to provide heated air to the bustle ring. But 16% of that is being blown out of holes so the waste cost is:

$Moneywasted_{holes} = 0.16 * 341 = 54.58$ $54.58 is being wasted every hour due to holes in the ring.

CONVECTION TRANSFER

Convection transfer is heat lost through transfer to a surrounding fluid, in this case the air. The amount of heat lost through convection is defined by:

$$\dot{Q} = hA(T_1 - T_2)$$

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Where h = heat transfer coefficient. This is the efficiency with which heat energy is transferred from an object to the air around that object. It depends on the surface conditions, the speed of the air and the temperatures of both the air and the bustle wall. In this case, a horizontal cylinder, a fair estimate is $h=1.31*\Delta T^{1/3}$ (ASHRAE, 2005) with h in BTU/hr-^{o}R-ft^{2}.

Combining this with the heat loss equation produces;

$$\dot{Q} = 1.31(T_1 - T_2)^{1/3} * A(T_1 - T_2) = 1.31A(T_1 - T_2)^{4/3} \quad \text{in BTU/hr}$$

The area may be approximated as a torus and a short section of round pipe. The toroid area is:

$$A_{torus} = 4\pi^2 rR = 4\pi^2(25.25)(108) = 107,658in^2 = 748\,ft^2$$

The duct section between the torus and the flange is 36 in long. Its area is:

$$A_{cyl} = \pi dl = \pi(50.5)(40) = 6,346in^2 = 44.1\,ft^2$$

The total area is therefore:

$$A_{total} = 748 + 44.1 = 792\,ft^2$$

Now the heat loss is:

$$\dot{Q} = 1.31(792)(T_1 - T_2)^{4/3} = 1038(T_1 - T_2)^{4/3} \quad \text{in BTU/hr}$$

Infrared inspections of the bustle ring have shown the skin temperature to be around 200F through the duct to the ring and at the relative cool spots in the ring. This appears to be the skin temperature in areas where the refractory is in good condition.

The ambient temperature surrounding the ring varies significantly through the seasons because the walls are very porous. An average temperature of 50F seems reasonable. If all of the refractory was in top condition and the skin temperature was at 200F, then the heat loss from the bustle ring would be:

$$\dot{Q}_{ideal} = 1038(200 - 50)^{4/3} = 827,280 \quad \text{BTU/hr}$$

This is the ideal condition for this refractory. Unfortunately, the infrared inspections show that about 50% of the skin is at a higher temperature than the 200F ideal, averaging about 325F. So we really need to calculate heat loss for 50% of the area at 200 and 50% at 325F to get a more representative value.

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$$\dot{Q}_{T=200} = \frac{1038}{2}(200-50)^{4/3} = 413,640 \quad \text{BTU/hr}$$

$$\dot{Q}_{T=325} = \frac{1038}{2}(325-50)^{4/3} = 928,135 \quad \text{BTU/hr}$$

$$\dot{Q}_{actual} = 413,640 + 928,135 = 1,341,775 \quad \text{BTU/hr}$$

This presents a difference of:

$$\Delta\dot{Q} = 1,341,775 - 827,280 = 514,495 \quad \text{BTU/hr}$$

In terms of dollars, this is:

$Moneywasted_{refractory} = 514,495 * 9.59 / 1,000,000 = 4.93$ <u>$4.93 is being wasted every hour through convection due to poor refractory.</u>

RADIATION TRANSFER

Radiation transfer is heat that moves from one body to another through radiation. This is how the sun warms the earth. The amount of heat lost through radiation is defined by:

$$\dot{Q} = \sigma F_\varepsilon F_g A(T_1^4 - T_2^4)$$

σ is the Stefan-Boltzmann constant and equals $0.1714*10^{-8}$ BTU/h-ft^2-F^4, F_ε and F_g are the emissivity, 0.8 for oxidized steel, and the geometry, 1.0 for an enclosed radiator, factors. The area is only ½ of the torus because the shell of the cupola is approximately the same temperature as the buste ring and little net heat transfer takes place between these bodies.

As with convection, the ideal radiation loss must be determined then that for the 50% at a higher temperature.

$$\dot{Q} = \sigma F_\varepsilon F_g A(T_1^4 - T_2^4) = 0.1714*10^{-8}*0.8*1.0*748/2*(T_1^4 - (460+50)^4) = 51.3*10^{-8}*(T_1^4 - 6.77*10^{10})$$

For 200F (over ½ of the area)

$$\dot{Q} = 51.3*10^{-8}*((460+200)_1^4 - 6.77*10^{10})/2 = 48,670 \quad \text{BTU/hr}$$

For 325F (over ½ of the area)

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$\dot{Q} = 51.3*10^{-8}*((460+325)_1^4 - 6.77*10^{10})/2 = 80{,}037$ BTU/hr

$\dot{Q}_{ideal} = 2*48670 = 97{,}340$ BTU/hr

$\dot{Q}_{actual} = 48{,}670 + 80{,}037 = 128{,}707$ BTU/hr

This presents a difference of:

$\Delta\dot{Q} = 128{,}707 - 97{,}340 = 31{,}367$ BTU/hr

In terms of dollars, this is:

$Moneywasted_{refractory} = 31{,}367*9.59/1{,}000{,}000 = 0.30$ $0.30 is being wasted every hour through radiation due to poor refractory.

CONCLUSIONS

The total hourly waste due to the ring condition is therefore:

$Moneywasted_{hourly} = 54.58 + 4.93 + 0.30 = 59.81$ $59.81 is being wasted every hour due to the condition of the bustle ring.

For a 12 hour a day, 5 day a week operation, this becomes an annual cost of:

$Moneywasted_{annually} = 12*5*52*59.81 = 186{,}600.00$ $186,600.00 is being wasted every **year** due to the condition of the bustle ring.

Bottom line:

$186,600 in heat cost is being wasted every year due to the condition of the bustle ring.

Furthermore, the poor material condition of the bustle ring skin strongly suggests that more holes will develop and that patching them is almost useless. Since the heat loss of the holes is 90% of the total, one more hole will amount to an increase of 45% or **$84,000.**

The only real solution to this problem is to replace the ring.

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Please call me if you have any questions.

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