

## **Reviving A 25 Year Old Fluid Bed Sewage Sludge Incinerator**

Louis T. Barry  
Chavond-Barry Engineering Corp.  
400 Route 518, Blawenburg, NJ 08504  
Milton Grundlock  
Gloucester County Utilities Authority

### **ABSTRACT**

In the early 1970's, The Gloucester County Utilities Authority installed a fluidized bed incinerator to burn sewage sludge produced at its sewage treatment facility. At the time of installation, fuel oil prices were below 20¢ per gallon. Capital cost was high, so the installation was designed without heat recovery. Wet sludge was pumped into the fluidized sand bed along with sufficient air and oil to complete the incineration process.

By the mid 1980's sludge production had increased, and the cold windbox model was struggling to keep up. Preheating of the combustion air was used to improve operation and production rate. Unfortunately, the flat metal plate used for the cold fluidizing air distribution system was limited to a preheated air temperature of 700°F. A shell and tube air preheater using the hot flue gas from the incineration process to heat the combustion air was installed. To avoid fouling, the dirty gas passed downwardly through the tubes while the clean air was passed over the outside of the same tubes.

In 1998, even greater capacity was needed from this old incinerator. Replacing the metal air distribution plate with a refractory dome or a high alloy metal plate was impractical since the windbox was too short and uninsulated. An air distribution system used for decades in the oil industry was the solution. The petroleum industry uses a set of parallel perforated pipes to introduce reactant gas into the fluid bed catalytic crackers. Adapting this technology to the cold windbox unit was quite successful. The 8'-6" diameter bed section was widened to 9'-0" to allow room for 8 parallel air pipes. Each pipe was perforated along two lines, 22½" from the bottom center line. The pipes were placed at an elevation such that their air discharge was approximately equal to bubble elevation from the original tuyeres. Preheated air is forced down each pipe-tuyere from a common manifold supported from the incinerator shell.

The original metal tuyeres were cut from the plate and the resulting holes welded closed. A layer of insulating castable was applied to the top of the metal plate to protect it from the high temperature of the bed. Several openings were provided to allow air to freely circulate through the abandoned windbox below the metal plate. To increase the preheater air temperature, a taller heat exchanger was installed on the center line of the previous preheater. Minor duct work changes reconnected the flue gas to the venturi scrubber.

After more than four years of operation, there are no signs of wear of the new pipe-tuyeres. The predicted capacity increase and fuel reduction were both achieved. As a means of demonstrating

the improvement, we evaluated the performance based on the sludge from the present dewatering equipment (23% dry solids).

<u>Windbox Temp.</u>	<u>Sludge, Dry Tons/Day</u>	<u>Oil, Gal/DT</u>
120°F	13.9	81
700	17.6	43
1200	21.1	14

With the cold and warm windbox limitations, much of the available fluidizing air was needed to burn oil just to maintain the minimum bed temperature. By preheating to a higher temperature, that air is now available for burning sludge dry solids.

The paper presents detailed photographs of the installation and results of performance evaluations.

## **KEYWORDS**

Sewage Sludge, Biosolids, Fluidized Bed Incinerator, Pipe-Tuyere Retrofit

## **INTRODUCTION**

This 1970's vintage Dorr-Oliver cold wind box fluid bed sewage sludge incinerator was retrofitted in the 1980's to a 700°F "warm" windbox by the addition of a heat exchanger. This upgraded the installation to the now traditional design wherein the hot flue gas leaving the freeboard passes downward through the tubes and the fluidizing air is preheated by passing through the shell side. This change did provide considerable fuel savings. In fact, it cut the fuel by 50%, in addition to the improved throughput. However, the Authority began burning outside sludge on a toll basis. This resulted in the dewatering becoming less dependably high so the average sludge processed fell far short of the target. Once again, with wet sludge too much of the air is needed to burn oil for heat diminishing the air available for sludge combustion.

The first solution, from a capital investment standpoint, would be to increase the sludge solids concentration. The Authority had just completed the installation of the second FBI which included new belt filter presses. While the solids were a little higher, they still could not dependably meet the needed dryness to reach the desired 17.2 dry tons/day (DT/D). Faced with replacing the entire incinerator, the decision was made to evaluate means to reduce the need for auxiliary fuel by higher combustion air preheat temperature.

Retrofitting a cold windbox design to a refractory dome hot windbox design poses some major problems.

1. The windbox is small and cannot be insulated for 1200°F.
2. The metal plate cannot withstand the preheated air temperature. It was designed for cold air and stretched to the limit operating at a maximum of 700°F.

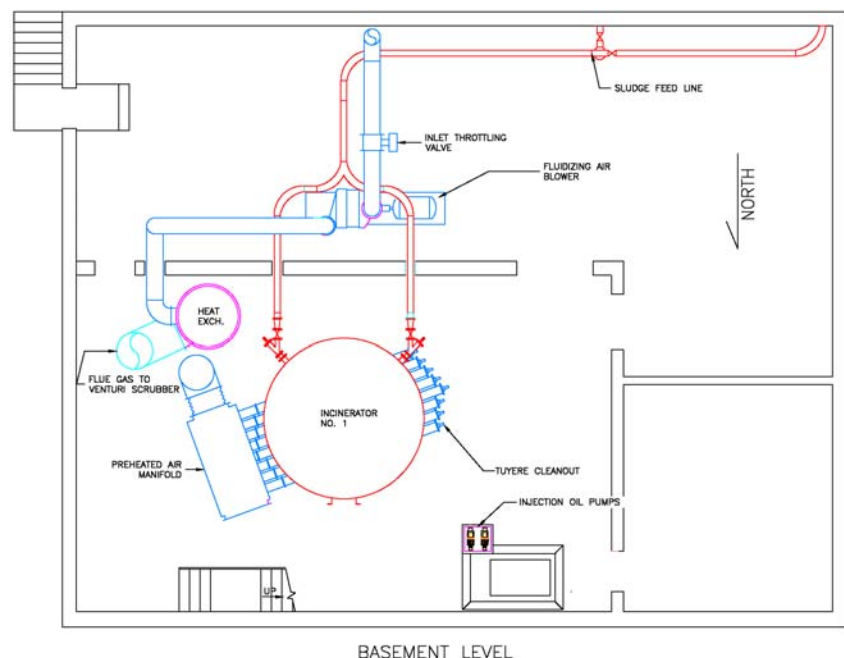
3. The shell was a straight wall design, making it difficult to install a refractory dome traditionally used for hot windboxes. Furthermore, the dome would take up valuable volume needed for the windbox.

The solution was staring us right in the face. The Authority's second fluid bed incinerator was designed with a unique pipe-tuyere air distribution system commonly used for catalytic cracking in the oil refining industry. However, the task of retrofitting an old incinerator with this technology was the question. The elements to be considered in designing a hot pipe-tuyere grid include:

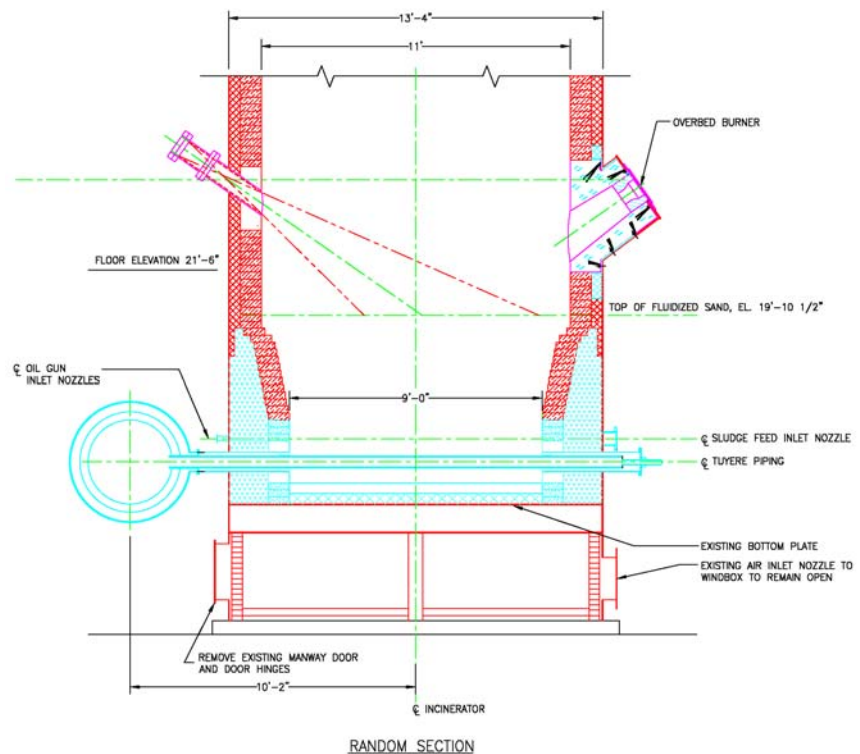
1. Pipe diameter and wall thickness
2. Number of pipes and their spacing
3. Hole diameter and number per pipe. Jet penetration was considered to be sure we did not make a "sand grinder" from the incinerator.
4. Material of construction
5. Thermal expansion
6. Keeping the sand from flowing back into the pipes. It is inevitable so there must be a means to get the sand out.
7. How to protect the metal air distribution plate needed for bed support.
8. How to handle the problem of a parallel distribution system in a round vessel and have equal air distribution.

## DISCUSSION

The final layout of the facility allowed for the larger heat exchanger to sit on the vertical center line of the old one. The fluidizing air enters the shell side of the heat exchanger at the bottom and exits near the top. The air then passes down a refractory lined duct into the basement level manifold where it is distributed to each individual pipe-tuyere. Two sludge feed pipes bring sludge from a neighboring dewatering building and inject it into the incinerator sand bed just above the pipe-tuyeres.



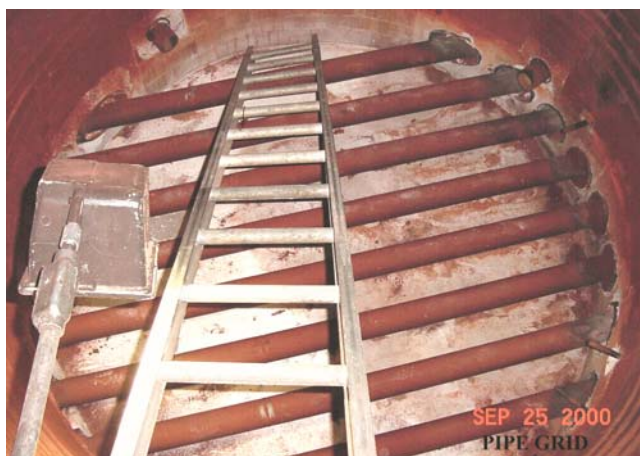
The Random Section drawing illustrates the incinerator modifications. Starting at the bottom, the existing bottom plate was retained to support the bed at rest. The two openings into the windbox were left without covers to allow air circulation. The internal insulation on the windbox walls was removed to allow heat to dissipate from the windbox into the room. After removing the original tuyeres and closing the resulting holes, a layer of insulation and hard castable refractory was applied on top of the plate. This limits the quantity of heat that reaches the windbox and, thereby, into the room. There is actually very little heat passing through the insulated support plate. The windbox operates cool enough that there is no noticeable heat into the room.



To allow a little more capacity, the bed diameter was increased from 8'-6" to 9'-0". A large diameter sight glass was added to better observe bed fluidization. The over bed burner was replaced with one of larger capacity to serve a dual purpose. Naturally, this is the heat up burner used to achieve operating temperature from a cold shutdown. However, this burner also serves to assist in maintaining a minimum 1500°F freeboard temperature as required by the state operating permit. If the freeboard gas temperature approaches this limit, the freeboard burner instantly fires to maintain the minimum required temperature.

Although not shown on this section, the installation is equipped with over bed air. Naturally, this air input is not as efficient as using adequate preheated air, but is used to maintain the

permitted minimum oxygen level on an emergency basis. The oxygen control system adds over bed air once the measured oxygen approaches the 3% permit low limit.



The thermal expansion concern is handled by allowing the pipe tuyeres to freely expand away from the manifold into a nozzle on the opposite side of the incinerator. In the pipe-tuyere photo above, the manifold is on the left and the pipe-tuyeres are free to expand to



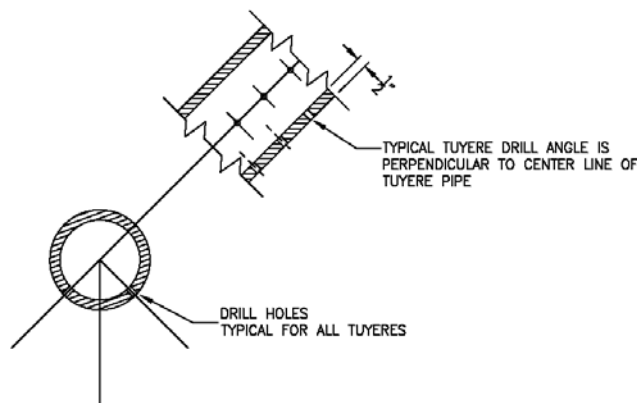
the right through the refractory wall and into the shell nozzles. This photograph was taken at the first cold shutdown in September, 2000 after nine months of operation. Subsequent inspections have shown no surface wear.

The concern that the pipe-tuyeres would wear away was unfounded. The photograph to the left shows the pipe-tuyeres retain the original sand casting surface roughness and the holes are still sharp edged as seen in the mirror. There are two rows of holes, although only one can be seen in the mirror.

The condition of the hard castable refractory can also be seen in this photograph. In determining the relative elevation between

the hot air jetting from the tuyere holes and the refractory protecting the bed support plate, we used the relationship developed by Zenz<sup>1</sup> to estimate the distance the jet would penetrate the sand layer. Zenz' relationship was accurate as evidenced by the lack of damage to the refractory. As a result of these calculations we were able to maintain the same bubble elevation and, therefore, lose no bed volume. For the maximum fluidizing air flow, the selected distance between the bubble line and the protective refractory is 7".

The sketch to the left shows the cross section of the pipe-tuyere. For this diameter bed the pipe-tuyeres were 5" OD with a 1/2" wall thickness. The two rows of holes are rotated 22 1/2° from the bottom of the pipe. This provides a path long enough to prevent the sand from filtering backward through the holes by allowing for the natural angle of repose of the sand.

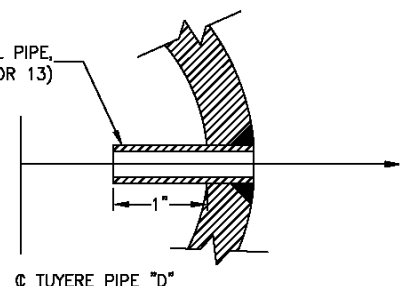


TUYERE HOLE DETAIL, (TYP.)

pass from the sides of the two out board pipe-tuyeres. See the illustration to the right for details. Care is needed here to assure that the jet blowing at the wall from the side of these tuyeres does not hit and erode the wall refractory. Once again, Zenz' relationship proved accurate enough

Placing parallel pipes into a round vessel clearly leaves two crescent shaped areas where there is less than ideal air flow. In these areas, we added nozzles allowing air to

1/8" SCHEDULE 40,  
310 STAINLESS STEEL PIPE,  
(TYP. FOR 13)



END TUYERE NOZZLE DETAIL, (TYP.)



to protect the wall.

When the fluidizing air blower is turned off suddenly or drops out during a power failure, the uneven settling sand/air mixture causes air and sand back flow in some tuyeres. When the air is resumed some of the sand is expelled through the holes, but some is jammed at the far end of the pipe. Each pipe-tuyere is fitted with a discharge pipe and valve to remove this deposit. A simple packing gland is used to allow the tuyere to expand and not leak air from the vessel. Since the gas is hot and laden with sand, the discharge system includes a water quench to cool and capture the dust.

## RESULTS

The initial firing of the modified incinerator went unexpectedly well. Following a slow careful dry out and heat up using the over bed burner, the sludge was finally turned on. After about 30 minutes of double checking every reading, we looked to see the feed rate. We were at capacity!

Not all was perfect. As part of the upgrade, the fixed metal throat venturi scrubber was replaced with a “plumb bob” design variable throat venturi. The high velocity through the old venturi continuously eroded the bottom cross over section causing shutdowns and excess maintenance costs. The replacement was specifically installed to eliminate this problem. However, the replacement eroded through just above the throat inlet area. After several repairs and no advice from the manufacturer, it was surmised that the sharp turn into the venturi throat caused the particulate to bombard one side of the inlet. Ironically, the old venturi, using the same inlet duct did not experience this problem.

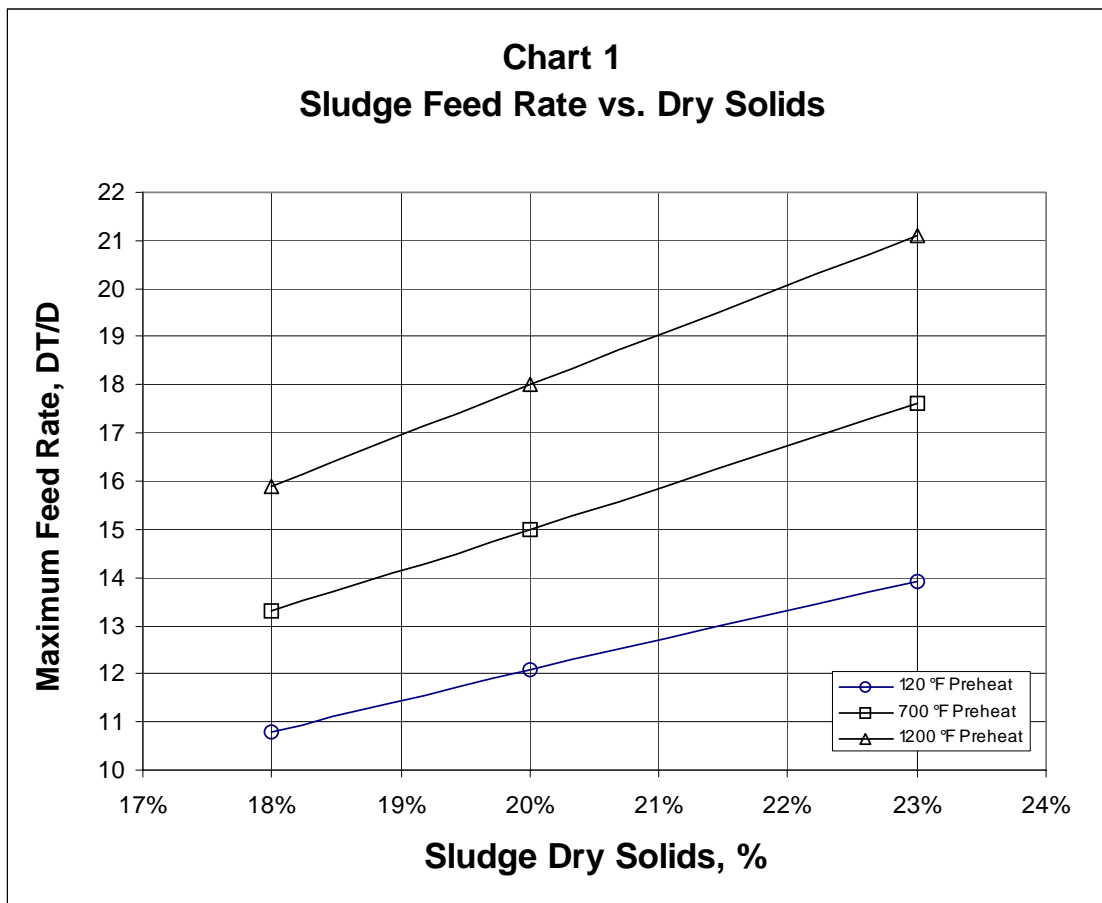
A long radius, refractory lined duct was installed to direct the flow of particulate laden gas straight into the venturi. This eliminated the problem. The lesson learned is that stream lines into a venturi are a critical design consideration.

The reasons for the up grade was to increase feed rate and decrease the fuel required per ton of dry solids fed. Chart 1, below presents the data showing the effect of preheat temperature on throughput at various sludge solids levels. The data cover the range of 18% to 23%, typical of the sludge concentrations that are handled at the Authority. The feed can be increased by 50% by preheating the air to 1200°F, regardless of feed solids content. Note that the freeboard temperature must be a minimum of 1500°F to meet the state permit requirement. To provide a margin of safety for operations, the is maintained at 1550°F. The higher temperature is used in both of the following charts.

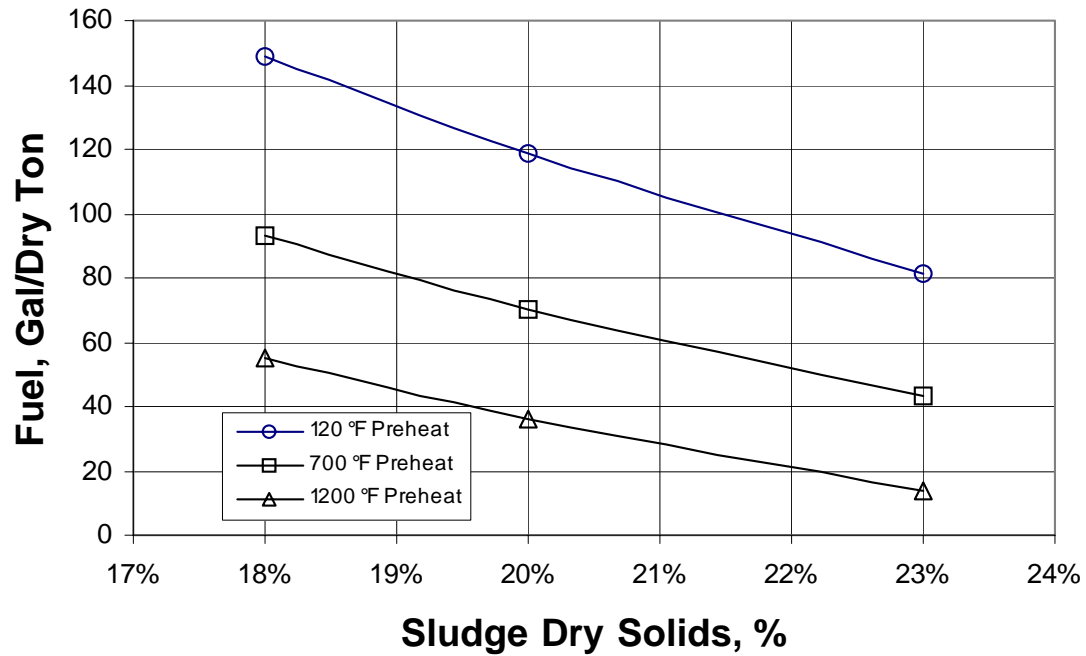


Chart 2, below, shows the effect on specific fuel requirement. As the sludge solids content is increased, the fuel savings decreases. When feeding 18% solids, the fuel can be reduced by two thirds if the combustion air is preheated to 1200°F. As the sludge gets drier we approach autogenous operation and the calculated fuel savings are greatly increased. At 23% dry solids, the fuel needed with a 1200°F preheat is about 15% of that needed with the cold windbox.

How is it running after four years? The short answer is, Great! Internal examination shows no sign of deterioration of the tuyere pipes or rounding of the tuyere holes. fluidization is unchanged and the capacity, ease of start-up and fuel efficiency remain as designed.



**Chart 2**  
**Fuel/Dry Ton vs. Dry Solids**



## REFERENCES

<sup>1</sup>Zenz, Frederick A. *Fluidization and Fluid-Particle Systems (Vol. II Draft -1989)*, PEMM-CORP Publications, Garrison, NY