Wet Scrubber Technology for Controlling Biomass Gasification Emissions

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ABSTRACT

A lumber facility had installed a small gasifier (< 1 MW) to gasify wood chips which are a byproduct of sawmill operations. The syngas produced by the gasifier is combusted in a dual fuel internal combustion engine (ICE) to produce electricity. Waste energy from the ICE in the form of hot water is used for drying lumber in a drying kiln at the site. An electrostatic precipitator (ESP) was used to clean the syngas produced by the gasifer. Operating problems developed with the ESP which caused the system to be taken out of service.

Modifications were made to the syngas cleaning system to replace the ESP with a Venturi scrubber. The Venturi operates downstream of a packed bed absorber which uses sub-cooling to condense water vapor. Sub-cooling grows the particulate to a larger size so they can be collected at higher efficiency in the Venturi scrubber. The Venturi removal efficiency for particulate matter larger than 1 micron in diameter is equal to or greater than the ESP. It is less efficient than the ESP for particles smaller than 1 micron in diameter; however, the engine can tolerate material of this size. The results of the modifications show that a Venturi scrubber system can be used to effectively control air emission from biomass gasifiers.

INTRODUCTION

A project was undertaken to convert woodchips from an East coast sawmill operation into syngas. The syngas would be used to generate approximately 320 kilowatts of electricity using a dual fuel internal combustion engine (ICE). In addition, approximately 1,800 MBH of heat created in generating the power would be used to heat the sawmill. The technology produces very little waste and can be sized to meet the electrical and heating needs for sawmills and similar types of businesses.

The gasifier system was commissioned in 2005. The original design used an electrostatic precipitator (ESP) to clean the syngas before combustion in the ICE. Problems developed with the ESP which caused the system to be taken out of service after operating for 53 hours. It was decided a better way was needed to clean the syngas from the gasification process. The cost to improve the ESP operation was prohibitive so an alternative pollution control technology was sought. Modifications were made to replace the ESP with a Venturi scrubber system.

SYNGAS CLEANING SYSTEM DESIGN

The system modifications replaced the ESP with a Venturi scrubber operating at 50 in. WC. The Venturi scrubber is placed downstream of an existing packed tower scrubber. A new induced draft fan is used to overcome the Venturi scrubber pressure drop. Placing the Venturi downstream of the packed tower scrubber provided the following advantages:

1. Water is condensed on the particulate in the packed tower scrubber. This grows the submicron particulate to a larger size so that they will be collected at higher efficiency in the Venturi scrubber.

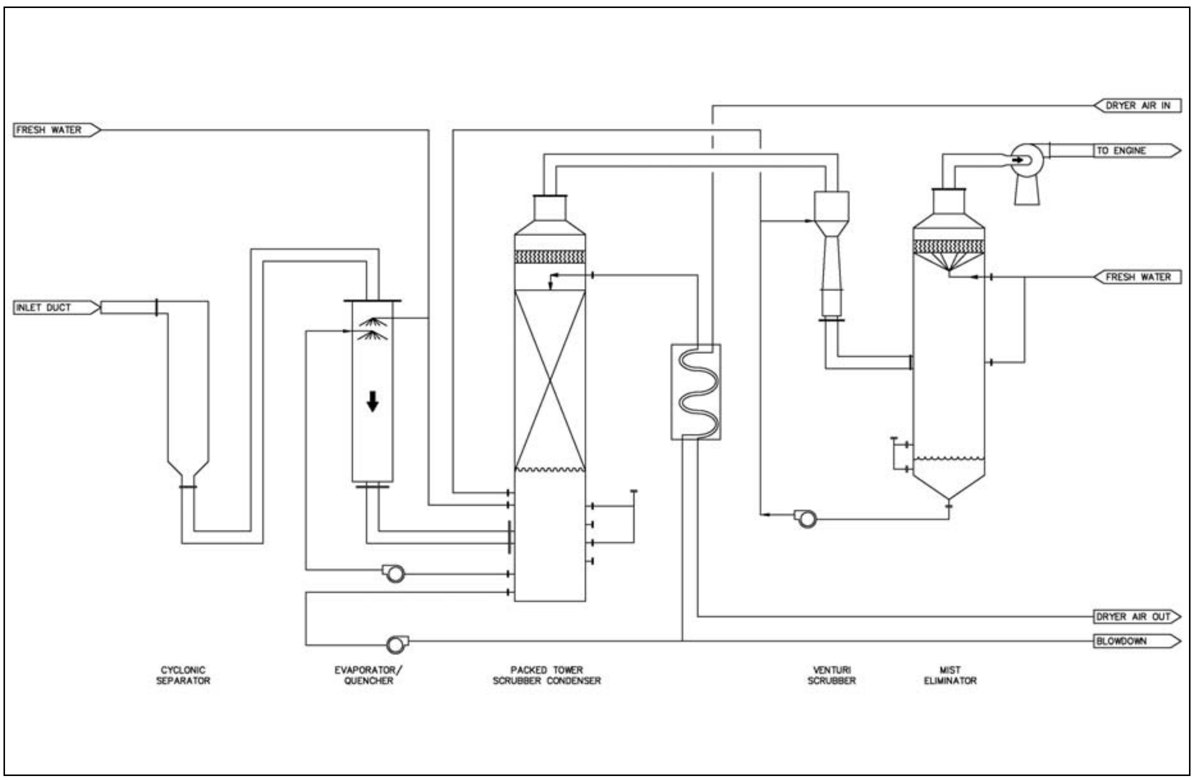
2. The gas volume is reduced by approximately 40% which means the fan horsepower is reduced accordingly.

3. Compression of the gas in the fan adds approximately 20^{O}F of reheat. This amount of reheat means that the syngas line from the fan outlet to the engine only needs to be insulated and not heat traced to avoid water condensation.

4. The Venturi scrubber does not use high voltage eliminating safety interlock requirement.

A Process Flow Diagram (PFD) for the modified syngas cleaning system using a Venturi scrubber is shown in Figure 1. The gas enters the syngas cleaning system at approximately 600 Nm3/hr (353 scfm) @ 15% moisture and temperature of 649 ^{o}C (1,200 ^{o}F). The inlet load is about 3,000 mg/nM^{3} (1.31 gr/dscf) of particulates and 1,000 mg/nM^{3} (0.437 gr/dscf) of tars.

Figure 1: Modified syngas cleaning system process flow diagram



The hot syngas from the gasifier first passes through a cyclonic separator for removal of particulate greater than 10 microns. The syngas then passes through an evaporative quencher to cool the gas to saturation.

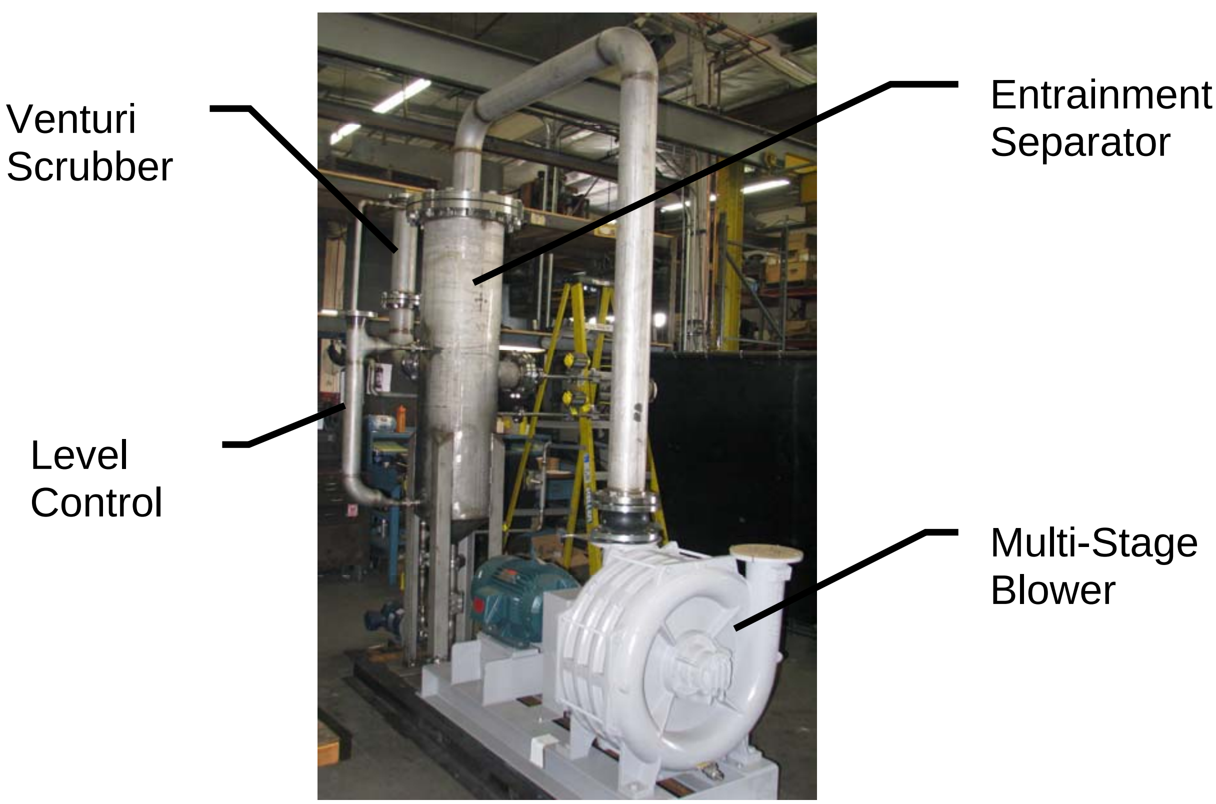
After the quencher, the syngas enters a condenser/absorber (C/A) tower to sub-cool the syngas. The packing is wet-film, random dumped polypropylene packing. Process water is collected in the C/A sump and re-circulated to the quencher and to the C/A through a fin tube cooler. A blowdown stream is taken from the C/A to purge solids from the system.

The sub-cooled syngas leaves the C/A and enters a highly efficient Venturi scrubber. The Venuri removes fine particulates before the gas enters a chevron style entrainment separator for water drop removal. Finally, the gas passes through a multistage centrifugal blower to compress the gas before it goes to the engine.

Recirculation liquid from the Venturi is collected in the sump of the entrainment separator vessel. The liquid is re-circulated to the Venturi with a recycle pump. The Venturi over flow is pumped to the C/A sump.

Figure 2 shows a picture of the Venturi system that was integrated into the existing equipment. The gas enters vertically downward at the Venturi inlet on the right hand side. The gas then passes from left to right through the mist eliminator then through the induced draft fan. The system is skid mounted and shipped as a packaged unit.

Figure 2: Venturi Scrubber System

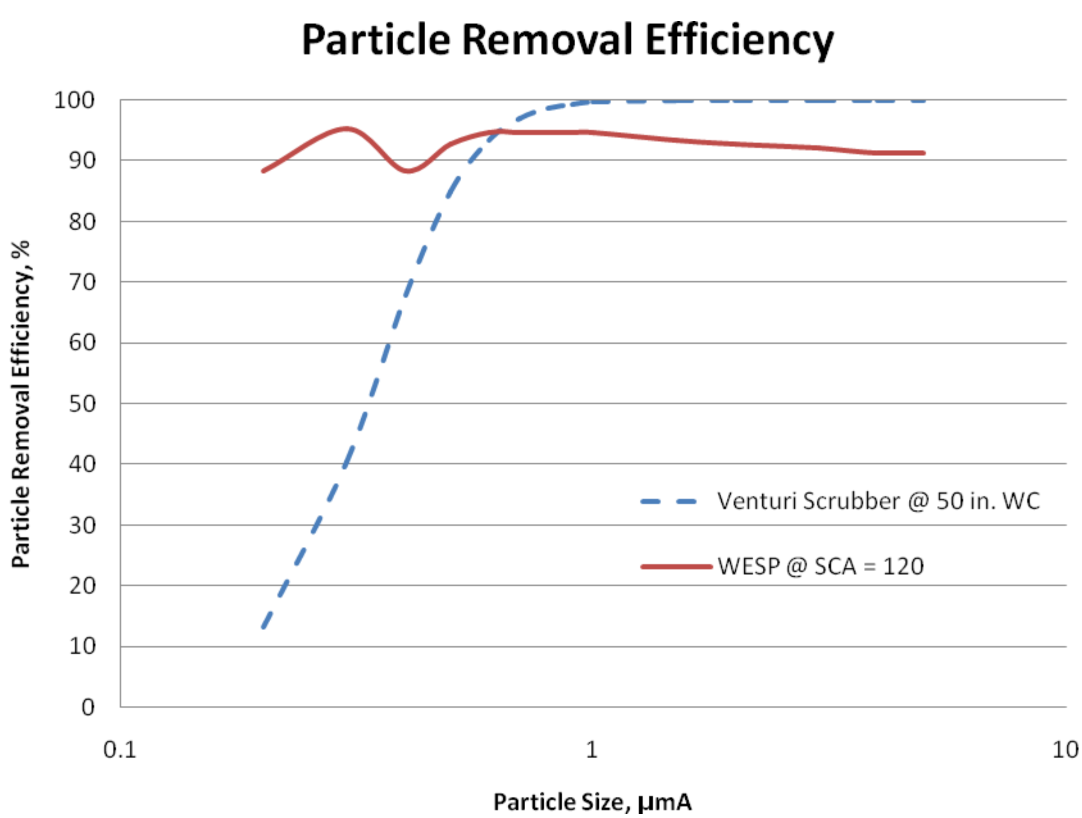


The syngas cleaning system is designed to take advantage of water vapor condensation effects to enhance particle collection and reduce energy consumption. Some of the water vapor condenses on the particles causing their mass and diameter to increase, which makes them easier to collect. The rest of the condensing vapor sweeps particles with it as it moves toward the cold surface. To a lesser extent, thermal forces resulting from the temperature gradient between the gas and the cold surface also enhance particle collection.

COMPARISON OF ESP AND VENTURI PERFORMANCE

Figure 3 compares particle removal efficiency for a ESP and Venturi scrubber system operating at pressure drop of 50 Inches W.C.. It can be seen that an ESP and Venturi have similar performances for particles greater than 1 micron. The removal efficiency of the Venturi, however, begins to degrade for particles smaller than 1 micron. Particle collection in a Venturi is enhanced when the size of particulate less than 1 micron is increased.

Figure 3: Particle removal efficiency comparison for ESP and Venturi



THE EFFECT OF SUB-COOLING TO IMPROVE VENTURI PERFORMANCE

Figure 4 shows the effect on particle size distribution (PSD) of condensing water vapor in the gas stream onto the particulate. The curve shows the particle size distribution in the "un-grown" state without sub-cooling (solid red line). In this case, 30% of the particulate is between 0.5 and 0.55 microns and 20% is approximately 0.35 microns. After sub-cooling (dashed blue line), the particle size increases from 0.5 to 0.55 microns to 0.65 to 0.7 microns and from 0.35 microns to 0.6 microns. The particle size distribution flattens out to just under 0.6 microns. The effect of sub-cooling is to "grow" the particulate, making it easier to collect them in the downstream Venturi.

Figure 4: Particle size comparison of initial and grown distributions

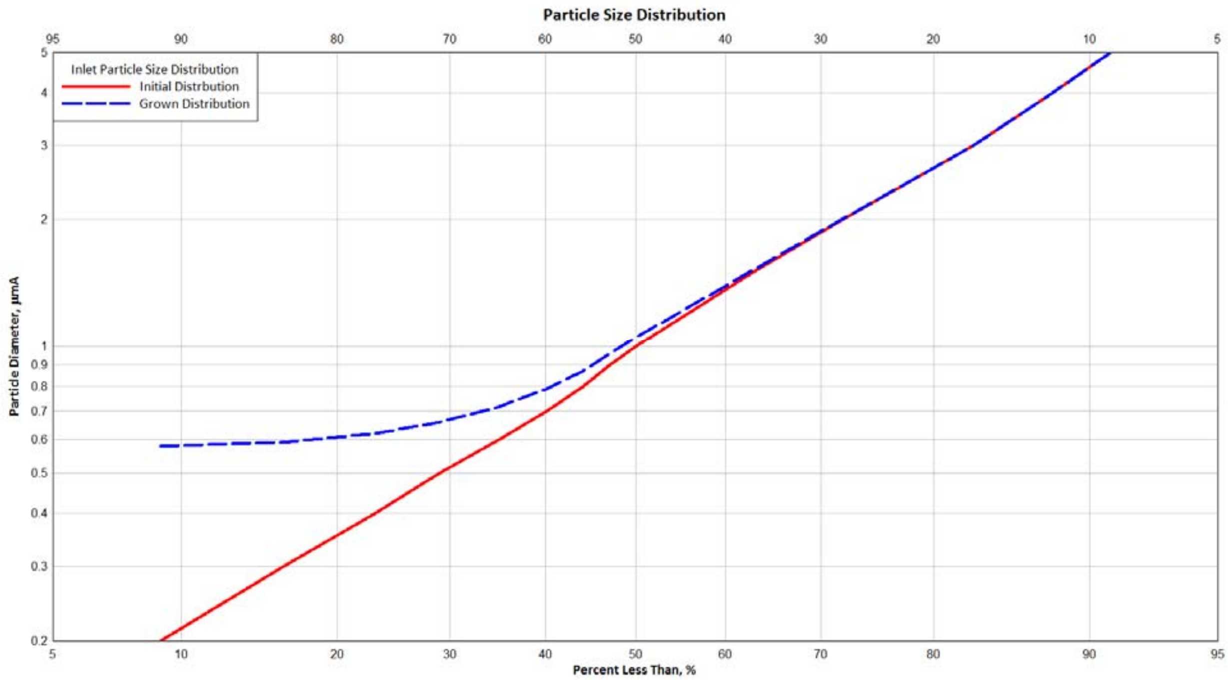
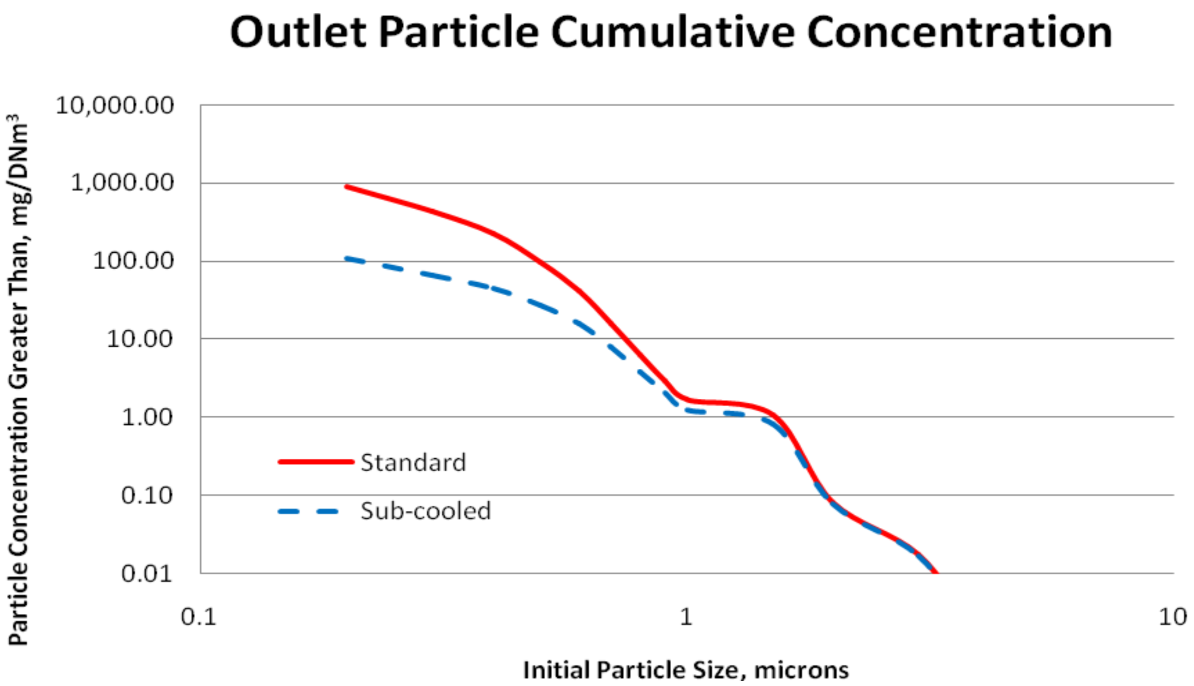


Figure 5 shows the standard inlet condition or un-grown state (solid red line) and the sub-cooled condition or grown state (dashed blue line). The outlet concentration for both conditions is essentially the same for particles up to 1 micron, approximately 1 mg/DNm^3. However, the total outlet concentration including sub-micron particulate is dramatically reduced from 1,000 mg/DNm^3 to 100 mg/DNm^3. Approximately 99% of the outlet concentration is less than 1 micron. These particulates are small enough and of low enough concentration to be combusted or pass through the ICE engine.

Figure 5: Outlet particle cumulative concentration



SUMMARY OF RESULTS / DISCUSSION

1. Operational problems developed with an ESP syngas cleaning system causing the system to be taken out of service.
2. The cost to improve the ESP operation was prohibitive so an alternative pollution control technology was sought.
3. The modified syngas cleaning system replaced the ESP with a 50 in. WC pressure drop Venturi scrubber.
4. The Venturi scrubber is downstream of a packed bed scrubber which uses sub-cooling to take advantage of condensation effects to improve the Venturi performance.
5. Sub-micron particulate is grown to a minimum size of just under 0.6 microns enabling the cumulative outlet concentration to be reduced from 1,000 mg/DNm^3 to 100 DNm^3.
6. Greater than 99% of the particulate after the Venturi is sub-micron. The outlet concentration is low enough for combustion in the ICE engine.
7. The modified syngas cleaning system design was successful in replacing the ESP and eliminated the need for high voltage safety interlocks.

CONCLUSION

This paper presents results for a modified syngas cleaning system design to replace an ESP with a Venturi scrubber to control air emissions from a biomass gasifier. The results demonstrate that the system design can take advantage of condensation effects using sub-cooling to improve the performance of the Venturi scrubber. Concentrations of residual aerosol after the Venturi scrubber will be low enough for combustion in a down-stream ICE engine. The re-design using a Venturi scrubber was more cost effective than improving the ESP operation, enabling the gasification system to return to operation.

REFERENCES

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KEY WORDS

wet scrubber, syngas, gasification, biomass, biomass gasifiers,Venturi scrubber, wet scrubber, gasifiers, pollution control technology, electrostatic precipitator