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RETROFIT INJECTION OF HUMID GAS FROM SLUDGE DRYER AND SECONDARY AIR IN WTE FURNACES OF QUÉBEC CITY

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ABSTRACT

This paper discusses the retrofit injection of humid gas from sludge dryer with secondary air in the WTE furnaces in Québec City. In 1992, a municipal sludge treatment plant was added in the WTE building. Three sludge dryers, each connected to a furnace, were added. Direct contact with hot furnace gas was used to dry sludge in a rotary drum. Humid gas from the dryer was returned to the rear wall of the furnace just above the finishing grate. CFD modeling showed cold flow of humid gas on the rear furnace wall, restriction of the combustion area on the principal grate, and stratification of the flow inside the boiler. A retrofit of the first chamber of the boiler was designed using injection of humid gas from the sludge dryer with secondary air on the front and rear walls. The main purpose of the retrofit was to maintain CO levels of under 57 mg/m^3 on a 4 hour mobile average. The first boiler was retrofitted in winter 2008 and results have been very encouraging.

1. INTRODUCTION

The Québec City waste-to-energy plant serves a population of 540,000. In addition to receiving residential waste, it also processes waste from the institutional, commercial, and industrial sectors. Built in 1974, it is made up of four furnaces with three grate sections designed by the supplier Von Roll. Each furnace has a capacity of 10 metric tons per hour. In 1992, three municipal sludge dryers designed by Swiss Combi were connected to three of the four furnaces. The hot gases from the furnaces are diverted as they emerge from the first pass just before the boiler and used for direct contact sludge drying in a rotational drum dryer. The wet or humid gas is returned to the combustion chamber and the dried sludge granules are returned separately by pneumatic conveying. The evaporating capacity of each dryer is 3,500 kg of water per hour and the weight capacity is 1.15 metric tons per hour of sludge in dry base. In 2008, 290,000 metric tons of waste and 19,600 metric tons of sludge in dry base were treated.

The furnaces have seen various upgrades over the years. Nonetheless, the injection of secondary air into the combustion chamber is one aspect that has changed little over time. During the review of the process, the proportion of secondary air to total air was only 12%, while best practices recommend a proportion in the range of 33%. The orientation of the airflow nozzles and level of airflow penetration were also problematic. The concept of injecting wet gases from the dryer and locating the furnace entry in the back above the third grate section has also been called into question.

2. CONCERNS

During the operational review of the WTE facility's furnaces in early 2005, it was noted that the furnaces were not delivering complete combustion. Bad homogeneity was being provided by the secondary air injectors. Computational fluid dynamic (CFD) gas flow simulations have demonstrated gas flow to be extremely stratified over the secondary air injectors. This bad homogeneity was caused by poor distribution due to the proportion of combustion and secondary air below the grates, as well as to poor distribution of air between secondary air injectors of the front and back walls. CFD simulations also showed that, despite better distribution and better air mixing, the temperature at the top of the combustion chamber remained relatively low. Furthermore, analysis of gas residence time over the secondary air injectors showed that gases had a transit time of less than one second before entering the boiler.

The injection of wet gases on return from the sludge dryer took place in the zone behind the furnace above the finishing grate, with typical flow varying between 18,000 and 20,000 m^3/hr. A flow measured at 6,600 m^3/hr within that typical flow originated from an infiltration of air at the rotational drum dryer entry and exit points. Wet gases were 110°C, had an oxygen content of 14%, and contained 33% humidity. This approach created a cold zone in which CO consumption was greatly reduced. A cold mainstream gas flow developed along the back wall of the furnace, tending to carry unburned gases. In waste and sludge co-incineration mode, the hourly CO concentration in flue gases regularly and continually exceeded 200 mg/m^3. Given the heterogeneity of wastes and variable humidity due to temperature and seasons, it is therefore advisable to install a primary combustion air heater to better regulate combustion during the most difficult periods.

A particular problem regarding the characteristics of wet gases also needs to be taken into consideration. Wet gases in the sludge dryer contain CO levels of 400 mg/m^3 and a particulate concentration of 3,000 mg/m^3. CO concentrations are high due to combustion initiated as the gas exits the rotational drum dryer. Particulate concentration is high due to the primitive design of the cyclone that collects particles as they leave the drum dryer. This technology is acknowledged to be of limited effectiveness.

The difficulties involved in drying sludge by direct contact with hot furnace gases raise the question of how to maintain drying. A review was conducted of the possibility of injecting sludge into the furnace after the sludge is mechanically dehydrated to a 30% solid content level.

Currently, sludge (30% solid content) represents 29% of the weight of the waste incinerated in the furnaces of lines 2, 3 and 4. This is a very high ratio and should be compared to the conventional ratio for direct sludge injection, which is 10% (where sludge is 20% solid content).

Direct injection of sludge into four furnaces would make it possible to reduce the ratio to 22% by weight, and, taking into account the high level of dehydrated solid content (30%), would enable a 15% load by weight. Therefore, approximately 18,000 metric tons humid per year would remain to be treated by drying, which would represent at least one active dryer. Considering that sludge quantity is always increasing, this solution is not feasible.

3. DESIGN

Several analyses and various fluid dynamic scenarios have shown that wet gas injection from the back of the furnace is the defective element, preventing complete combustion of unburned gas. The Von Roll furnace in waste-incineration-only mode actually provides relatively efficient combustion, despite inadequate secondary air injection. With good quality waste, the CO concentration varies between 50 and 100 mg/m^3. When sludge and waste co-incineration is brought online, furnace efficiency is affected.

The location of the sludge injection point at the forward furnace arch just below the secondary air injection nozzles was effective. Observations and computer modeling indicate that the sludge burns in suspension in the combustion area over the principal grate at a rate of 1.1 metric tons per hour. No trace of unburned contents was found in the combustion residue.

Two options have been studied for moving the wet gas injection point by replacing some of the combustion air with wet gases at either the primary or secondary air level.

The option for injecting humid gases by substituting some of the primary air was quickly rejected. Complicating factors involved in this approach included high water content, acid gases, and strong odors.

Injecting wet gases by substituting some of the combustion air with secondary air was examined more closely. A variant on this possibility, that of using a retractable nozzle to inject wet gases into the stoker, was considered. This variant was abandoned due to a lack of space around the furnaces. Installation costs for three of the four furnaces would also be very high.

The concept was fine-tuned by adding a feeder on the front and back of the furnace to receive wet gases and secondary air. After gases pass through these feeders, they would be injected into the furnace through sixteen nozzles 125 mm (5") in diameter and divided evenly between the front and back, eight nozzles on each side. On the wet gas circuit, a fluid pressure amplifier would be required to ensure the penetration of these gases in the furnace, as well as a slice valve to cut off the circuit when the dryer is stopped and the furnace is operating in waste-incineration-only mode.

In waste-incineration-only mode, the concept is simple. The slice valve shuts off the wet gas circuit and secondary air passes only through the feeders before entering the furnace via the injection nozzles.

In sludge/waste co-incineration mode, the priority is the wet gas circuit from the dryer. The amount of secondary air introduced would be in addition to the amount of wet gases. The goal is to obtain dispersion of the total wet gas flow in the front and back nozzles identical to the secondary air flow in those nozzles. To do this, the front and rear wet gas flaps should be positioned using a dispersal regulator.

4. RESULTS AND DISCUSSION

Construction on a first line was completed in winter 2008. Adjustments and performance testing were conducted in May 2008. The main difficulties encountered were (a) buildup of deposits on the rear furnace arch near the secondary air nozzles (b) measurement of wet gas flow, (c) condensation in the wet gas conduit under certain conditions, and (d) control during the unsteady states of dryer shutdown and startup.

The accumulation of deposits on the rear arch of the combustion chamber is now less of an issue. A disruption in the air distribution between the front and rear surfaces was undoubtedly the cause. Air starvation on the rear surface may have caused a vertical eddy that drew materials onto the rear arch. Maintaining sufficient uninterrupted gas velocity in the rear arch nozzles ensures acceptable clearance of the rear arch.

Measuring wet gas flow was problematic. Dust plugged the openings and built up in front of the “Annubar” type flowmeter. Air purges at 2 minute intervals maintained correct operation.

Condensation occurred in the wet gas conduit under certain circumstances. The conditions that caused this are still not understood. Condensation appeared at the base of the slice valve and in the rear feeder as well as in the underlying nozzles, specifically at the low points of the wet gas network. Dust stuck to the condensation and nozzles tended to clog. Because this restricted flow through the nozzles of the rear branch, an unintended disequilibrium in the dispersal of wet gases between the front and rear branches was created. This did not occur in the front branch because the low point of this circuit was located at the nozzle end, and the nozzles sloped toward the furnace interior. We should mention that the conduits are made of stainless steel and insulated. Investigations are taking place to resolve this situation.

The steps and adjustments during unsteady state startup and shutdown are being reviewed. Essentially, the instability of pressure in the wet gas conduit causes an oscillatory behavior in the drying process. The equipment startup and power increase procedures must be standardized to avoid pressure variations. On the other hand, when the dryer is stopped, equipment cooldown is too slow in automatic mode due to the excessive circulation of gases. A dryer bypass circuit exists for cooling but is less effective than previously, due to the priority given to wet gases. A solution is being developed to improve the operation of unsteady state sequences.

5. CONCLUSION

Improving secondary air injection and returning wet gases from the rotary dryer to the furnace can make it possible to ensure stable and effective operation of the furnace in waste/sludge co-incineration mode while meeting applicable regulations. This C$17.6 million upgrade makes it possible to continue operating these furnaces for a minimum target period of 15 years. This targeted approach puts off major replacement costs and makes it possible to maintain waste treatment costs below C$70 per metric ton.

In addition, resolution of the acute problem of integrating a municipal sludge dryer functioning through direct hot gas contact into a waste incinerator furnace confirms the feasibility of an approach that had been neglected over the last decade. Several strict safety control measures must however be respected in order to ensure that these two processes can function together successfully.

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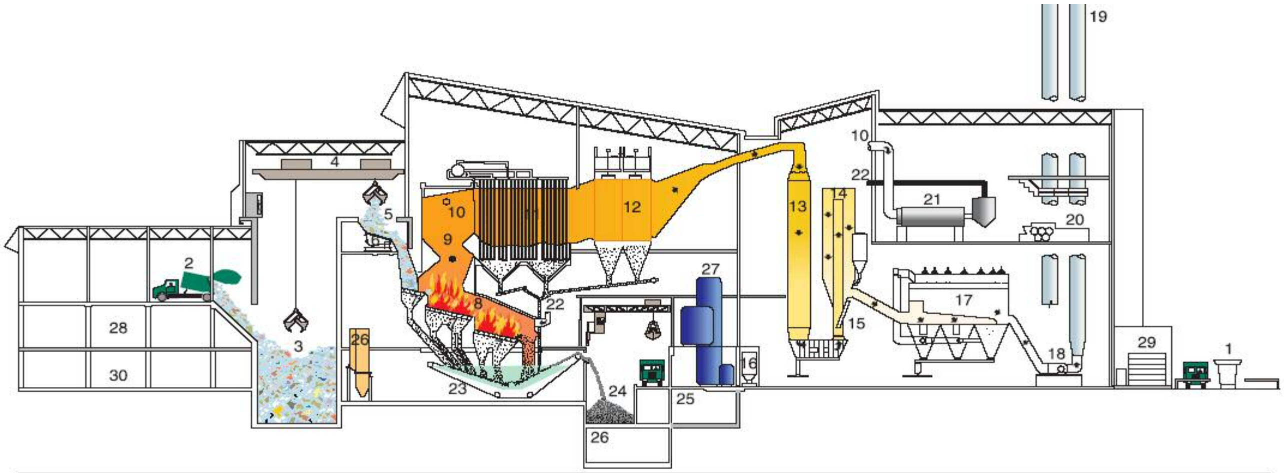
ANNEX A

QUÉBEC CITY WTE



1. Poste de pesée
2. Quai de déchargement
3. Fosse à déchets
4. Pont-roulant
5. Trémie d'alimentation
6. Table vibrante
7. Grilles d'incinération
8. Chambre de combustion
9. Injection des boues séchées
10. Prélèvement des gaz chauds
11. Chaudière
12. Électrofiltres
13. Tour de refroidissement
14. Réacteur
15. Injection de chaux
16. Dosage du charbon activé
17. Dépoussiéreur à manches
18. Ventilateur de tirage
19. Cheminée
20. Filtre à bandes
21. Séchoir
22. Retour des gaz humides (buées)
23. Extraction des mâchefers
24. Fosse à mâchefers
25. Réservoir d'eau de procédé
26. Traitement des effluents
27. Traitement de l'eau des chaudières
28. Atelier et magasin
29. Expédition des boues
30. Garage en location pour la ville de Québec

ANNEX B

INJECTION OF SECONDARY AIR AND HUMID GAS FROM SLUDGE DRYER