

LESSONS LEARNED: MODIFICATION TO OPG'S RADIOACTIVE WASTE INCINERATOR

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Abstract

The radioactive waste incinerator which processes low level waste at the Ontario Power Generation Western Waste Management Facility has been in operation since the year 2002. The purpose of the incinerator is to safely process both solid and liquid low level waste generated by station activities. The majority of waste incinerated consists of paper, wood, plastic, rubber, cotton, and hydraulic oil.

The incinerator has undergone a recent modification in the year 2015. This modification was in response to an overheating event in the underfire air duct which resulted in suspension of solid waste incineration. Underfire air duct plugging is a common challenge to many incinerators worldwide. Underfire air duct plugging leads to a reduction in combustion efficiency, additional maintenance burdens, and processing downtime. Thermal damage due to overheating can also occur if flammable material flows through the underfire air duct and burns.

The modification was completed safely and successfully by OPG in conjunction with industry partners. The modification has resulted in the return to solid waste incineration as well as improved sustainable performance. The incinerator has now evolved from a controlled air design consisting of both underfire and overfire air to a controlled air design consisting of only overfire air.

The paper will address lessons learned during the modification. The paper will also explore key differences between the operation of the original incinerator design and the new design.

1. Introduction

Ontario Power Generation (OPG) operates a controlled air, fixed hearth incinerator at the Western Waste Management Facility (WWMF) in Tiverton, Ontario. This is a relatively small scale incinerator designed for a normal processing rate of 5000 pounds (2268kg) of solid waste per day and 9 litres per hour of liquid waste. The incinerator safely processes low level radioactive waste generated from maintenance activities. This waste includes, but is not limited to mops, pails, cloths, paper, filters, and protective clothing. The waste management facility provides a prominent support function for the nuclear generating stations, as approximately 90% of waste generated at nuclear stations is low-level waste. [1]

The main methods at the WWMF to manage low level waste include direct storage, compaction, and incineration. There is a waste acceptance criteria outlined in an OPG procedure that the low level waste must meet to qualify for incineration. This criterion is based on safety, environmental considerations, effect on equipment, and feasibility. Figure 1 shows the processing methods for common waste types. Of the three methods, incineration is capable of the highest volume reduction ratio. Since waste and ash require safe storage, a high volume reduction ratio is beneficial in minimizing the waste footprint. Ensuring that the incinerator is reliable, safe, and efficient helps to ensure that this process plays a key role in environmental conservation.

Low Level Waste Segregation Guide		
INCINERABLE Maximum Dose Rate: 60 mrem/h contact	COMPACTABLE Maximum Dose Rate: 200 mrem/h contact < 100 MPCa	NON-PROCESSIBLE Maximum Dose Rate: 1 rem/h at 30 cm
- Paper, Paper Towel, Cardboard - Wood (< 2' x 2' x 2') - Cotton Gloves - Tyvek Coveralls, Booties, and Hoods - Browns (buttons and zippers are acceptable) - Cloths / Clothes - Plastic Pails / Bottles (spray bottle springs are acceptable) - Plastic Mop Buckets / Mop Heads - Floor Buffing Pads - Plastic (e.g. bags, tarps, booties, blue matting, pink FME material, plastic wrapping, shrink wrap) - Mitchell Tritium Cartridges - Smears / Filter Paper - Hard Hats - Rope / Nylon Slings (metal removed) - Scintillation in plastic vials packaged in plastic pails All bags must be limited to 11.5 kg (25lbs). Metal components must be smaller than a nickel. 	- Empty Plastic Drums - Metal Mop Buckets and Presses - Metal Filings and Lathe Turnings - Safety Shoes - Air/Rubber Hoses - Rubber Area Floor Matting - Rubber and Latex Gloves - Rubber (e.g. gaskets) - Plastic Suits (Mark III / IV) - Vicraft Hood - Electric Cable (< 1/4" dia.) - Plastic Conduit - Insulation - Fire Blankets and Fire Retardant Material - Ventilation Filters - Metal pail handles / Wire / Metal Banding - Light Gauge Metals (e.g. sheet metal, copper, "mini pie plates") - Glass All bags must be limited to 11.5 kg (25lbs). 	- Concrete and Cement Blocks - Soil - Heavy Gauge Metal (e.g., beams, IX vessels, angle iron, plate metal, etc.) - Metal Components (e.g., pipe, scaffolding pipes, metal planks, motor flanges, valves, etc.) - Tools / Nuts and Bolts - Wire Cables and Slings - Electrical Cables (> 1/4" dia.) - Hazardous Waste (e.g. Light Bulbs / Ballasts, Batteries, Chemicals) - Drummed Waste (e.g. Welding Rods) - Solidified Liquids - Desiccant - Floor Sweepings, Dust Bane, Stay Dry, etc. - Comfo Respirator Filters with metal components - Large Vessels  ONTARIO POWER GENERATION Refer to WWMF-CWMF-0015

Figure 1: Waste segregation guide

This paper highlights a recent modification to improve the OPG incinerator's reliability, safety, and efficiency at managing incinerable waste. In the year 2014, there was an underfire air tube overheating event. Immediate action was taken to place the incinerator in a safe state and to suspend solid waste incineration. A significant modification was completed in the year 2015 to enable the safe return to solid waste incineration. Furthermore, the modification improved reliability of the incinerator as well as its volume reduction ratio.

2. OPG incinerator pre-modification configuration

The OPG incinerator is an Anderson 2000 model, installed in the year 2002. It consists of a primary chamber with overfire air ports and underfire air ports, and a primary chamber propane burner. Two secondary chambers are located above the primary chamber. There is a secondary chamber propane burner on one of the secondary chambers. A spray cooler, a baghouse with slaked lime and activated carbon injection, and an exhaust stack are downstream of the chambers. Figure 2 and Figure 3 show a simplified diagram of the OPG incinerator.

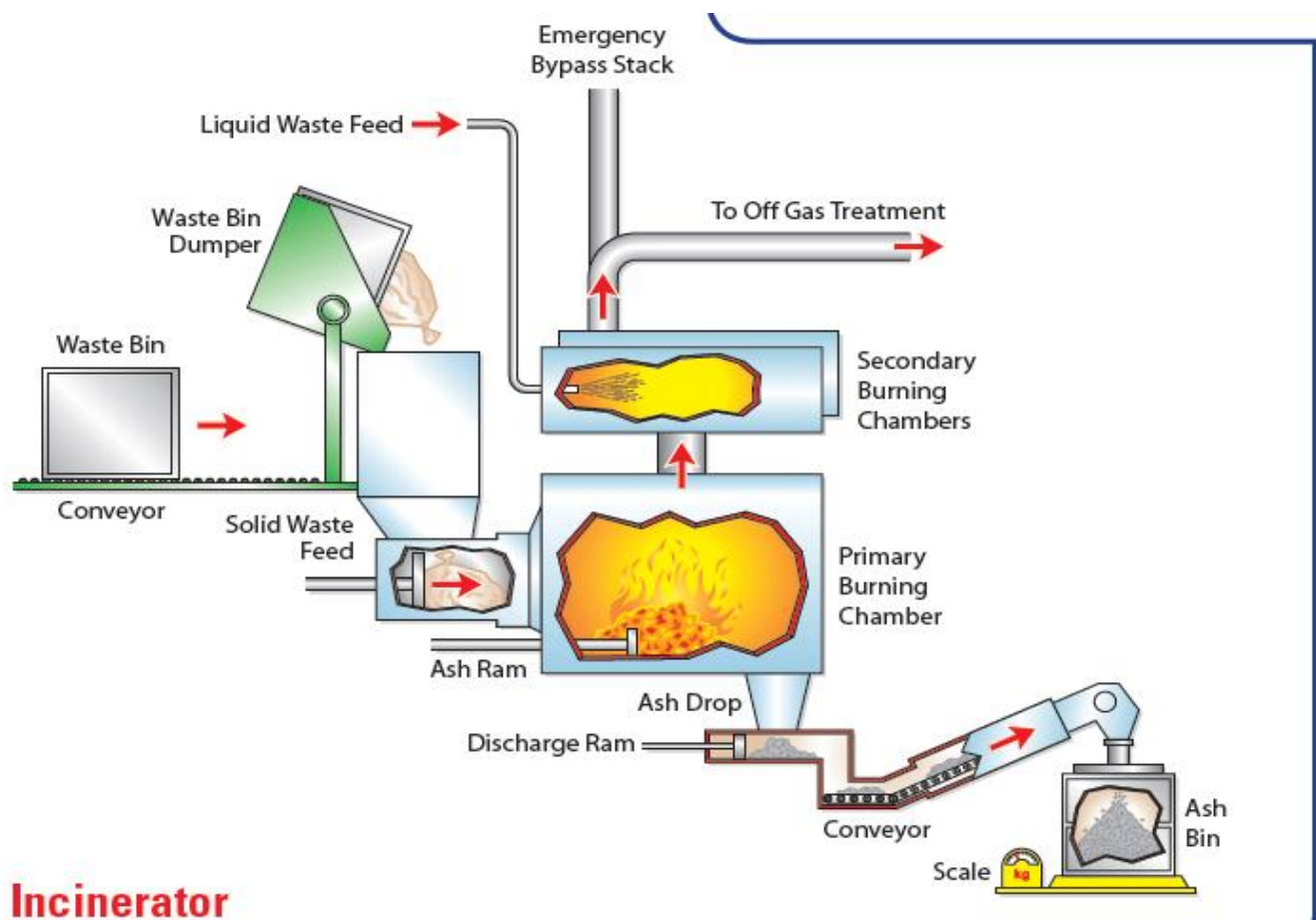


Figure 2: Incinerator process

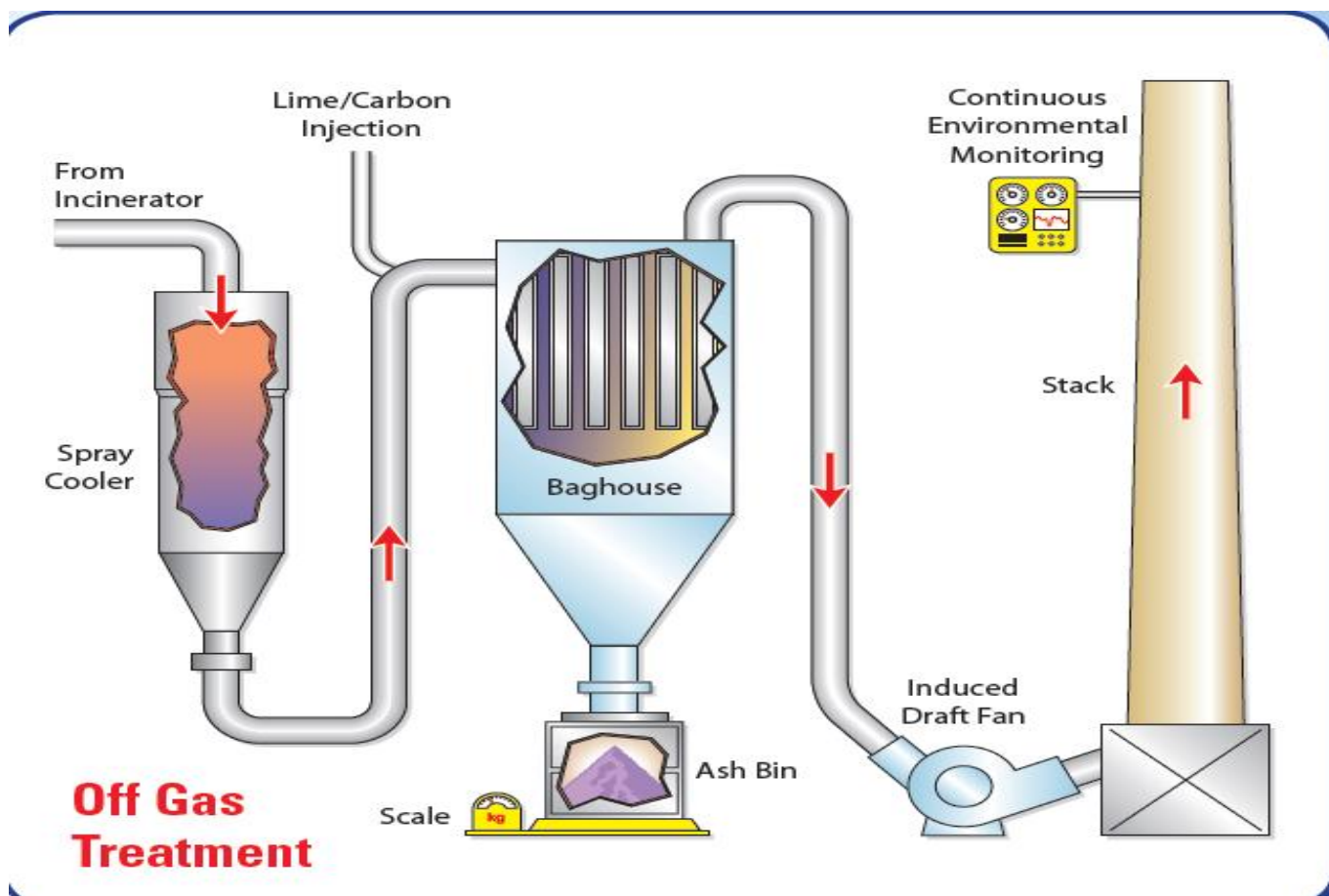


Figure 3: Incinerator process (2)

Solid waste is sorted, bagged, and fed into the primary chamber at a feed rate of 5-15kg batches every 6-10 minutes. The primary chamber is set to operate in the range of 800°C to 1220°C. Underfire air is supplied to the bottom of the waste bed and overfire air is supplied to the top of the waste bed to promote combustion in the primary chamber. The waste is converted to flue gas and ash from the combustion process. Bottom ash is pushed out of the primary chamber and collected in ash bins. These ash bins are stored in low level storage buildings on the waste management site. Flue gas from combustion travels to the secondary chamber. The secondary chamber is set in the range of 1000°C to 1220°C.

The flue gas is cooled by the spray cooler and travels through the baghouse where lime and carbon react with the flue gas to control emissions. The baghouse filters fly ash from the flue gas. This fly ash is transferred into ash bins which are stored in the low level storage buildings. Flue gas is monitored by the Continuous Emissions Monitoring system before it exits through the exhaust stack.

In addition to solid waste, the incinerator incinerates liquid waste. Liquid waste is filtered and injected into the secondary chamber.

3. Underfire air overheating

In February 2014, a localized overheating event occurred in the underfire air duct which caused this duct to sustain thermal damage. A greasy viscous substance was found inside the air duct and was identified as oxidized petroleum hydrocarbon. The root cause of the overheating event was an inadequate underfire air design, resulting in leakage and build-up of incinerable material into the duct.

The four underfire air tubes sat on the floor of the primary chamber. They were constructed of Inconel and were perforated to allow air to jet out and create turbulence for combustion. Solid waste was fed directly on top of the underfire air tubes. Theoretically, any trace liquid from the waste would quickly convert to vapour in the primary chamber. However, the underfire air tubes were performing sub-optimally and were not supplying enough air to the waste. This caused a lack of turbulence and temperature gradients in localized areas of the primary chamber, which allowed liquids to retain their state instead of vaporizing. Trace liquids travelled; gravity-fed, through the perforations in the underfire air tubes and down into the air duct below where ignition by a hot particle occurred.

The issue of underfire air plugging is one of the most frequent problem areas common to this type of incinerator [2]. By design, the underfire air tubes are in contact with the ash bed; hence, the tubes are susceptible to plugging, even with vigilant maintenance programs in place. Plugged underfire air tubes prevents the waste from getting the optimal proportion of air for combustion. The underfire air tubes are also prone to damage and are a high maintenance item. Damaged tubes could create pathways for unburned combustibles to travel through.

4. Modification

A modification was executed in the year 2015 to remedy the overheating issue. Figure 4 is a photograph circa 2002, of the underfire air tubes located on the refractory floor inside the primary chamber. Figure 5 shows the primary chamber after the modification. As per the modification, the underfire air tubes were removed and the refractory floor was converted into a solid hearth.



Figure 4: pre-modification: underfire air tubes **Figure 5: post-modification: solid hearth**

Figure 6 shows the overheating damage to the underfire air header duct external to the primary chamber. Per the modification, as shown in Figure 7, the air pipes leading from the header duct to the primary chamber floor were capped so that the air header duct no longer supplies air to the location where the underfire air tubes used to be, but still supplies air to the overfire air tubes.



Figure 6: Damage to underfire air duct

Figure 7 post-mod: underfire air tubes capped

The header duct transports air from the blower to several locations in the primary chamber to aid in combustion. These locations were the underfire air tubes (pre-modification) situated at the primary chamber floor and overfire air ports on two sides of the incinerator. Figure 8 is a sketch of the excess air configuration, highlighting the portion of the air duct which was damaged by overheating.

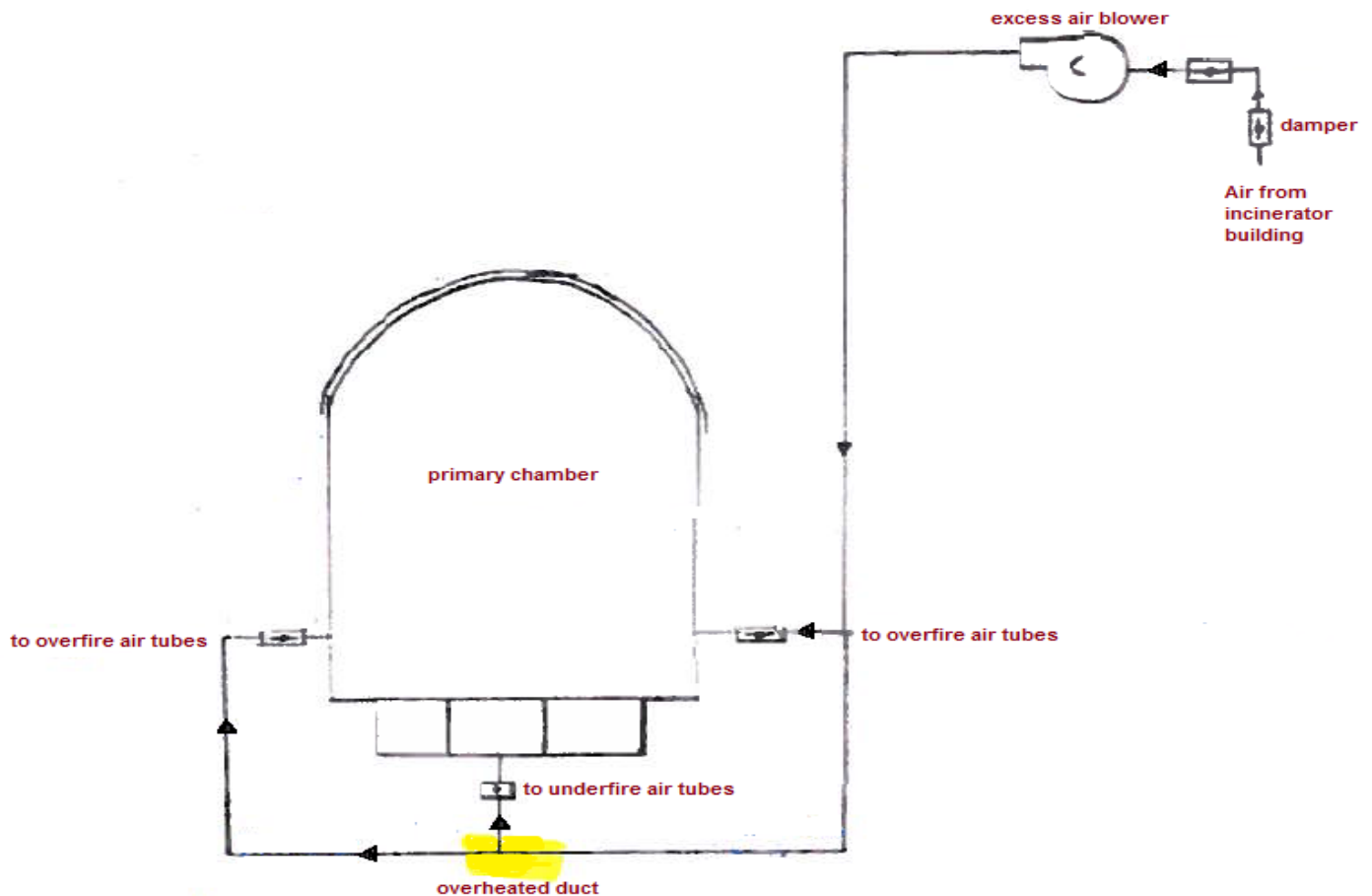


Figure 8: Sketch of the pre-modification excess air configuration

The overfire air plenum was redesigned to ensure sufficient air distribution in the absence of underfire air tubes. Prior to the modification, there were numerous overfire air ports along the primary chamber walls. The overfire air from the main air duct was distributed evenly between all overfire air ports. The overfire air ducts were prone to plugging due to their small diameters; however, the plugging was not as severe as the underfire air tube plugging. Following the modification, the plenum was designed with fewer overfire air ports; however, each port had a larger diameter. The new overfire air ports were individually calibrated to allow a predetermined amount of air into the chamber. The amount of air was a decreasing gradient with the ports near the waste entry point having the highest air flow rate. The new overfire air plenum contributed to improved combustion due to improved air-fuel ratio capability.

One of the functions of the underfire air is to provide turbulence in the ash bed to encourage burning. In the absence of underfire air tubes, the single primary burner was replaced with two smaller burners. The two burners were placed strategically on either side of the waste bed in order to create the turbulence and the even temperature distribution required for good combustion. Figure 9 and Figure 10 show a comparison of the primary chamber before and after the modification.



Figure 9: primary chamber 2002 being transported to site

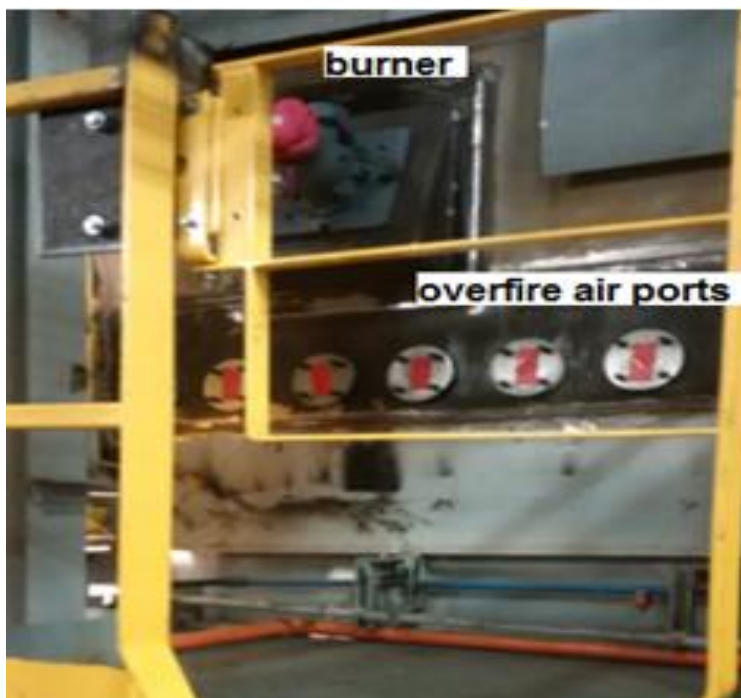


Figure 10: primary chamber 2015 modification

5. Performance improvements

5.1 Mitigation of overheating events

Overheating events have occurred in the same underfire air tubes twice before the modification. The first instance occurred in July 2013. A more extensive occurrence occurred in February 2014. The modification removed the underfire air tubes; rendering it impossible to have a repeat overheating event in that location. There have been no similar overheating events anywhere else in the incinerator system since the modification.

5.2 Regulatory compliance

The incinerator continues to meet regulatory and environmental standards. The incinerator continues to undergo routine annual emissions tests per the Ministry of the Environment. The incinerator passed the annual test following the modification and complied with all regulatory criteria.

5.3 Operability and maintainability

The modification has not introduced any unmanageable operator or maintenance burdens. The modification removed the need for underfire air tube maintenance, which was an extensive item in the past. The removal of the underfire air tubes will also increase reliability of the incinerator.

The new overfire air ports are larger in diameter and are less prone to plugging. There is a longstanding preventative maintenance program in place for cleaning the overfire air ports on a set frequency. The new overfire air ports are found to be in good condition in each maintenance occurrence and do not have significant plugging. The port conditions will continue to be trended and consideration may be given to reduce the frequency of the preventative maintenance on these new ports.

Routine thermal imaging inspections and visual inspections of the chamber's internal refractory walls show no significant degradation of the chamber refractory caused by the new burner design.

5.4 Ash quality

The ash continues to be white-grey in colour; indicating that low percentages of carbon remain in the ash. Black ash is undesirable, and indicates that high percentages of carbon remain in the ash. Limited amounts of carbon in the ash indicates that available fuel has been consumed and complete combustion has taken place. [3] The bottom ash produced following the modification was finer than the bottom ash produced prior to the modification. Fine ash is an indicator of good combustion. The presence of clinkers and large unburned materials was significantly reduced following the modification. This shows improved incinerator performance. To quantify this improvement, an approximate volume reduction ratio of the incinerator was calculated using the following equation:

$$\frac{\text{solid waste fed [kg]} * \text{Density of solid waste } \left[\frac{\text{m}^3}{\text{kg}}\right]}{(\text{fly ash [m}^3\text{]} + \text{bottom ash [m}^3\text{]})}$$

Prior to the modification, the volume reduction ratio of the incinerator was 22:1 for solid waste fed to the system; which represents a 95% reduction of the solid waste.

Following the modification, the volume reduction ratio for the incinerator was 38:1 for solid waste fed to the system; which represents a 97% reduction of the solid waste.

This improvement in volume reduction ratio leads to both long-term and short-term benefits for reducing waste footprint. These benefits include a reduction of storage bins used and fewer storage buildings constructed. This in turn reduces caretaking and building maintenance activities as there will be fewer storage buildings.

6. Key Lessons Learned

The most significant lesson learned was the importance of a balanced air fuel ratio. Balanced air distribution in the primary chamber of the OPG incinerator led to:

- improved ash quality
- improved volume reduction ratio
- more even combustion throughout the ash bed

Another significant lesson learned was that although controlled air, fixed hearth incinerators are generally operated with both underfire and overfire air, it is possible to modify the incinerator to use solely overfire air and achieve good results.

7. Conclusion

Improved reliability of the OPG incinerator is important for not only the industry's current needs, but also its future needs. The nuclear industry is very dynamic; and there are several significant projects in motion for the upcoming years. In addition to routine maintenance activities in various stations, there will be a refurbishment at the OPG Darlington generating station and decommissioning activities at the OPG Pickering generating station. The amount of low level waste received at the OPG WWMF is expected to increase in the next ten years to accommodate the refurbishment and decommissioning activities. Reliable and efficient operation of the OPG incinerator ensures that the facility is poised to safely accept and manage the future influx of waste.

8. References

- [1] World Nuclear Association, “What are nuclear wastes and how are they managed?” Online. <http://www.world-nuclear.org/nuclear-basics/what-are-nuclear-wastes.aspx> 2016.
- [2] W.R. Niessen, “Combustion and Incineration Processes: Applications in Environmental Engineering” Fourth Edition, CRC Press, 2010, pp. 369.
- [3] R. Neulicht, M. Turner, D. Wallace, S. Smith, “Operation and Maintenance of Hospital Medical Waste Incinerators”, Diane Publishing Company, 1990, pp45.