ENVIROENERGY SOLUTIONS

Presentation of APC and Wet Electrostatic Precipitation

Technology

Agenda

- Introduce participants
- Review WESP technology
- Review the Applications of WESP
- Questions & answers

People

EnviroEnergy Co.

- Dr. Isaac Ray
- Dr. Boris Altshuler
- Henry DelGatto
- Jacob Tsukerman P.E.

People

Dr. Isaac Ray

- Senior Consultant

•Specializes in Electrostatic and Magnetic aspects of Aerosol Physics and its applications to APC equipment design

•Expertise in WESP technology

•Experience in US since 1977 and in former USSR since 1965

•PhD Mechanical Engineering

People

Dr. Boris Altshuler

• Senior Chemical and Process Consultant

•Worked extensively in air pollution control industry in the USA since 1990 and in Gas Industry in Russia since 1965

•Specializes in Chemical Engineering Aspects of APC and related equipment design

•Ph.D. Chemical Engineering

Strengths

- Multiple “Wet” Technologies
- Integrated Approach
- Multi-Industry Experience
- Process Engineering Expertise
- Focus is on Difficult Applications
- Hundreds of Installations

ENVIROENERGY APC TECHNOLOGY

- Particulate Scrubbers
- Gas Absorbers
- Wet Electrostatic Precipitators
- Carbon Bed Adsorbers

Systems Benefits

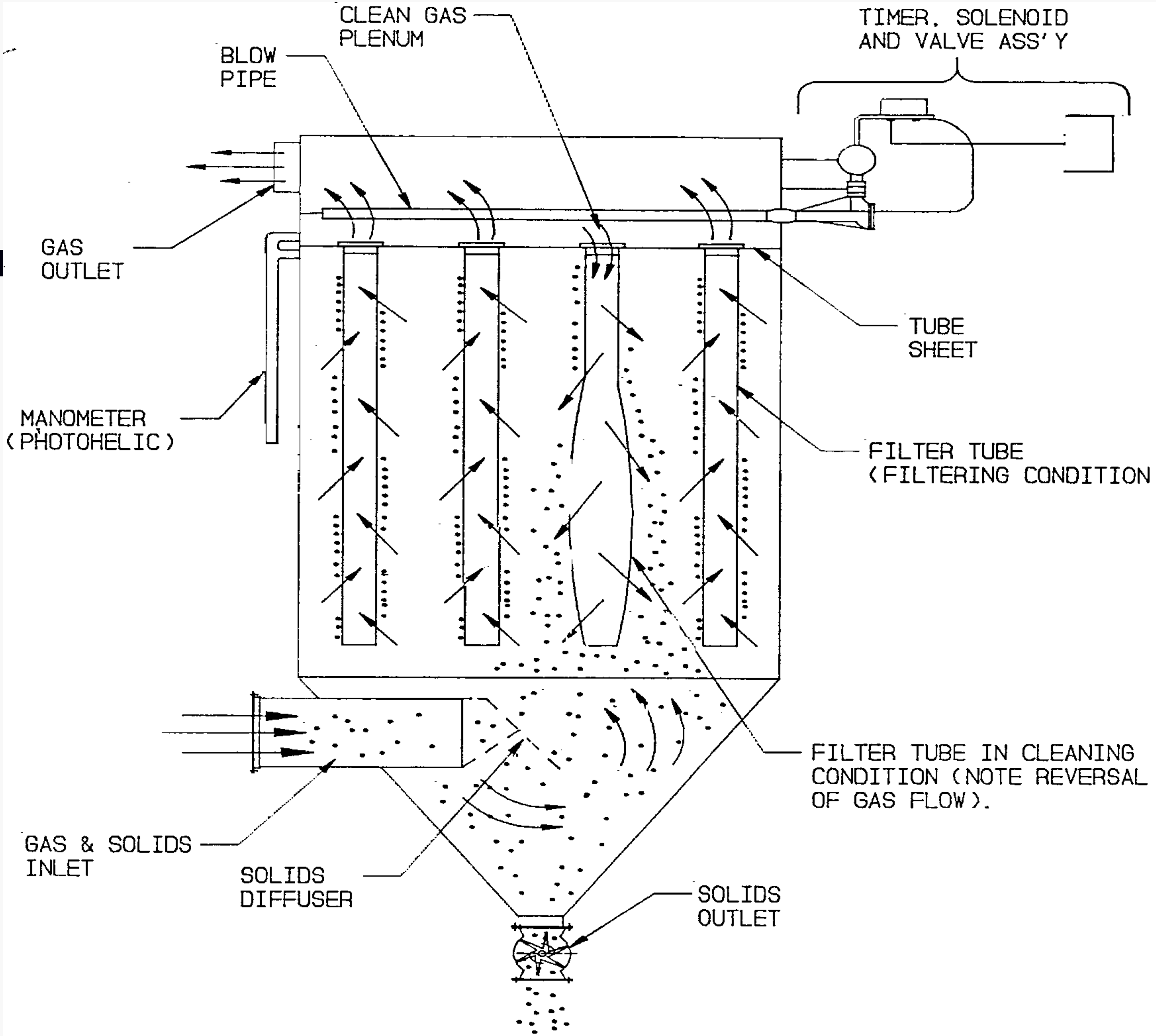
– Up To 99.99% Collection Efficiency
– Low Pressure Drop
– Minimum Energy Usage
– Low Maintenance
– On-line Reliability

Project References (partial)

- Lucent Technologies
- Eastman Chemical
- DuPont
- International Technology
- Bechtel
- Wheeling-Pitt Steel
- Smurfit-Stone
- PCS Phosphates
- Shaw Industries
- Sierra Pine
- EPA
- Dept.of Defense
- General Electric
- Kyanite Mining
- M&M Mars
- International paper

Process and Technology Information for Particulate and Metal HAP Control

Control Technology	Collection Efficiency	Particle Diameter, µm	Operating Temperature, °F	Pressure Drop, in w.c.	Advantages	Disadvantages
Cyclone Collector a. Conventional b. High Efficiency	a. < 90.0 b. > 90.0	> 15	40–700	a. 2–5 b. 2–8	Collection of large particulate emissions is very effective. Recovery of product is possible. No liquid waste streams are generated.	Removal of submicron particulate is ineffective. Energy requirements are moderately high.
Fabric Filter a. Low Capacity b. Medium Capacity c. High Capacity	90–99.9	> 0.3	a. < 200 b. 200–400 c. > 400	4–10	Control of small-diameter particulate is effective but limited to dry solid particles. Inlet particulate loading has minimal effect on control efficiency. Material collected is dry.	Large physical space (footprint) is required. Fabric filters are temperature-sensitive. Moisture in gas can "cake up" and lead to plugging. Fire and explosion hazards exist. Gas conditioning is required. Does not remove toxic gases or organic vapors.
Venturi Scrubber a. Low Energy b. High Energy	> 99.0	0.5–5.0	100–700	a. 5–15 b. 20–60	Collection of fine particulate (in corrosive environments) is very effective. Physical space requirements (footprint) are small. Reduction of emissions in high-temperature and/or high-humidity gas streams is very effective.	High-speed, high-energy fans constructed of exotic alloys are required. Maintenance and operation are costly. Corrosion-resistant alloys are required. Fabrication is relatively expensive.
Ionizing Wet Scrubber	> 99.0	> 0.5	100–700	0.5–1.5	Energy costs for charging plate are relatively low. Gas scrubbing and particulate removal occur simultaneously.	Capital costs are relatively high. Liquid waste streams are generated. Efficiency of a single pass is only 40% for submicron particles and a large footprint is required for multi-pass design.
Collision Scrubber	> 99.0	> 0.5	100–700	30–50	Collection of submicron particles and trace metals is effective, but limited.	Capital costs are relatively high. Energy requirements are extensive. Liquid waste streams are generated.
Electrodynamic Venturi	> 99.0	> 0.5	100–700	5–15	Collection of submicron particles is effective, but limited only to small concentrations of submicron particles.	Capital costs are relatively high. Operating experience in the U.S. is limited. Liquid waste streams are generated.
Dry Electrostatic Precipitator	> 99.0	0.5–20	250–700	0.5–4	Collection of submicron particles with high efficiency from hot gas without water discharge. Low energy requirements.	Large footprint; moving parts. Inability to remove vapors. Secondary reentrainment. Inability to remove particles with high electrical resistance. High-voltage power-input limited to approx. 500W/1000 cfm of gas.
Wet Electrostatic Precipitator	> 99.9	0.01–20	40–200	0.5–4	Small footprint; no moving parts. Removes solid and liquid particles, organic and inorganic vapors. No reentrainment. Efficiency does not depend on physical and chemical properties of the particles. Low energy requirements. High voltage power input as high as 3000w/1000cfg of gas, if required. Low maintenance and operating costs.	Relatively high capital cost. Liquid waste stream generation.

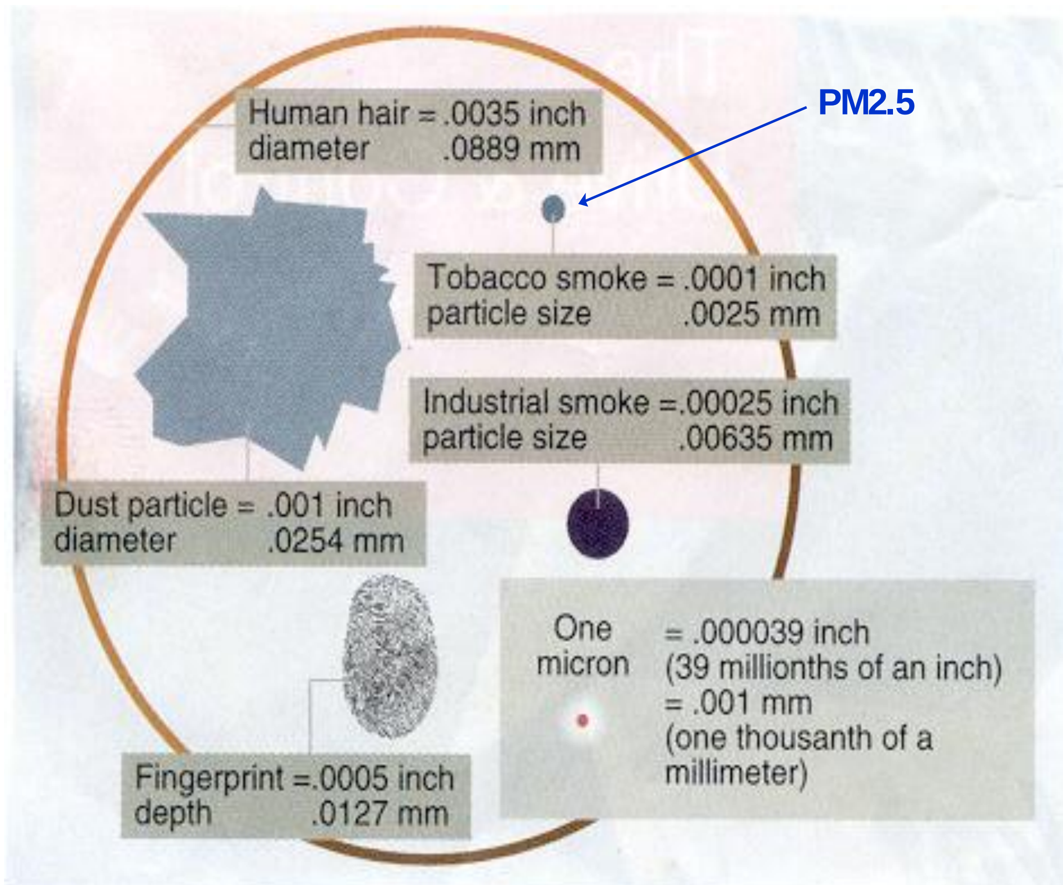

CLEAN GAS
PLENUM
BLOW
PIPE
TIMER, SOLENOID
AND VALVE ASS'Y
GAS
OUTLET
TUBE
SHEET
MANOMETER
(PHOTOHELIC)
FILTER TUBE
(FILTERING CONDITION)
FILTER TUBE IN CLEANING
CONDITION (NOTE REVERSAL
OF GAS FLOW).
GAS & SOLIDS
INLET
SOLIDS
DIFFUSER
SOLIDS
OUTLET

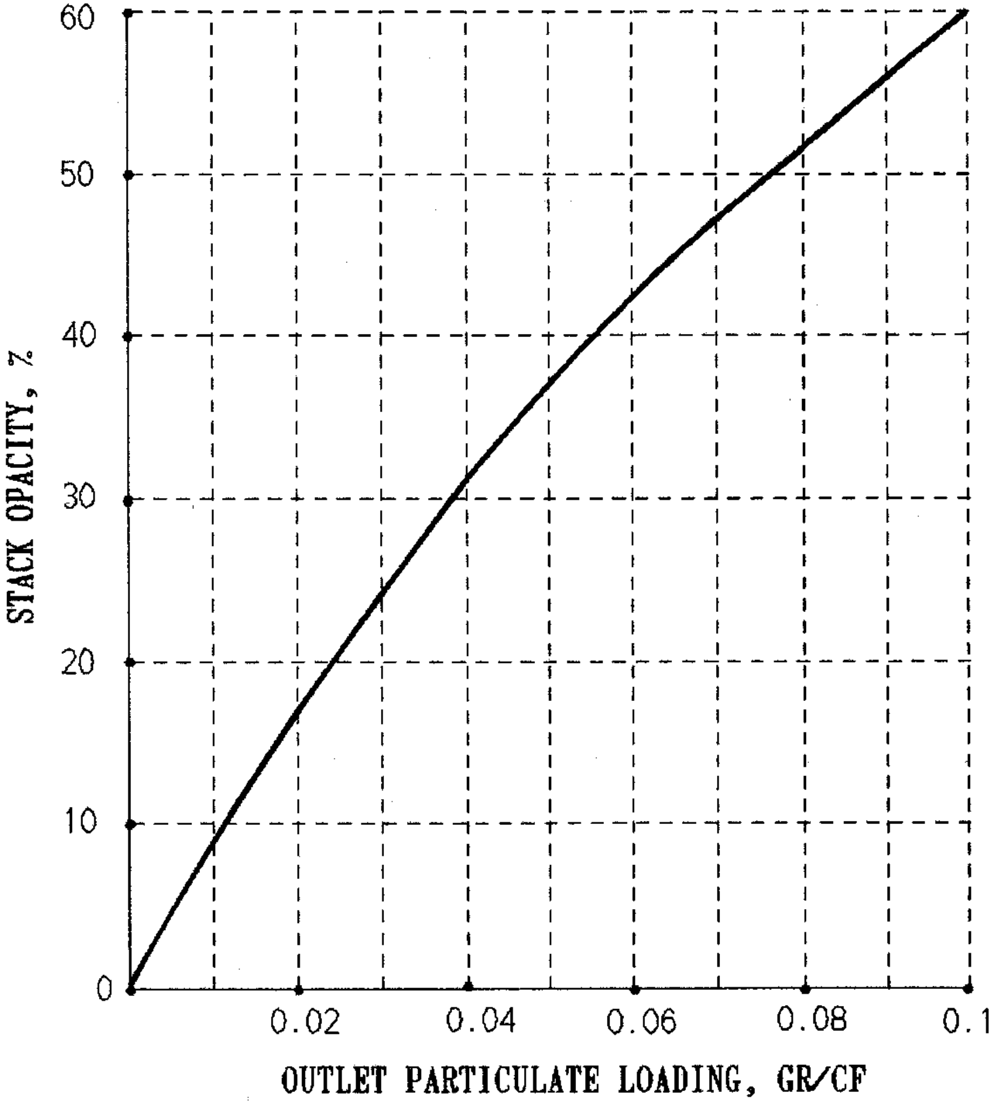
Competitive Technologies

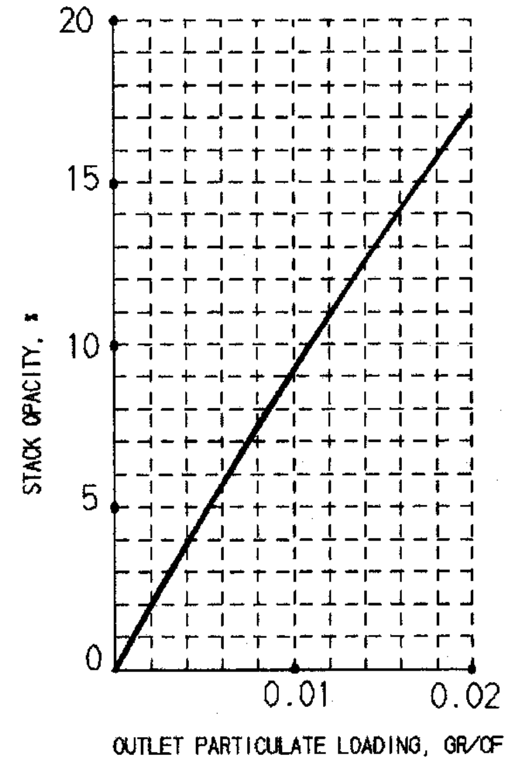
	HCL	Hg	PM2.5	Metals
Dry Scrubber	X	X		
ACI/Fabric Filter		X	X	X
Wet Scrubber	X	X		
Wet ESP	X x	X	X	X

What is PM2.5?

Particles, acid mists, liquid droplets, & toxic metals that are less than 2.5 microns in size

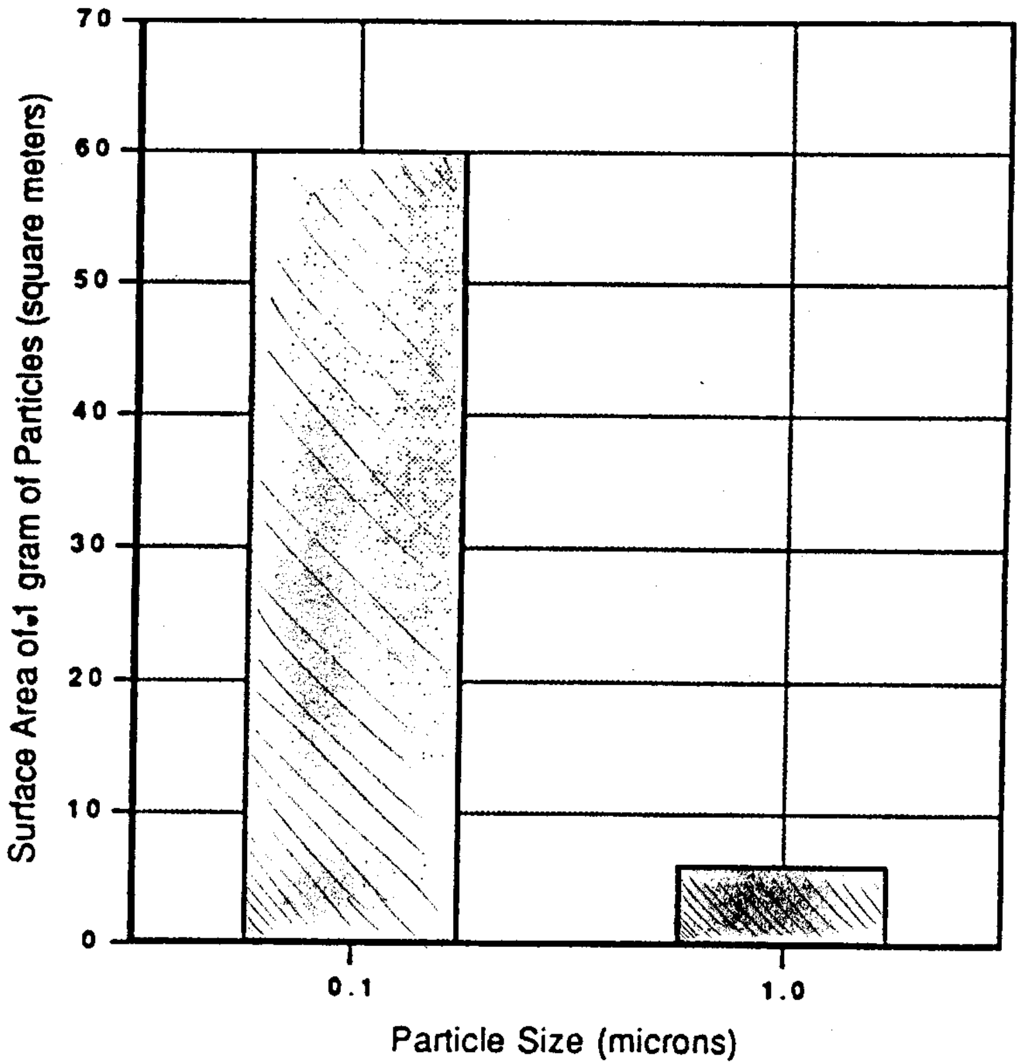




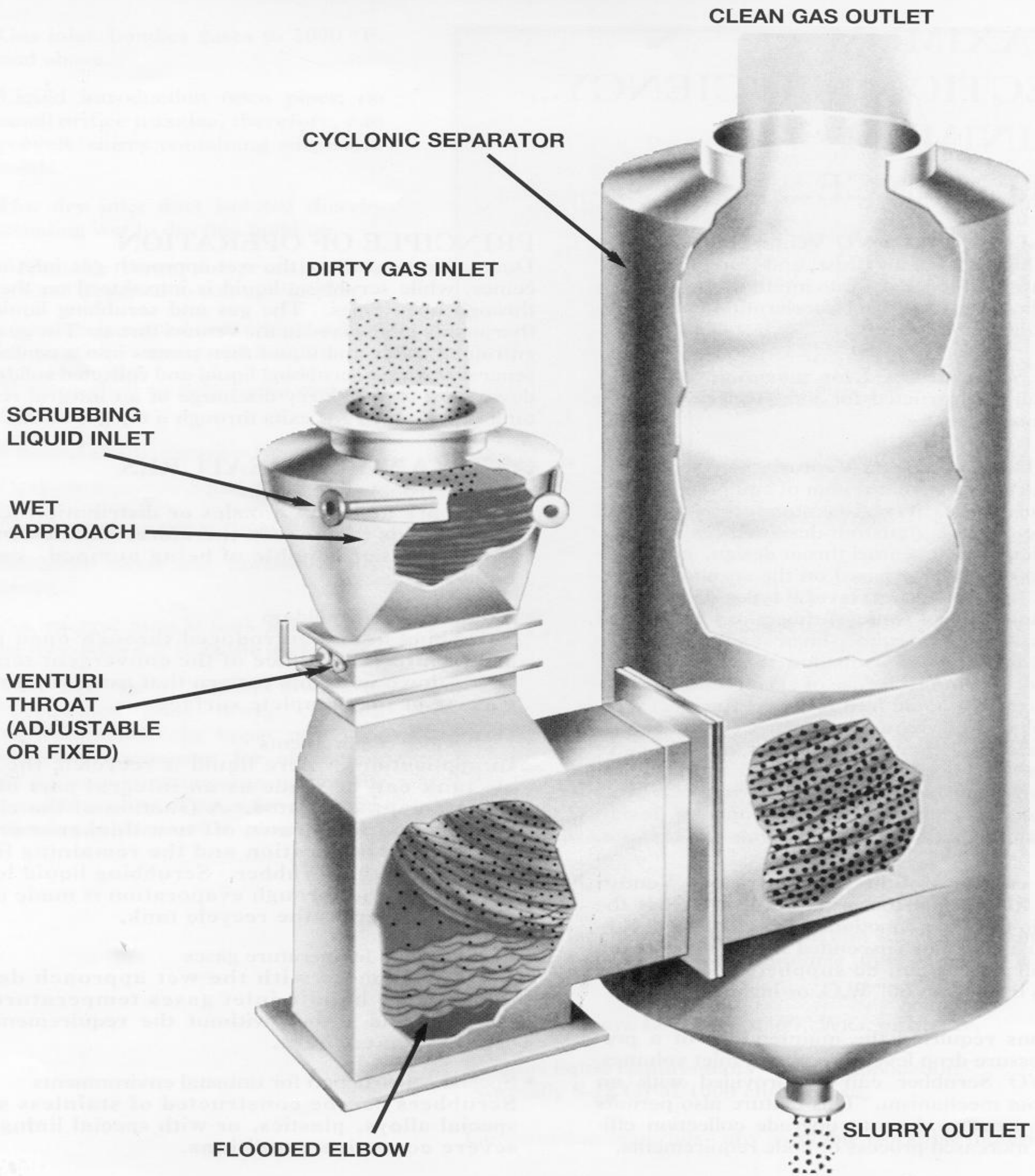


NOTE: STACK DIAMETER - 5'-0"
PARTICLES SIZE - 0.3÷0.5 MICRON

CORRELATION OF OPACITY
WITH OUTLET MASS CONCENTRATION



EFFECT OF PARTICLE SIZE ON SURFACE AREA


CLEAN GAS OUTLET
CYCLONIC SEPARATOR
DIRTY GAS INLET
SCRUBBING LIQUID INLET
WET APPROACH
VENTURI THROAT (ADJUSTABLE OR FIXED)
FLOODED ELBOW
SLURRY OUTLET

EPA/625/6-86/014
September 1986

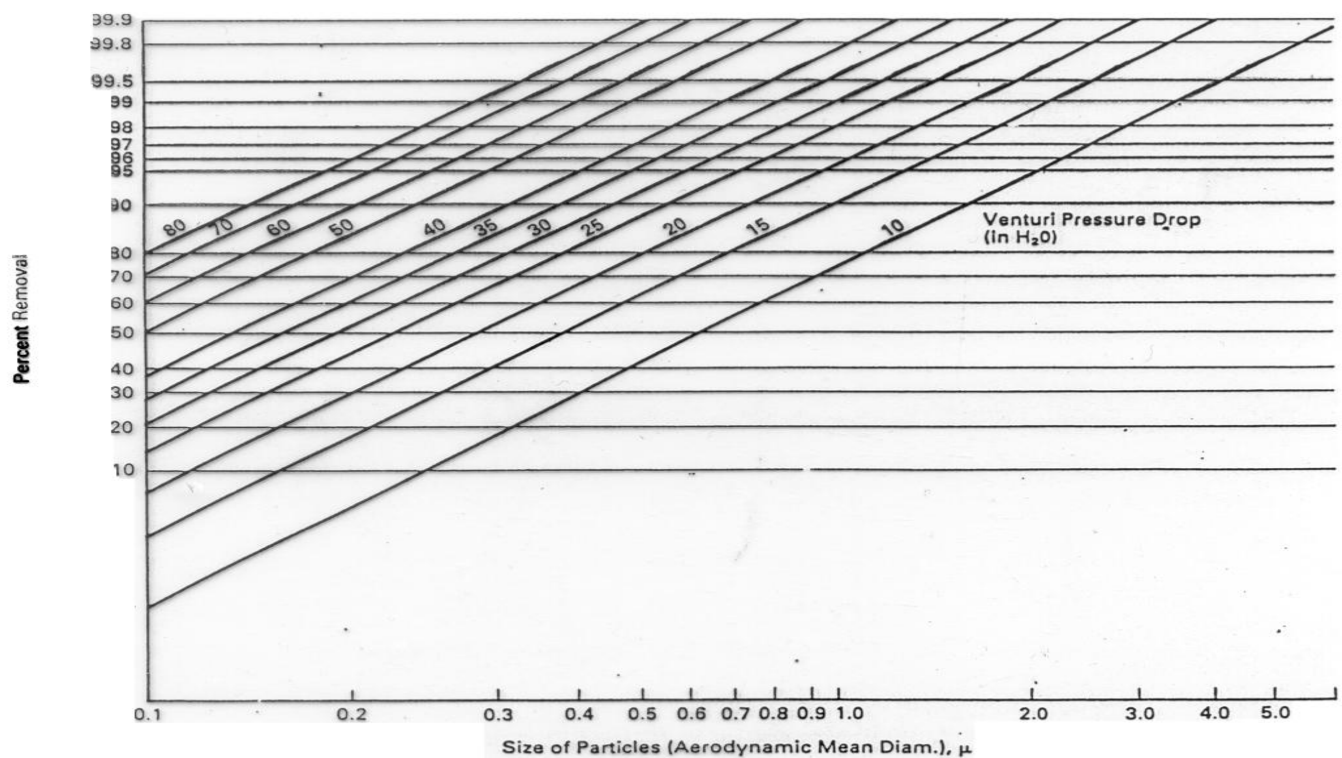
Air and Energy Engineering Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Center for Environmental Research Information
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

Handbook

Control Technologies for Hazardous Air Pollutants

Figure 4-20. Venturi scrubber collection efficiencies.



What is a WESP?

- Developed by Dr. Cottrell in 1907
- Originally Applied to Sulfuric Acid Mist production
- Used in Numerous Industrial Applications
- Since 1970 extensively used in Air Pollution Control
- Collection Surfaces Continuously Cleaned

Why Wet ESP Technology?

- High Removal Efficiency for PM2.5, Metals and SO_3
- Incremental Hg, SO_2 & NO_x Control
- Opacity reduction to < 5%
- Modular Design for Scale up
- Low Maintenance- no moving parts

<u>A Final Polishing Device</u>

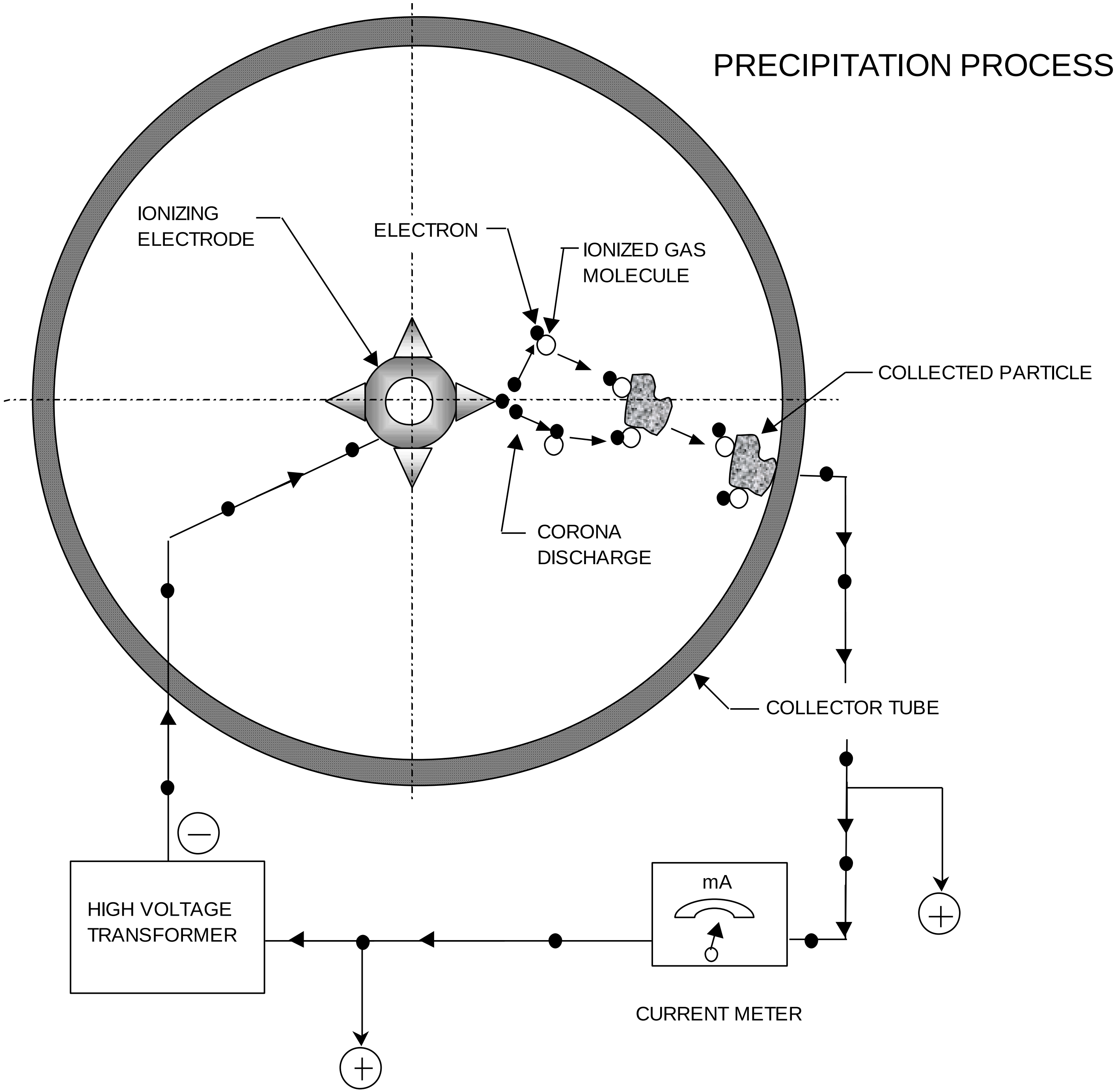
Installed after course particulate & acid gas removed

Dry vs. Wet ESP

Operating Parameter	UNITS	DRY ESP	WET ESP
PRECIPITATION RATE	FT/SEC	0.05 - 1.00	0.15 - 2.00
SCA	FT2/MCFM	50 - 1000	50 - 500
CORONA POWER	WATTS/MCFM	50 - 500	500 - 3000
GAS VELOCITY	FT/SEC	3 - 8	3 - 15+

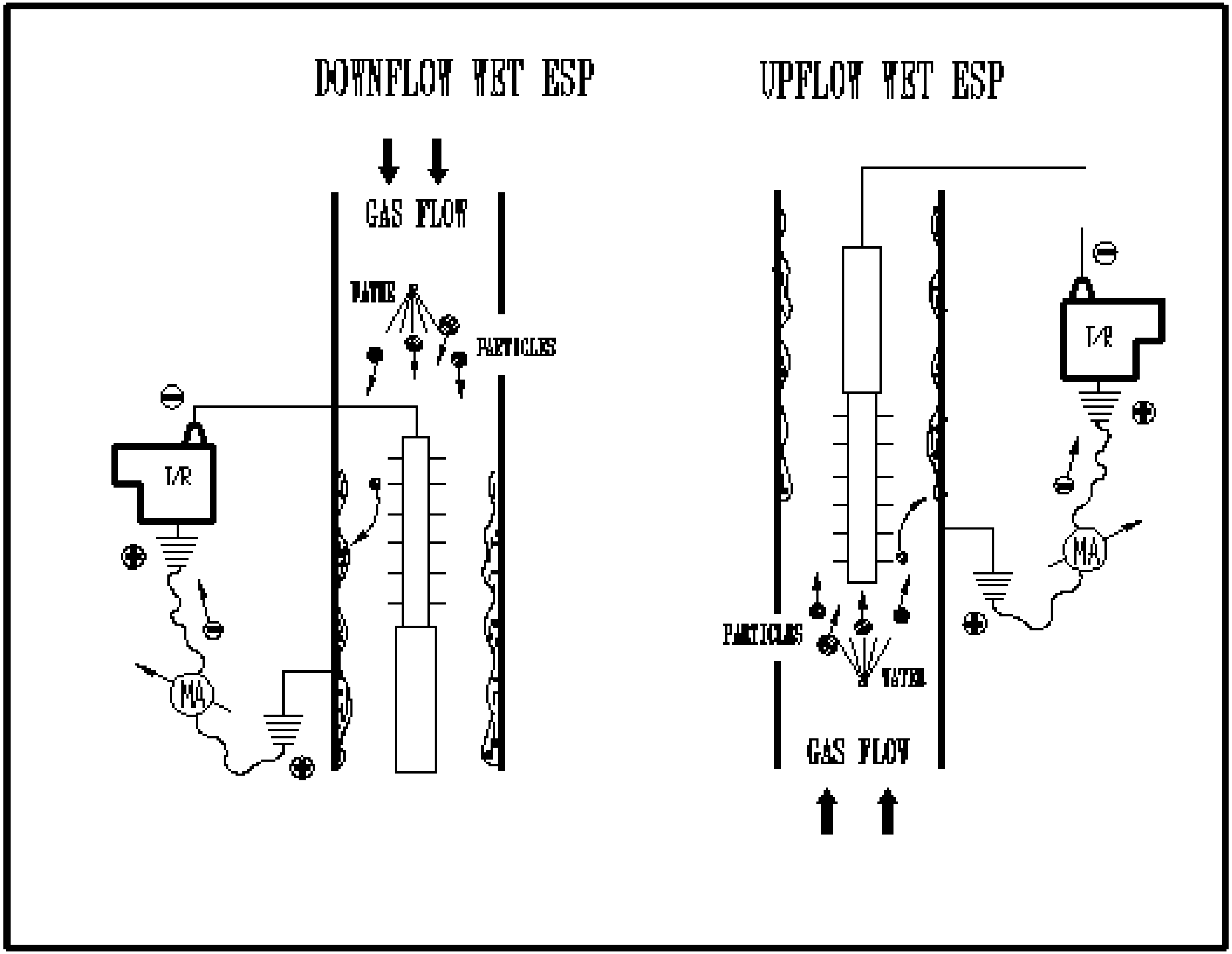
OPERATIONAL ISSUES	DRY ESP	WET ESP
BACK CORONA	YES	NO
RE-ENTRAINMENT	YES	NO
SO3 REMOVAL	NO	YES
PM 2.5 REMOVAL	NO	YES
MERCURY REMOVAL	NO	YES
OPACITY REDUCTION	NO	YES
WASTE WATER TREATMENT	NO	YES

PRECIPITATION PROCESS

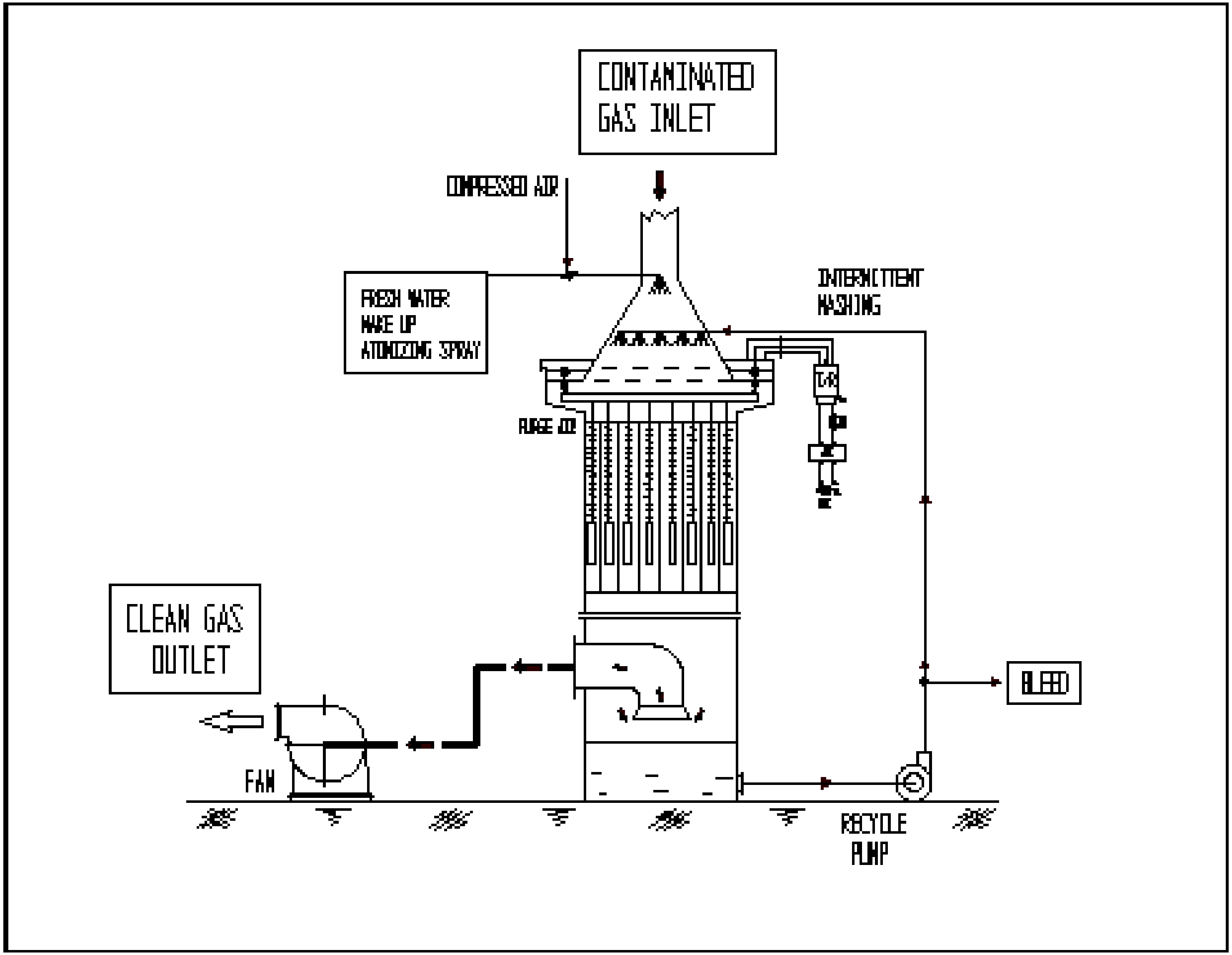


WESP Tube & Electrode

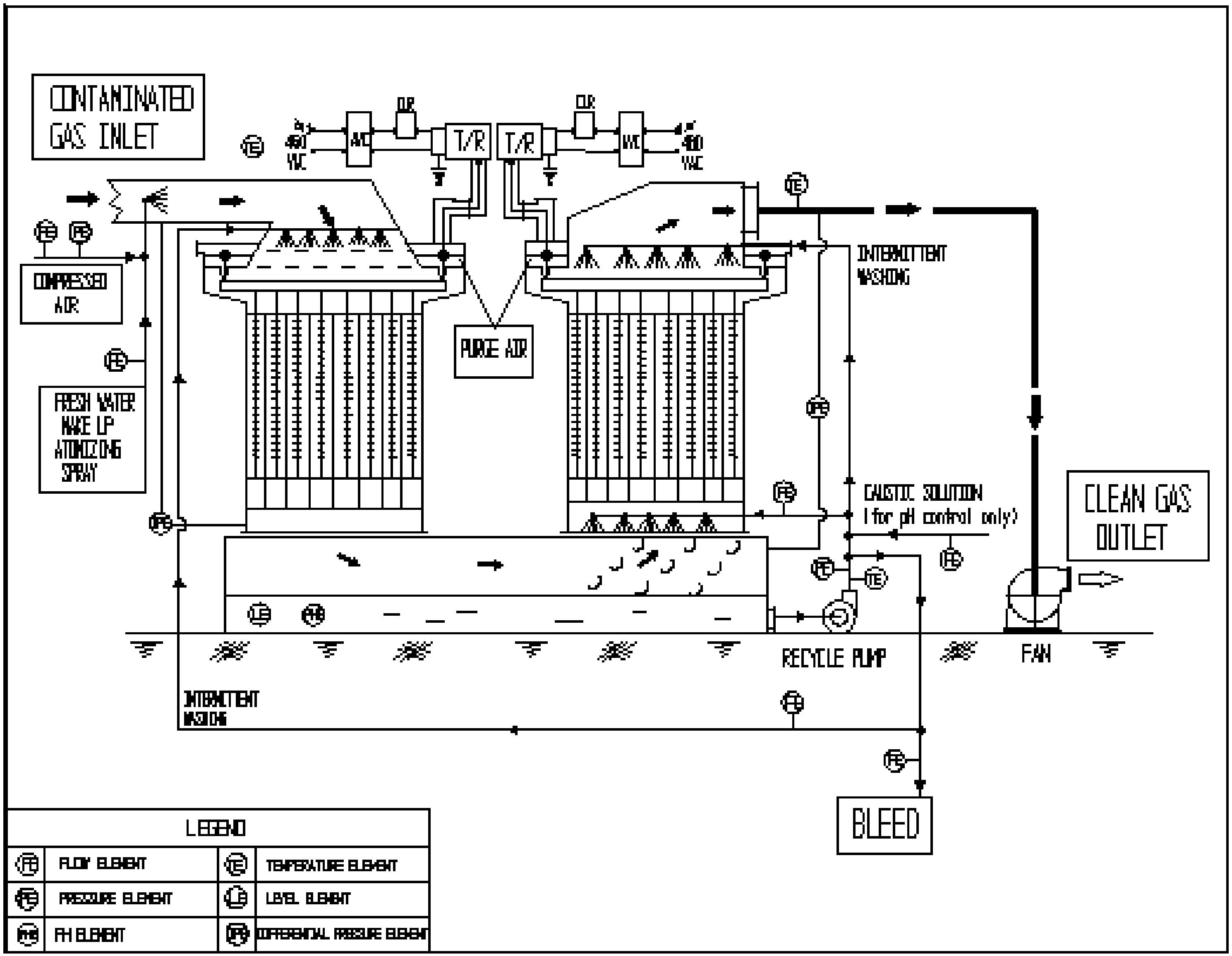
“ Horizontal Irrigated Plate WESP

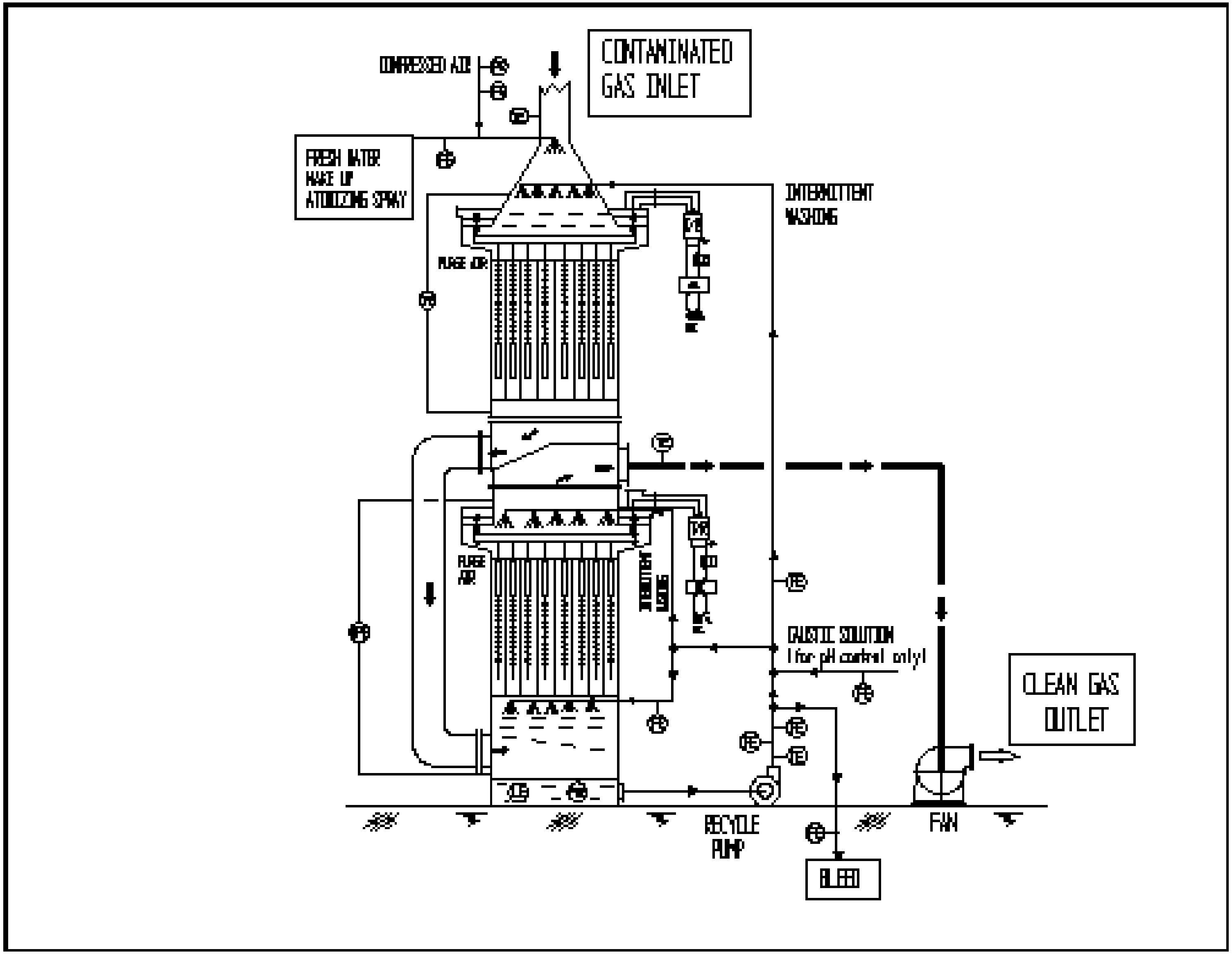


DOWNFLOW WET ESP
UPFLOW WET ESP
GAS FLOW
WATER
PARTICLES
T/R
MA
T/R
MA
PARTICLES
WATER
GAS FLOW


CONTAMINATED
GAS INLET
COMPRESSED AIR
FRESH WATER
MAKE UP
ATOMIZING SPRAY
INTERMITTENT
WASHING
PURGE AIR
CLEAN GAS
OUTLET
FAN
BLEED
RECYCLE
PUMP

OPERATIONAL CHARACTERISTICS	DOWNFLOW WESP	UPFLOW WESP
CONTINUOUS SELF CLEANING	YES	NO
HIGH EFFICIENCY FOR SUBMICRON MIST REMOVAL	NO	YES


CONTAMINATED GAS INLET
COMPRESSED AIR
FRESH WATER MAKE UP ATOMIZING SPRAY
480 VAC
AVC
CLR
T/R
T/R
CLR
AVC
480 VAC
PURGE AIR
INTERMITTENT WASHING
CAUSTIC SOLUTION (for pH control only)
CLEAN GAS OUTLET
RECYCLE PUMP
FAN
INTERMITTENT WASHING
BLEED
LEGEND
FLOW ELEMENT
TEMPERATURE ELEMENT
PRESSURE ELEMENT
LEVEL ELEMENT
PH ELEMENT
DIFFERENTIAL PRESSURE ELEMENT


CONTAMINATED GAS INLET
COMPRESSED AIR
FRESH WATER MAKE UP ATOMIZING SPRAY
INTERMITTENT WASHING
PURGE AIR
CAUSTIC SOLUTION (for pH control only)
CLEAN GAS OUTLET
RECYCLE PUMP
FAN
BLEED

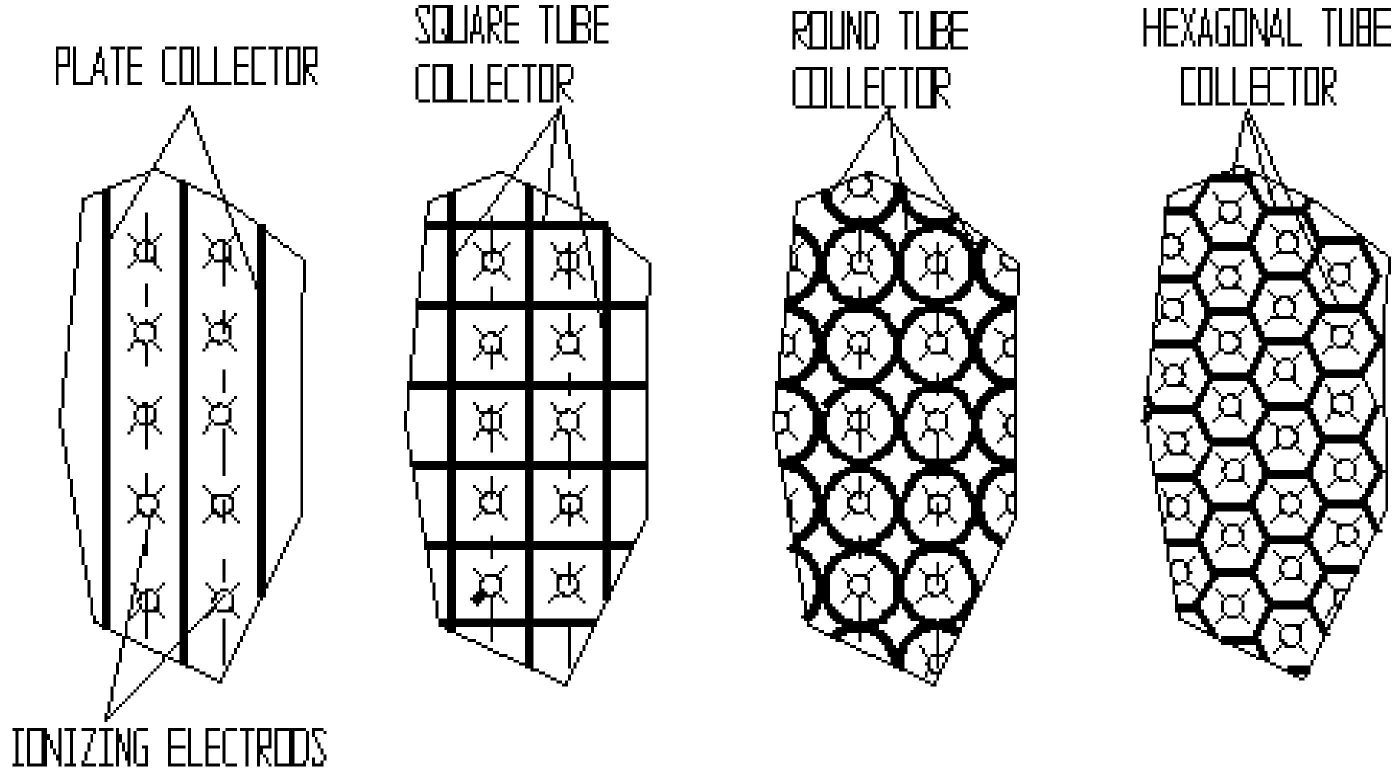
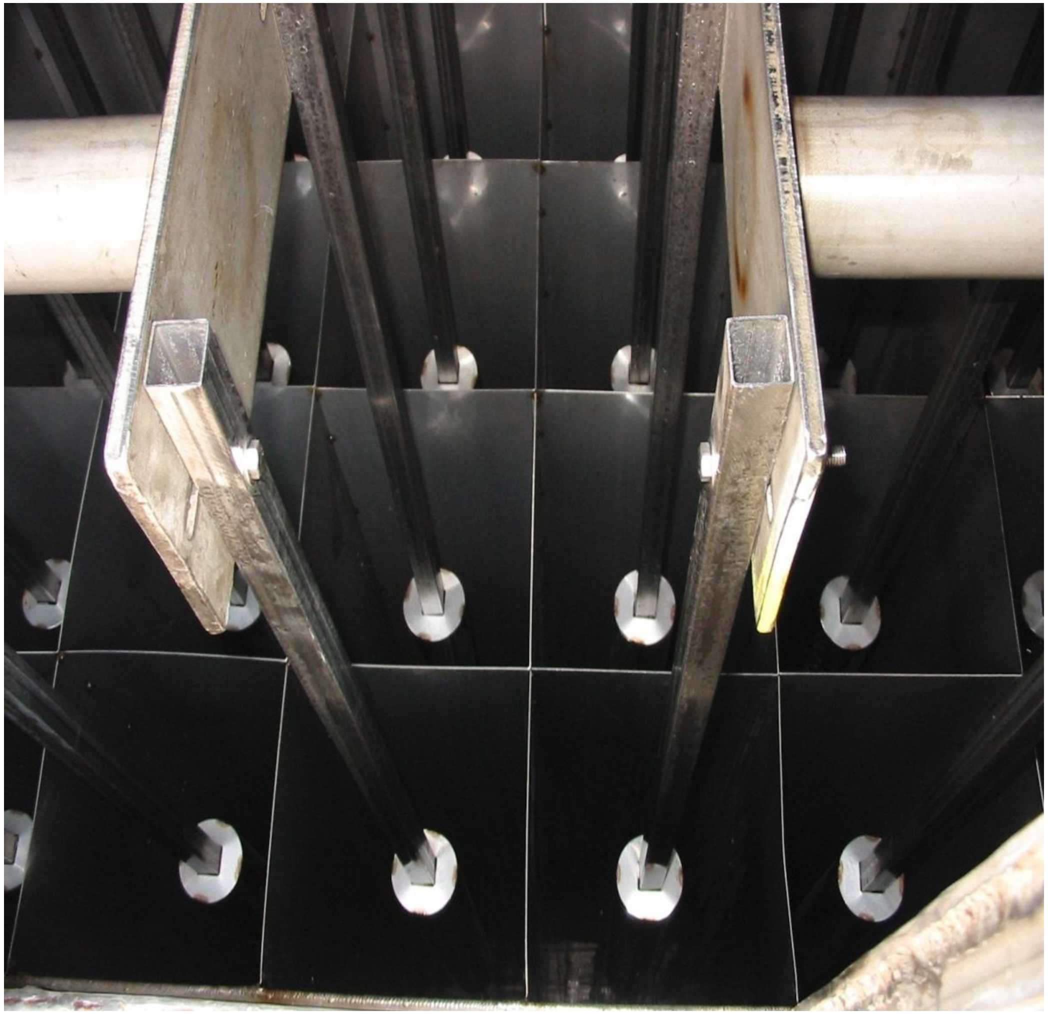


PLATE COLLECTOR
SQUARE TUBE
COLLECTOR
ROUND TUBE
COLLECTOR
HEXAGONAL TUBE
COLLECTOR
IONIZING ELECTRODS

WESP & TURBO-GRID SCRUBBER

Vertical Tubular square tube WESP



Comparison of Technologies

Dry Approach

Dry Scrubber/Baghouse

- Higher pressure drop-filters
- Requires more fan capacity
- Doesn’t cool gas-more volume
- Lower velocity
- Larger footprint
- Bags are pulsed-holes & blinding
- More Maintenance
- Dry waste by-product
- Larger volume of waste
- No water treatment required
- Higher capital cost
- Higher operating cost

Wet Approach

Wet Scrubber/Wet ESP

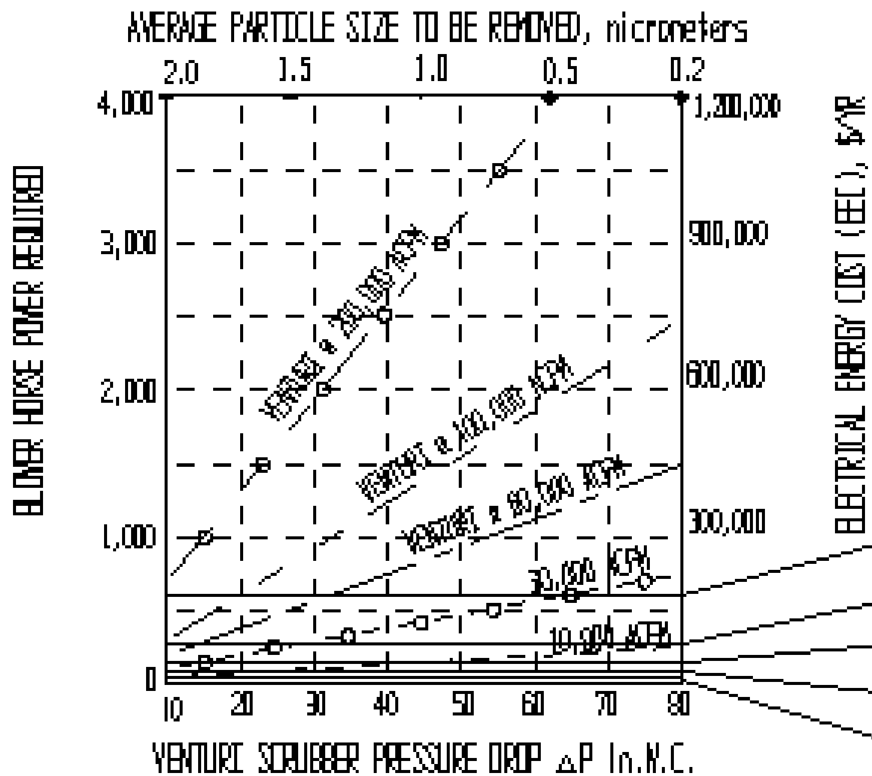
- Lower pressure drop-open design
- Less Fan capacity
- Cools Flue gas -reduces volume
- Higher velocity 8-12 ft/sec.
- Smaller Footprint
- No moving parts
- Less Maintenance
- Wet waste by-product
- Waste treated & concentrated
- Wastewater treated & recycled
- Less capital cost than baghouse
- Lower operating cost

ENERGY COST COMPARISON BETWEEN VENTURI SCRUBBER AND WET ELECTROSTATIC PRECIPITATOR

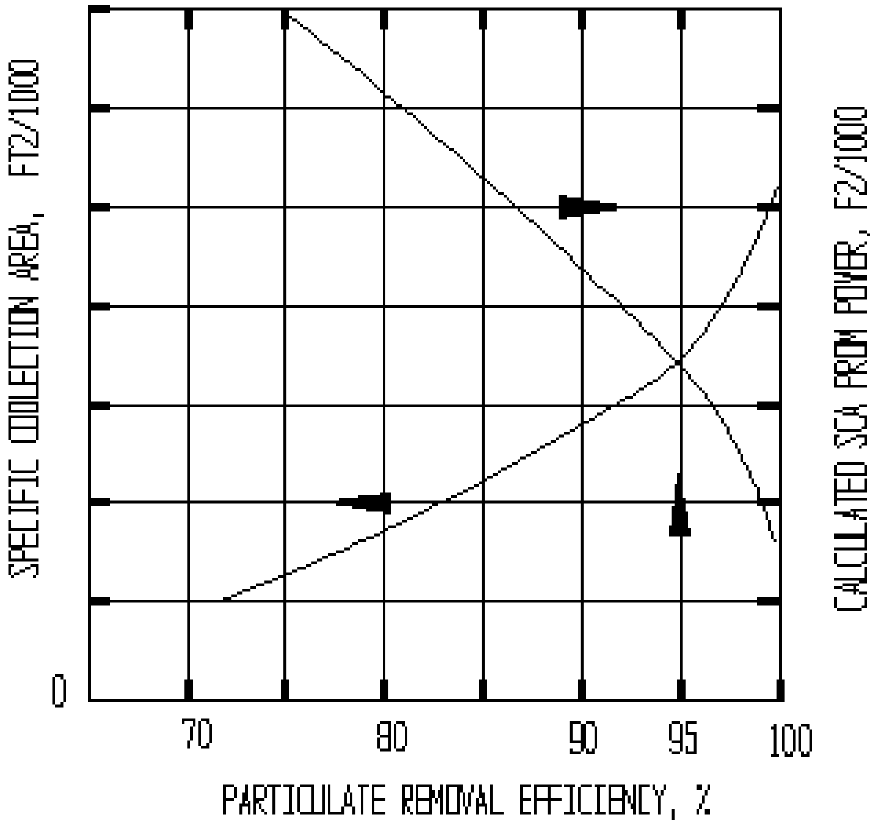
THE GRAPH IS BASED ON THE FOLLOWING:

1. ΔP VALUES FOR VENTURI BASED ON EPA/625/6-86/014 HANDBOOK
2. REMOVAL EFFICIENCY ....95% (*)
3. OPERATING TIME .... 8000 HRS/YEAR
4. ELECTRICAL ENERGY COST..... 5 ¢/KWH

(*) FOR EFFICIENCY OF 99% THE ENERGY COST FOR VENTURI ON THE GRAPH MULTIPLY BY 1.43
FOR WET ESP THE ENERGY COST REMAINS THE SAME.



WET ESP	
SATURATED GAS FLOW ACFM	EEC, $/YR
200,000	172800
100,000	86300
80,000	51780
30,000	25890
10,000	8600



SPECIFIC COLLECTION AREA, FT2/1000
CALCULATED SCA FROM POWER, F2/1000
0
70
80
90
95
100
PARTICULATE REMOVAL EFFICIENCY, %

Fiberboard Manufacturing

Particle Board Manufacturing

Test Results - Hazardous Waste Incineration

Pollutant	Units	Test Runs	MACT Limits	%
Particulate	Gr/dscf, 7%O2	0.0024-0.0030	0.015	99.94
HCL/Cl2	ppmdv,	2.96-4.84	77	99.95
Chromium	Ug/dscm	39.7-42.8	97	99.97
Lead	Ug/dscm	3.59-3.85	240	99.95
Mercury	Ug/dscm	1.82-1.98	130	79%
Dioxin/furan	Ng TEQ/dscm	0.0131-0.0892	0.4	N/D

WESP operating at Zero opacity (Textile process)

WESP System with Rod-Deck Scrubber upstream treating 15,000 ACFM.

WESP AT MOORE TEXTILE, EL SALVADOR

Single Pass WESP and Rod-Deck scrubber combination delivering Zero opacity from the exhaust of 30,000 ACFM @ 130 Deg.F.

EnviroEnergy also has provided oil-water separator.

Demonstration WESP- SCRUBBING system

Designed by ENVIROENERGY SOLUTIONS, INC. for WOW Energy

Project funded by the state of TEXAS

COLLECTOR AND IONIZING ELECTRODES

WESP 20,000 ACFM capacity installed in EL SALVADOR

High temperature Cyclonic Separators and Venturi Scrubber on Zirconium Oxide Furnace

EnviroEnergy Solutions have designed and fabricated complete recovery and Air Pollution Control System for ATI plant in Albany Oregon.

Final polishing of the exhaust is performed by our WESP unit.

Two Pass Multistage self- cleaning WESP delivering Zero Opacity on Metal oxide furnace

HIGH VOLTAGE IS OFF AT THE WESP

OPACITY IS MORE THEN 60%

HIGH VOLTAGE IS ON AT THE WESP

Two pass WESP unit is delivering ZERO OPACITY at the outlet from metal oxide furnace.

The WESP Capacity is up to 30,000 ACFM @ 130 Deg F

WESP System delivering Zero Opacity

The application is Waste to Energy combustion with oxidizing chamber capacity 12,000 ACFM @ 150 Deg.F with scrubber/quencher upstream from the WESP cooling the gas down from 400 Deg.F

Opacity

Figure 4-1. Appearance of Plumes at 10:13 on 3 AUG 98

Figure 5-4. Plume Appearance on August 4 at 10:36
with Sun Behind Photographer

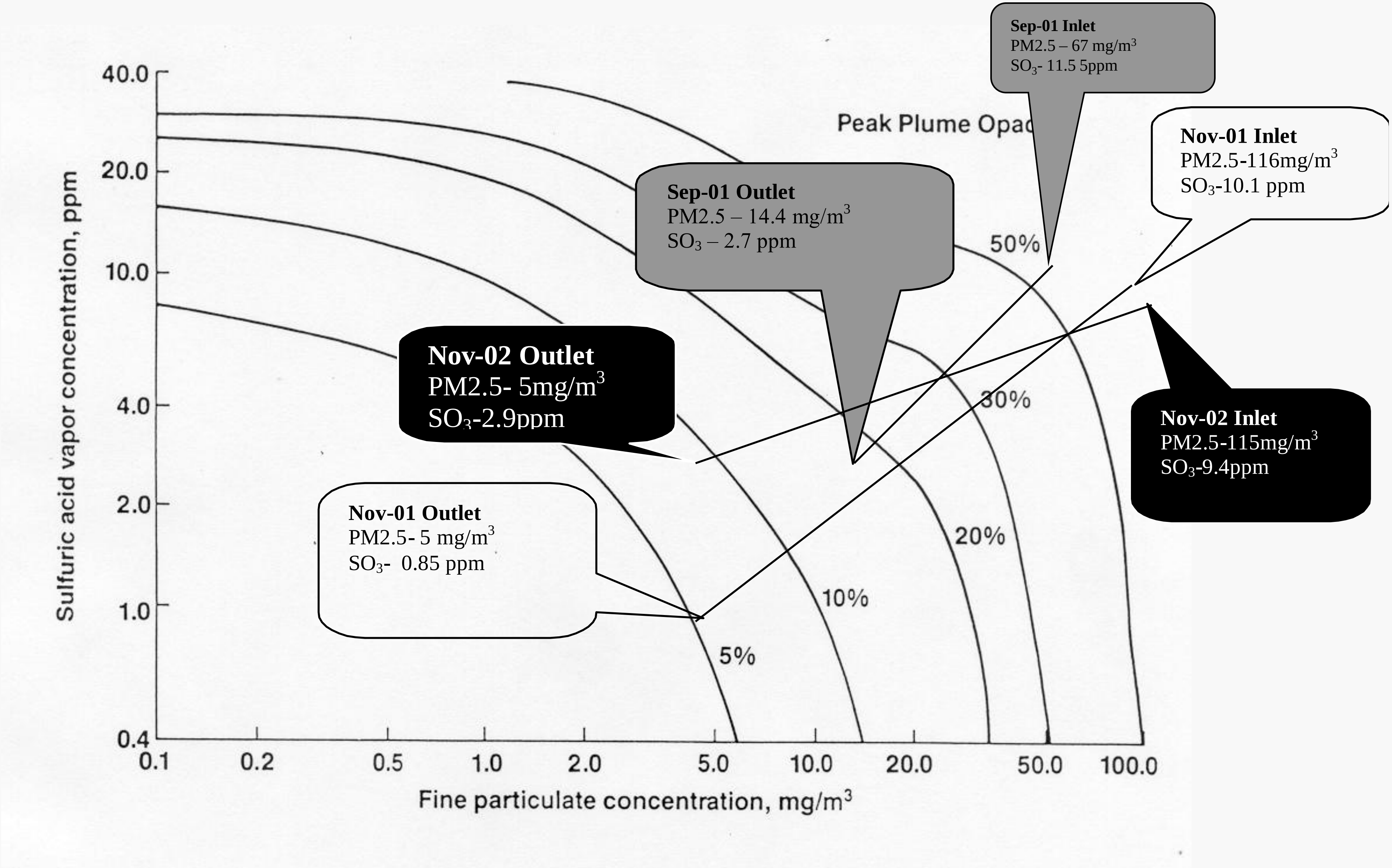
Typical Performance for WESP

– Capable of removing particles as small as 0.1 micron with 99.9+% efficiency
– Equally as effective in removal of acid mist droplets, uncollected in scrubber
– Near perfect mist elimination minimizing droplet carryover

Design Factors

- Particulate or droplet concentration and size
- Velocity of the gas through the WESP
- Collection surface area
- WESP operating voltage and current

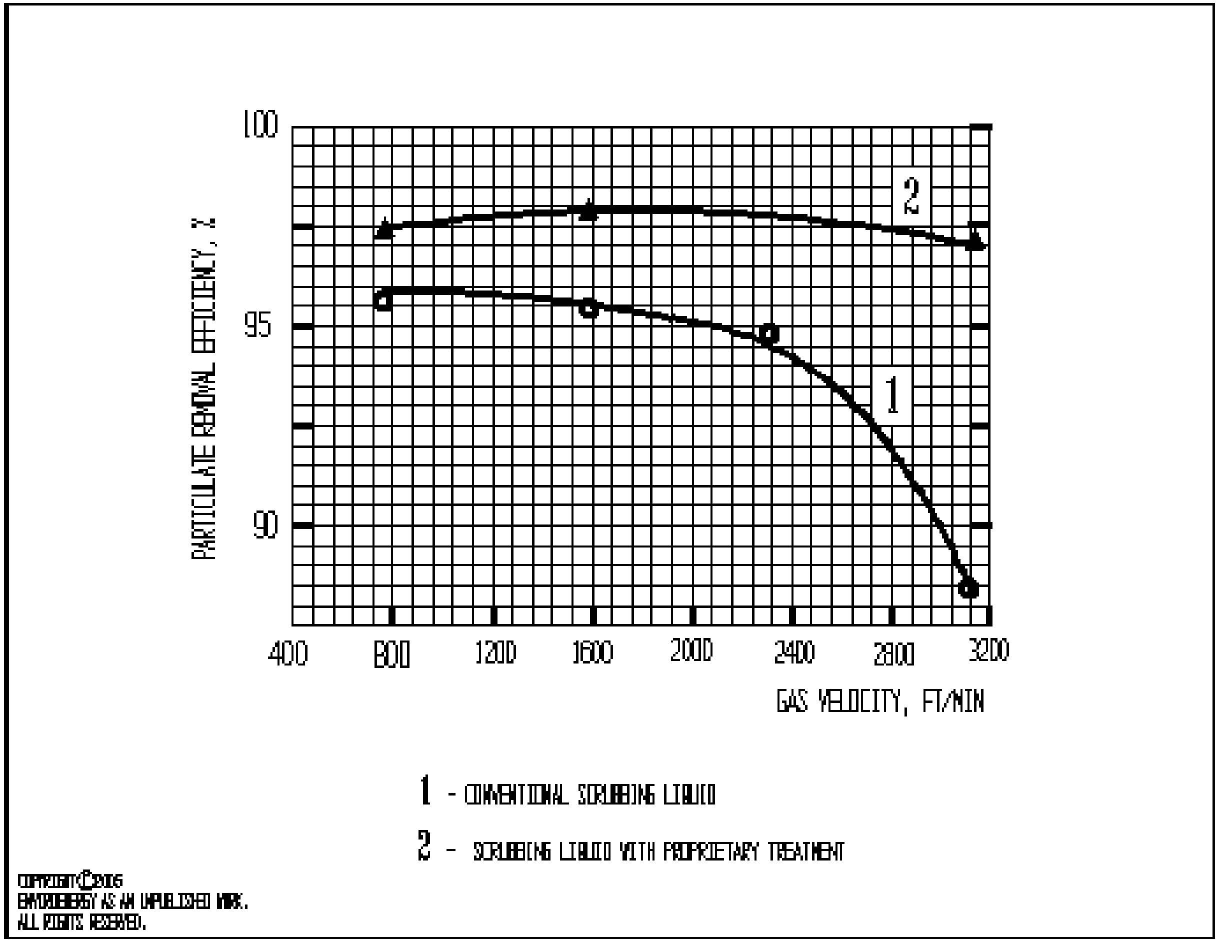
Iso-Opacity Chart of Test Results



Elemental Mercury Removal

TEST	ELEMENTAL MERCURY REMOVAL EFFICIENCY, % (TEST TEMPERATURE – 130 F)	
	CONVENTIONAL SCRUBBING CONDITIONS	SCRUBBING CONDITIONS WITH PROPRIETARY TREATMENT
1	30	86
2	24	83
3	26	85
4	33	93
AVERAGE	28.2	87.2

Improvement of Scrubber's efficiency by liquid treatment



The Message

- ENVIROENERGY WESP is a proven technology for removal of $PM_{2.5}$, Metals, H_2SO_4, etc. from combustion or any other process source flue gas

- WESP can provide “multi-pollutant” control in a single, integrated device

- WESP is the most cost-effective solution for compliance with the Industrial Boiler MACT Regulation

Wet ESP Markets

Focus	Industrial	Utility
HIGH	**Boiler MACT**	**Hybrid dry-wet ESP**
Prospects	Industrial Boilers burning wood, oil, or coal over 10mmBTU	Coal-fired utilities plants with dry ESPs 50-200MW in size
Driver	EPA Boiler MACT Standard	State Opacity Limits
HIGH	**Process Industries**	**FGD Application**
Prospects	industries such as textile, mining, plastics, steel, pulp & paper etc.	Coal-fired utilities with FGD or planning to install FGD
Driver	EPA MACT standards State Regulations	EPA Acid Rain, Mercury & PM2.5 Standards

WHAT TO REMEMBER ABOUT THE WESP PROCESS

- **ELECTROSTATIC TECHNOLOGY FOR REMOVAL OF THE SOLID PARTICLES AND LIQUID DROPLETS FROM THE MOVING GAS STREAM IS THE ONLY TECHNOLOGY THAT DOES NOT INFLUENCE THE GAS MOVEMENT BUT APPLYING THE REMOVAL FORCE DIRECTLY ON THE PARTICLE .**

- **WET ELECTROSTATIC PRECIPITATOR (WESP) IS THE ONLY DEVICE ON THE MARKET THAT IS CAPABLE OF REMOVING MOST OF THE POLUTANTS IN THE SINGLE DEVICE WITH EFFICIENCY CLOSE TO 100%.**

- **BY REPLACING THE HIGH ENERGY VENTURI SCRUBBER WITH THE WESP THE PAY-BACK IS LESS THAN TWO YEARS AND AFTER THAT THE WESP BECOMES A MONEY MAKER FOR THE CLIENT PROVIDING DRAMATICK ENERGY SAVINGS**

WHAT TO REMEMBER FOR THE WESP SALE PROCESS (CONT.)

- **ENVIROENERGY PROPRIETARY PATENT PENDING WESP TECHNOLOGY IS PROVIDING ADDITIONAL BENEFITS FOR THE CLIENT INSURING TOTAL REMOVAL OF THE POLLUTANTS WITH 100% INCREASE OF THE ON LINE RELABILITY REGARDLESS OF THE PROCESS SWINGS.**

- **UNLIKE OTHER VENDORS THAT ARE PROVIDING ONLY ONE AVAILIBLE TO THEM WESP DESIGN, THAT IS NOT ALLWAYS IS THE BEST FOR THE APPLICATION ENVIROENERGY IS CURRENTLY PROVIDING UP FLOW, DOWN FLOW, DUAL FLOW AND CONDENSING WESP'S WITH HEXAGONAL , SQUARE AND ROUND TUBES AND CONDENSATION CAN BE ACCOMPLISHED BY LIQUID OR AIR COOLING AROUND THE COLLECTING TUBES.**

WHAT TO REMEMBER FOR THE WESP SALE PROCESS (CONT.)

- ENVIROENERGY IS CAPABLE TO DELIVER THE WESP SYSTEM ON THE TURN-KEY BASIS INCLUDING THE ZERO LIQUID DISCHARGE FOR WATER TREATMENT THAT IS VITALLY IMPORTANT FOR THE WESP OPERATION AND USUALLY IS REQUIRED BY THE CLIENT.
- THE COMBINED EXPERIENCE IN THE FIELD OF THE WET ESP AND WET SCRUBBING FOR THE KEY TECHNICAL PERSONNELL (MECHANICAL, CHEMICAL AND ELECTRICAL) AMOUNTS TO 120 YEARS.
- ENVIROENERGY KEY WESP PERSONNEL HAS MORE U.S. PATENTS AND TECHNICAL PUBLICATIONS IN THE FIELD OF WESP THAN ALL OTHER VENDORS COMBINED.

ENVROENERGY SUPERIOR ELEMENTS OF THE WESP

(PARTIAL LIST)

- **IONIZING ELECTRODES ARE CUSTOM DESIGNED FOR EACH JOB AND ARE OF RIGID SOLID STEEL CONSTRUCTION PROVIDING UP TO THREE TIMES MORE DENSITY OF ELCTRICAL FIELD THAN ANY COMPETING DESIGN.**
- **INSULATOR COMPARTMENTS HAVE DOUBLE PROTECTION FROM THE CONTAMINATION AND EQUIPPED WITH INDIVIDUAL SMALL ESP'S**
- **COMPUTERISED SIZING OF THE WESP AND RELATED HIGH VOLTAGE EQUIPMENT IS INSURING THE LONG LASTING HIGH EFFICINCY OPERATION REGARDLESS OF THE CHANGES IN THE GAS COMPOSITION AND PROCESS CONDITIONS.**