spray research, inc.

SUMMARY REPORT

Report Title

Recent Experiences In Carryover Performance Evaluations
Of Full-scale Mist Eliminator Systems

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Introduction

Spray Research, Inc. has recently performed evaluations of the carryover performance of full-scale mist eliminators fitted to the wet scrubbers at three powerplants. The three sites represent three mist eliminator designs from two manufacturers and three wet scrubber designs. Confidentiality considerations require that detailed systems design parameters not be disclosed in this Report.

At two of the sites, dropsize analyses on the carryover were performed with a Dantec laser fiber-optic phased doppler particle analyzer (PDPA) [Dantec Measurement Technology, 777 Corporate Drive, Mahwah, NJ 07430]. A Greenfield Instruments Model 700A video imaging particle analyzer (VIPA) [Greenfield Instruments, 50 Greenfield Street, Greenfield, MA 01302] was used at a third site. Both instruments were fitted into specially designed probe housings.

Testing was performed between 5.5 and 8.0 meters downstream of the mist eliminators. Access into the horizontal duct sections was by way of top-mounted flanged and lined ports.

The objective of these studies was to collect droplet size distribution data with the PDPA and VIPA instruments of the droplet carryover in the gas stream. This data would then be used to calculate the liquid loadings of the gas streams (mg/Nm3).

Spray research, inc. serves the broad spectrum of industries and agencies which use or are otherwise concerned with spray atomizers by providing sophisticated spray and atomizer laboratory analysis and contract design, development, re-engineering and consultant services. It is the first independent testing laboratory specializing in spray atomizers and spray research. By careful design of the laboratory facility and equipment, sophisticated testing capability with simulants and non-water-based solutions is safe and routine. Although the laboratory is structured to meet the stringent Good Laboratory Practices standards of the Environmental Protection Agency, these particular studies were not performed as GLP studies.

Methods

Test Substances

Scrubbed flue gas exiting from the wet scrubbers was used as the test substance at all three sites. The gas streams contained both liquid and solid particulates. Surfaces exposed to the gas streams became coated with deposits that varied with site, sampling location and time of day from almost clear to milky grey to brownish-grey. Solid particulate content also appeared to vary considerably.

The range of *nominal* gas conditions encountered were:

- Pressure: -3.7 mm to +18.7 mm Hg
- Temperature: 44 - 52°C
- Condition: Saturated
- Velocity: 2.1 - 6.7 meters/sec
- Water loading: <50 - 200 mg/Nm^3

Test System

Testing was performed between 5.5 and 8.0 meters downstream of the final mist eliminator stages. Access into the horizontal duct sections was by way of top-mounted flanged and lined ports. The gas streams were sampled at between three and five equally-spaced insertion depths.

The PDPA and VIPA probe housings were attached to a segmented probe extension fitted with an integral flanged adapter/packing gland and stop rings. The probe extension provides 2.75 m. of insertion depth adjustment as well as houses the probes' signal and control wiring and purge air delivery line. The probe extension features an alignment key to maintain positive alignment of the probe sampling windows with the gas flow. Changes in insertion depth were accomplished manually by pre-setting the stop ring and then lowering the probe extension after loosening the packing gland.

The tests were conducted in industrial powerplant settings without humidity or temperature control external to the duct.

The mist eliminators and bulk entrainment separators (where fitted) were thoroughly cleaned and damaged elements replaced immediately prior to the testing. The normal mist eliminator (*M*E) and bulk entrainment separator (*BES*) (where fitted) wash cycles were active throughout the testing.

Summary Results

Carryover Loading

Loadings at individual sampling locations across the three sites ranged from a minimum of 980 mg/Nm^3 to a maximum of 3290 mg/Nm^3.

There is a moderate correlation of increasing loading with increasing insertion depth. There is some indication of a reversal of this correlation for samples taken close to the ducts' sidewalls. This may be indicative of turbulence effects.

The velocity data shows a trend of decreasing velocity with decreasing distance to the sidewalls. This trend is particularly evident at the shallow insertion depths, with the velocity profiles flattening out as the insertion depths increase.

The raw summary carryover statistics (mg/Nm$^{3)}$ for the three sites tested are as follows:

Site	Mean	S-StD
1	2132	1052
2	1920	814
3	1245	323

Table 1: Summary statistics for loading (mg/Nm$^{3)}$

Contribution of large (> 40 µm) droplets to carryover loading

In laboratory ME tests performed with the PDPA and VIPA instruments, the maximum particle diameters encountered have generally been under 30 µm. This compares to the range of maximum particle diameters of 80 µm to 157 µm observed in the full-scale tests.

When the mean liquid loadings (mg/Nm^3) are calculated based on the volume of particles under 30 µm and 40 µm for each of the three sites, the resultant values reflect loadings that are within the range of the laboratory data. Clearly, the high loadings seen in the full-scale data sets are the result of particles greater than 40 µm in diameter.

Site	Mean	S-StD
1	75	9
2	37	15
3	34	11
Lab	39	6

Table 2: Summary statistics for loading (mg/Nm^{3}) based on particles <30 µm

Site	Mean	S-StD
1	149	14
2	40	24
3	36	13
Lab	39	6

Table 3: Summary statistics for loading (mg/Nm^{3}) based on particles <40 µm

There are several mechanisms that can reasonably be supposed to be the source of these large (>40 µm) particles:

1. Re-entrainment off the trailing edges of the final ME stage elements,
2. solid particulates, and
3. condensation of the expansion-cooled gas mediated by seed particles (either liquid or solid).

Of these three mechanisms, other data suggests that re-entrainment off the last stage ME elements is the largest contributor of these large droplets.

Velocity

As stated previously, the velocity data shows a trend of decreasing velocity with decreasing distance to the sidewalls. This trend is particularly evident at the shallow insertion depths, with the velocity profiles flattening out as the insertion depths increase.

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There is also a moderate inverse correlation between depth and velocity. The velocities recorded at the shallow insertions was significantly higher than those at mid- and bottom-level insertion depths. The velocities recorded at the lower insertions were statistically equal. These velocity profiles are congruent with the flow fields to be expected at the sample distances downstream of the right-angle inlet configurations.

Particle Diameters

Across the three sites, there appears to be no significant correlation between insertion depth and the reported particle size means (D32 and DV0.5). These reported particle size means were also statistically equivalent across the three sites.

Unexpectedly, there is a moderately strong correlation between large maximum particle diameter and the shallow insertion depths. This correlation also holds for the DV0.9 diameter, indicating that the reported large Dmax at the shallow insertion depths are not simply artifacts of the test system. This data, combined with the measured velocity profiles, suggests that these large particles are the result of re-entrainment off the last ME stage elements.

Contribution of ME/BES Wash Cycles to Carryover Loading

Time series data on [data rate] as a function of ME and BES (where fitted) wash cycle state was taken at all three sites.

This limited set of data shows a strong correlation between [data rate] and the [ON] wash state. Across the three sites, [data rate] increased an average of 45% during the [ON] wash cycle states.

Site	Average Increase ([ON] State)
1	52%
2	44%
3	38%
All Sites	45%

figure 4: Average increase in [data rate] during [ON] wash state

At the two sites evaluated with the PDPA, data gathered during the time-series tests seem to indicate a correlation between the [ON] wash state and the counting of the larger diameter particles. Unlike laser PDPA instruments, the VIPA cannot at this time resolve time-series data such as particle diameter/arrival time or velocity/diameter/arrival time information. The accuracy of this observed correlation could not be tested at the site evaluated with the VIPA.

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Interestingly, the data may suggest an inverse relationship between [data rate] and alignment of the active wash header to the sample port. That is, higher [data rates] were generally recorded as the transverse offsets between the active wash headers and sampling ports were increased.

It is doubtful that the increased [data rate] recorded during the [ON] wash cycle states is due primarily to the wash water droplets passing directly through the ME's. It is more likely that the higher [data rate] arises from increased re-entrainment off the trailing edges of the final ME stage elements due to the higher ME loading experienced during the wash cycles. Another contributing mechanism could be that increased cooling of the saturated flue gas during the [ON] spray state promotes the condensation of the water vapor onto seed particles (liquid or solid).

Conclusions

Mean carryover loading across the three sites ranged from 1245 to 2132 mg/Nm^3 .

Droplets under the 30 µm maximum diameters generally encountered during laboratory ME testing accounted for less than 7% of the measured full-scale carryover. The relatively large carryover loadings seen in the full-scale studies are the result of modest counts of particles between 40 and 160 µm in diameter.

The large particles counted during the study are not artifact data.

The observed velocity profiles are congruent with the expected flow fields for the sampling locations, duct configurations and nominal inlet gas velocities. There is a steep velocity gradient at the shallower insertion depths. A more modest gradient is in evidence as the ducts' sidewalls are approached.

Particle diameter means (D32 and DV0.5) are relatively stable across the sampling locations, insertion depths and sites. The largest maximum and DV0.9 particle diameters occur at the shallow insertion depths.

The ME/BES wash cycles significantly affect [data rate], although their effect on overall loading could not be definitively ascertained due to limitations of the VIPA instrument used at one of the sites. The PDPA data and qualitative observations, however, suggest a significant effect.

The carryover loading, velocity, particle mean diameter and time-series data all support the interpretation that the majority of large droplets are produced by accumulation/re-entrainment of liquid off the trailing edges of the final ME stage elements.