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QUESTIONS AND ANSWERS
FOR EES WESP TECHNOLOGY FOR MARINE DIESEL EXHAUST.

Thank you very much for the opportunity you have given us to present our air pollution control technology.

It has been our experience that regardless of how extensive the presentation was, there are always some additional questions that remain unanswered. We thought that these Q& A may be of particular interest.

Question: Why we should install the Scrubber on the exhaust line from ship's diesel engine?

Answer: International regulations (IMO Annex VI of MARPOL 73/78) are forbidding the use of Heavy Fuel Oil (3.5 – 4.5 % S w/w) starting January 1st 2020, unless ship is equipped with the Scrubber for SO_2 removal to make the exhaust equivalent to the use of low sulfur fuel.
Also, unlike land based Scrubber system that are always struggling for the source of scrubbing water and expenses for the chemicals for SO_2 scrubbing, the Ocean ships based scrubbers on the other hand have the ADVANTAGE of abundant amount of required cold and clean liquid and also natural alkalinity of ocean water.

Question: Are the currently used Scrubbers capable of removing all regulated pollutants from the large marine diesel exhaust?

Answer: No scrubber in the world regardless of the design is capable of efficiently and economically (with low back pressure) removing such pollutants as:

- Particles of soot ranging in size from 0.01 micron to 0.3 micron whereas a scrubber is removing only particles above 3 microns and mist eliminator that required to separate water from the gas at the exit from the scrubber cannot stop any liquid droplets smaller than 15 microns. Those droplets can carry other pollutants from the scrubber in to the outside environment.
- Sulfuric Acid droplets that are in the same size range as the soot particles.

Question: What are the operating conditions and energy requirements for the scrubber to remove soot and sulfuric acid?

Answer: It is undisputed fact that even reflected in the official chart published by US EPA (See Appendix A) that in order for any scrubber to remove those pollutants the pressure drop (or back pressure) should be at least 60 in.w.c. that will result in the loss of power for 30 MW engine around 1490 H.P. or 3.7% of total power or waste of the fuel.

Question: Is any other way to remove those toxic pollutants without any penalty for the energy production?

Answer: Yes, the technology called wet electrostatic precipitation (WESP) that originally was used as early as 1907 for removal of Sulfuric Acid from cooper smelting gas.
EES has started using it 40 years ago and has developed using contemporary state of technology protected by multiple US Patents (see Appendix B).

It is important to note that in addition to the removal of Soot and Acid with efficiency of 99.9 % with back pressure only less than 1 in.w.c. the latest Patent pending Technology by EES is also removing close to 50% of NOx due to the oxidation of NO portion by the High voltage Corona discharge in to NO_2 follow by scrubbing action.

In short, despite the use of energy for High voltage generation (about 1.3 kw per MW of diesel engine's power) overall energy consumption is about 50 times lower for the same efficiency of sulfate particulate removal due to the dramatic difference in the back pressure.

Question: So what is EES proposing for the Marine Diesel Engine exhaust cleaning?

Answer: Based on EES 40 years of experience in the land based Air pollution control (APC) system design, fabrication and installation we are proposing custom built APC that is uniquely combining WESP and Scrubber Technology using Ocean water.

Question: What are the bases of the WESP design evaluation from different vendors?

Answer: The following are the basis for the WESP evaluation:

- <u>Material of construction</u> for the high voltage section for instance, high quality alloys such as Hastelloy C-276 or AL6XN are preferred material of construction, as compared to PVC, FRP or conductive FRP.

This is even more important for high temperature applications such as incineration. In order to comply with the latest MACT regulations, the use of high intensity and high current electrostatic field are necessary. Those fields can provide a spark or arc at the rate of 60 sparks per minute in any precipitator regardless of its design.

The power of an arc can have energy up to 1000 Watts liberated in 0.001 sec.; this can result in "burning" and extensive damage to the collector plates or tubes if manufactured of plastic materials.

Choosing a plastic WESP may seem like a "good idea at the time", but in the long run, it is likely to result in shortened equipment life and maintenance problems.
For most of the industrial applications involving VOC emissions low grade stainless steel type 304 will suffice. In the event there are traces of acids can be found in the gas we are recommending steel type 316 L or AL6XN if there are some chlorides.
Under no circumstances we will use Carbon steel for construction of internal components of the WESP.

Of course one can design a WESP with much lower operating power and voltage level below the sparking level, but the result would be double or even triple the size of the WESP. It is worth to note that 2 PASS Flow WESP by EES has cold water continuosly being sprayed in the inlet and this design is virtually immune to any high temperature spikes, and this also eliminating the dry/wet interface area that is most susceptible to the corrosion process.
Proper design of the recycle water treatment system with automatic PH control is vitally important for the corrosion issue.

- <u>SCA</u> - specific collecting area (FT^2/1000 acfm).

- <u>Corona power generated</u> during wet operation under no particulate load conditions [guaranteed by vendor] (Watts/1000 acfm)

- <u>Supply of the scrubbing section</u> as a part of the WESP.

- <u>Supply of the rest of the WESP system elements</u> should be compared item by item, including spare parts list.

- <u>Guaranteed efficiency</u> for all the items of the MACT or other regulations.

Question: *Assuming that vendors are supplying the same amount of collection surface (FT^2), what kind of WESP should be selected?*

a) Plate type (horizontal or vertical) WESP or;

b) Vertical Tubular WESP

Answer: The answer to this question is given in the "ESP Bible" by Dr. H. White (see Appendix A). In short a tubular WESP of the same size can operate at twice the velocity as the plate type for the same efficiency of removal.

Question: *If the vertical tubular WESP is selected, what kind of tube shape is better? (Providing that all vendors are complying with the SCA requirements and supplying vertical tubular WESP, what shape of tube should be preferred?)*

A) Square
B) Hexagonal
C) Round

Answer: EES is using all three shapes depending upon the Application Square and hexagonal shapes are less costly since utilization of both surfaces (internal & external) takes place, and it results in lower pricing for the equipment. Those shapes are primarily being used for large gas volumes with moderate efficiency requirements. A round tubular shape it is not cost effective since 20% of the cross section is wasted but is more rigid, has more uniform electrical field, and the space between the round tubes can be utilized for the introduction of the cooling medium such as cold water or cold ambient air in order to create the condensation effect for continuous self-cleaning action in the up flow section of the 2 PASS flow WESP.

The most advantages usage of the round tubular WESP is for small to medium gas volumes with low inlet particulate load of solids and high moisture content and where a single pass unit required delivering very high efficiency.

It is also perfect for the applications with acid mist and high temperature saturated gas.

Question: *How important is the proper selection of high voltage equipment and design of the electrical controls for the WESP?*

Answer: When the high voltage power supply does not operate properly then the mechanical portion of the electrostatic precipitator is reduced to the level of very expensive duct work. The common mistake made is when an electrical system originally designed for the Dry ESP is used for the WESP since the Wet ESP energization requirements are far different i.e., current levels are usually 5 times higher then Dry ESP. Also, there are no resistivity and back corona problems and since most of the WESP's are single field units, they should be able to handle corona current suppression within a single electrical field.

The problem that the WESP designer is facing is unpredictability of the gas gap resistance during the process conditions since the space between the ionizing electrode and collecting tube wall is containing charged particles and liquid droplets of most of the time unknown size and quantity.

Most of the failures in the WESP installations can be attributed to improper selection of the power supply.

The over sizing of the high voltage transformer is detrimental to the WESP performance as much as under sizing and with single pass there is no second chance when high load of particles and droplets is virtually is “ chocking ‘ the Current flow in the circuit where the gas gap in the tube is a part of it.

In the 2 PASS flow WESP by EES there are two smaller transformers- one for each section comparing to one large size for a conventional single section (pass).

In this case in the event when the first down flow pass will perform less efficient that it was designed for due to the particulate and droplets overload but it is usually reducing the loading in to second up flow pass to the extend that the electrical characteristics of the gas is not to much different from the clean gas and the second power supply will realize its full potential and the total efficiency of the system will be as required.

Thus the 2 PASS flow WESP by EES will insure the performance of the electrical system and as a result efficiency of particulate removal regardless of the discrepancy between the real inlet load and one that was assumed or supplied by the client or have changed as the process have.

Question: *In addition to the dry particulates, a WESP should be able to handle a substantial load of liquid droplets injected into the electrical field to keep the unit clean. What is the most efficient method of delivery of the cleaning liquid into the WESP?*

Answer: The method of liquid delivery based upon spray injection into the electrical field from the top of the unit (downflow WESP) or from the bottom (up-flow WESP), results in some disruption of electrical energization by the direct spray of water unless the droplets of the liquid are small and can be treated by the Electrical field as a particle that will be charged and collected. Large liquid droplets can create the sparking and arcing resulting in lower efficiency of particulate removal if only the single pass is used.

Liquid can emerge from the spray nozzle in the shape of a <u>stream</u> rather than a <u>spray</u> when the nozzle is partially plugged. This stream of water is acting as the wire creating a complete “short” in the SINGLE PASS WESP rendering it temporarily inoperable.

Clogged nozzles also can deprive some portion of the collector section from the washing. Needless to say, it takes only 1 sq.ft of contaminated collection surface to bring the WESP performance down from expected 99% efficiency to a disappointed 40% or even less. Please note that total collection surface of the WESP module averages 4000 sq.ft

Again in the 2 PASS flow WESP at least one pass is always operational and in the down flow pass that is designed mainly for removal of large particles and droplets there are spray nozzles with large openings.

In the up flow section of EES 2 PASS flow WESP the liquid is delivered as a fine mist that partially is originated in the down flow section by high voltage sparks and arcs and also delivered as clean make-up by the nozzles with small openings.

For the applications such as Marine Diesel Engine with hot and saturated gas the up-flow section of the WESP can be built as our Patented Condensing type with round tubes that are cooled on the outside by cold ocean water and that can also diminish the vapor plume from the stack and produce fresh water as product of condensation.

Question: *What can be done if there is not enough moisture in the gas to condense?*

Answer: By injecting waste steam, if available, into the gas stream below the collecting section, WESP can be operated at normal self-cleaning conditions.
The additional positive effect of the steam condensation on the surface of the submicron particles results in growth of their size by a factor of 10, dramatically increasing removal efficiency.

Question: *What is the most important operating parameter for the consistent high efficiency of the WESP?*

Answer: Operating voltage (average) shown on the meter of the front panel. [KV]
And operating Current shown on the meter [Ma]

Question: *What is EES doing differently from the other vendors to keep the operating voltage steady?*

Answer: EES has the following features separating its design from others in the world market:

- Design and development of the 2 PASS flows WESP is utilizing all the positive features of both down flow and up flow types and according to the Patent Pending design the shortcomings of those types are being eliminated.

- Continuous self-cleaning in both sections
- Top support for the ionizing electrode frame resting on 4 insulators that in addition to the conventional hot air purge system have a short single tube ESP protecting insulators from contamination

- Superior computerized method of predicting the operating parameters of the WESP under process conditions and as the result proper selection and sizing of the high voltage transformer and related components.

Unlike other vendors EES guaranty the electrical power input into the WESP system and as the result the efficiency of particulate removal Regardless of the fluctuations in the gas composition.

- Custom design of the Ionizing electrodes for each application insuring the delivery of the negative ions for all particles to provide saturation charge and their subsequent collection.

- Special design of the shape for ionizing electrodes that is insuring the sharpness of the ionizing needles year after year and in fact, the movement of the particles in the gas provide the self- sharpening effect for the electrodes.

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If you still have some general questions or specifics related to your application, please do not hesitate to call. Again, thank you very much for your interest in our technology.

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