Improved combustion and emissions for MSW Burn-Management Unit applicable to remote communities in Alaska

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Tok Welding and Fabrication
Report Prepared by Zender Environmental Health and Research Group

Summary

The Phase 1 project objective was to investigate whether insulation of the conventional burn unit manufactured by Tok Welding could increase burn temperatures and thus improve combustion efficiency and emissions. A longitudinal comparative study was performed with two burn units operated simultaneously during a 6 week period in Summer 2008.

Figure 1 Conventional uninsulated unit, "Burn Unit 1" on the left and insulated unit "Burn Unit 2" on the right.

Phase 1 was a success in that it identified for the first time burn unit temperatures generated *in situ* with an Alaska Village wastestream, as well as the minimum level of peak temperature achievable. As expected based on the limited number of open burning studies conducted for "backyard burn barrels", temperatures were highly variable between trials for the same unit. Temperature profiles also differed between the two units during the trials. Opacity of the two smoke streams was likewise variable between trials and differed markedly from each other during trials. Opacity was measured (Method 9) for one trial during an evaluation visit by the EPA Alaska Office Air Quality Scientist. Opacity was markedly better for the insulated unit for the bulk of the burn.

Maximum stack temperature achieved (1664 F), was significantly higher than expected, although it ranged over 750F in the same unit between trials. Maximum temperatures were achieved more quickly and dropped more quickly than expected as well. Stack temperatures in the insulated unit took slightly longer to achieve maximum temperature and maintained a high temperature for a longer time than the non-insulated unit.

Another difference between pilot and field trials was waste type and water content. With one exception, pilot trials were conducted with cardboard only, presenting a significantly different BTU/lb and water content.

Methodology

A longitudinal comparative study was performed on burn unit temperature profiles during Summer 2008. The conventional uninsulated unit, "Burn Unit 1" is the unit already produced by Tok Welding and being used by approximately ten rural Alaska Native Villages statewide as of Summer 2008. The insulated unit, "Burn Unit 2", was a unit of identical proportions that was fitted with a composite steel wall of sandwiched high-temperature insulation product. See Figure 1. The insulation extended around the top two-thirds of the chamber, and the bottom one-third of the stack. Two additional passive appropriate technology design features were developed and included in Unit 2. Essentially, a 4" shelf "expansion chamber" was created for particles to settle onto after impingement or settlement. Holes were cut in the middle third of the stack to divert a portion of the air stream into a 22" wide tube around the main 18" stack. Also, to add additional turbulence in the stack, two beveled and angled 'agitator' structures 4' long and 4" wide were hung up within the stack.

To compare the burn performance, high temperature probes were welded into the stacks of both units, with the probe tips extending horizontally to approximately six inches in, equal to ½ of the stack diameter, and the probes connecting to a data logger that recorded temperatures every 10 seconds. Data was sent via satellite transceiver during the first two weeks of the project. At that point, it was determined by the field team that logistics allowed manual downloading of the data-logger to avert potential theft of the satellite equipment from an unsecured, public place. To document gross differences in smoke opacity, digital pictures of the smoke emissions were taken every 5 minutes, for one hour. A temperature laser gun (Extech Instruments High-Temperature IR Thermometer, Model# 42545) was used every 5 minutes during the first hour of the burn on seven different locations of the units to provide a backup temperature comparison, and to determine if waste loading or type would provide differential waste temperatures within the chamber and stack from run to run.

Both pilot and field testing in a Village setting were performed with the conventional unit and a prototype insulated unit operated in tandem for a period of six weeks. Pilot trials used a weighed amount of cardboard for five trials, and a weighed amount of field-collected trash for one trial. Field trials consisted of weekly burns with the full wastestream of Dot Lake Village (pop 56) that was typically loaded into their prior burn unit, and thus represented a typical village waste load into a burn unit. A video which shows an overview of the equipment setup *in situ* at the Dot Lake Village landfill may be viewed at http://video.google.com/videoplay?docid=-2110339647816936142 and a video which shows waste ash in burn units, post-burn, is at http://video.google.com/videoplay?docid=-5915774344590335709.

Results

Temperature profiles, ambient weather, and waste loading for each trial are presented in the full report. Table 1 provides descriptive statistics over the course of the project. The gross variability in the trials resulted in the decision to not perform further statistical analyses regarding the existence and value of significant differences in temperatures. Phase II of this project will provide more detailed information regarding emissions and will allow for a larger number of pilot runs with controlled, identical wastestreams. Visual observations documented by photography indicated better opacity from the insulated unit overall. Some periods of time during some trials showed higher opacity for the insulated unit compared with the uninsulated unit. However, this result may be due more to the variability in waste load between the units than the unit design. The duration of the Project did not allow for evaluation of the impact of the expansion chamber or agitator baffles on the temperature profiles. Both features displayed marked impingement and settlement of particulate matter at project end.

Discussion

Interestingly, the insulated unit exhibited a lower maximum temperature for at least 4 of 6 of the pilot trials (an equipment malfunction resulted in non-capture of the insulated unit temperature for one pilot trial). However, the insulated unit had the higher peak during 4 of the 6 field trials where temperature data was collected. The duration of the project, number of parameters involved in ultimate temperatures, and field limitations, allowed neither for an evaluation as to the underlying causes nor of the role of individual parameters. However, one thought was that the insulated unit would perform better with a fuller waste load. Indeed, during the one trial where the burn units were loaded to the higher percent capacity, the greatest degree of peak temperature difference occurred between the two units of the trials where the insulated unit achieved the highest temperature.

Lighting one of the Burn Units

Insufficient data is available with identical waste loading (capacity and type) to make a determination as to whether insulation provides a reliably higher peak temperature. With higher waste loading of mixed wastes, indications are that peak temperature is either similar or higher than an un-insulated unit. Higher waste loading would mean that Villages would need to burn less often, offering advantages in burn time flexibility and smoke exposure duration. The cooler outside wall temperatures of the insulated units offer an additional advantage in safety from accidental burn injury.

The variability in hottest points of the unit during and between trials demonstrates that waste loading has an impact on ultimate combustion efficiency. A similar finding has been demonstrated with burn barrels. Waste loading parameters must be evaluated to optimize a design.

Total burn duration, at high, medium, and low temperatures, is longer with the insulation unit. Smoke opacity was evaluated overall to be significantly better with the insulation unit. It is not clear whether net positive, nor significant, benefit was achieved with the passive agitator or expansion chamber features. Evaluation of these features is clearly needed as well in future trials.

Conclusions

From Phase 1, it is clear that insulation has a marked positive magnitude effect on the temperature profile. Due to insufficient data, we could not determine with finality whether insulation has a marked effect on peak temperature. However, the two highest peak temperatures (based on 10 second interval logging) were achieved by the insulated unit. And indications were that higher waste loading may improve insulated unit performance more than uninsulated unit performance, resulting in a more consistent high peak temperature range. An insulation design is thus a promising, low-cost, low-maintenance parameter to further develop so as to identify an optimum design for emissions. A cleaner burn is accomplished with hotter temperatures, longer time-in-transit, and higher turbulence, and the insulated unit appears to offer these at a low additional cost in production.

Our insulated design resulted in a peak temperature during a field trial with an unsorted weekly village wastestream of over 1,664.06F – which approaches that of incinerator technology. This temperature is significantly higher than previously thought attainable for simple burn unit design, and based on basic combustion principles, offers the potential for cleaner emissions than other burn options feasible for small and isolated rural Alaska villages.

Also identified in Phase 1 as a promising development opportunity are the “local behavior” operating parameters of waste load and type. Phase 1 demonstrated that these parameters have a marked effect on both temperature profile and peak temperature, and their determination and use of their optimum values – i.e. the optimum operation – can contribute significantly in achieving higher temperatures consistently and for longer duration periods.

To develop the technology for commercialization in a manner that provides the highest degree of environmental health benefits to the target audience, there is a need to continue the R & D so as to refine design based on parameter evaluations. Phase II will allow an adequate duration of testing, as well as direct testing of particulate emissions, thus enabling us to make conclusions regarding best design.

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Table 1. Comparison between insulated and uninsulated burn unit temperature profiles

Fuel Type:	**Cardboard (weighed identical)**				**MSW (approx. similar load)**			
Burnbox:	#1 (Non-insulated)		#2 (Insulated)		#1 (Non-insulated)		#2 (Insulated)	
Number of datasets:	5		4		8		8	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Peak Temperature (F)	1521.25	65.38	1457.62	90.46	1176.12	275.94	1151.37	318.87
Initial phase duration (min to peak temp)	5.90	0.89	6.50	1.73	8.12	2.50	10.58	5.96
Mid-Range Duration, Heating (min between 390F and 850 F)	1.33	0.41	1.88	0.85	2.45	0.96	4.08	3.20
Mid-Range Duration, Cooldown (min between 850F and 390 F)	13.47	3.84	25.88	8.07	18.86	7.05	25.67	8.11
High Temp Range Duration (min over 850F)	7.00	0.71	8.00	1.83	10.64	8.46	14.00	17.92