REINHOLD ENVIRONMENTAL Ltd.

2012 APC Round Table
& Expo Presentation

July 16-17, 2012, in Baltimore, MD / Hosted by Duke Energy, Entergy, FirstEnergy, Southern Company & TVA

Wet ESPs – More than Just Adding Water

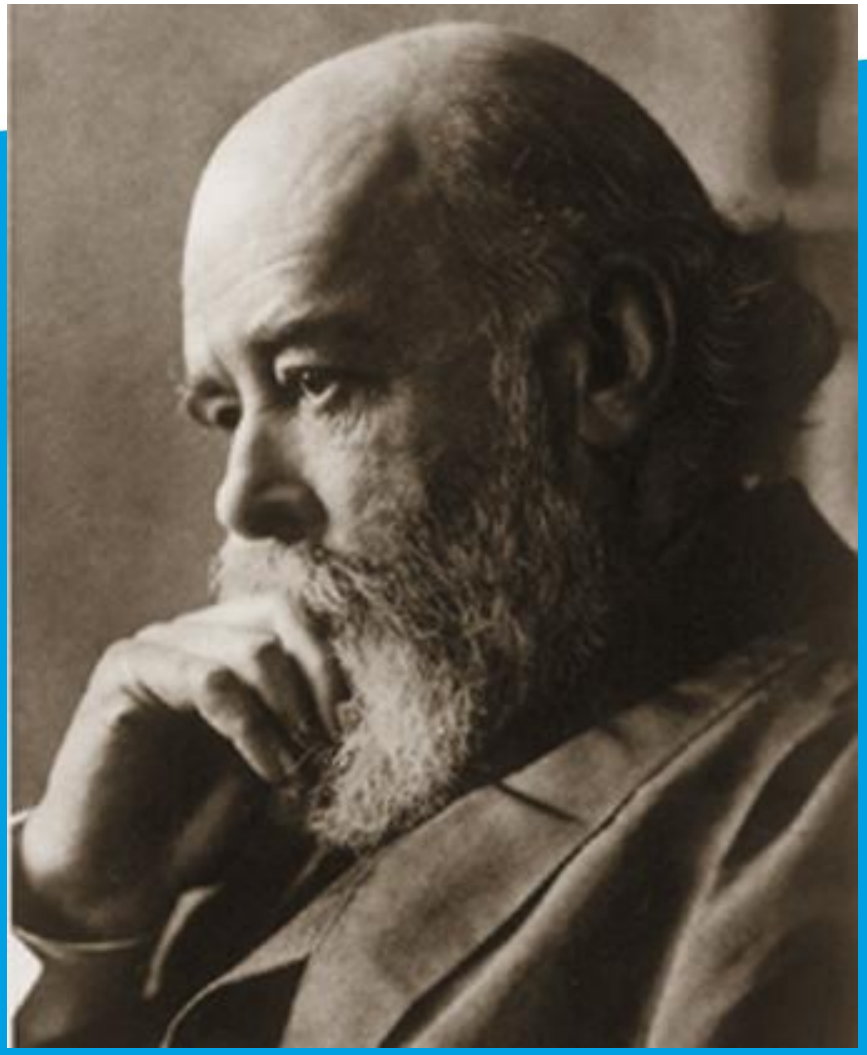
Clive Cottingham

Early Observations and Experiments

Lodge Cottrell

- Electrostatic Effects Observed from Gilbert in 1600, Franklin in 1745 and Nahrwold in 1878
- Sir Oliver Lodge with Alfred Walker attempted to remove lead dust from Smelter in UK 1885 – Unsuccessful due to poor power supply and very difficult dust
- Lodge took out a Patent for a High Voltage Rectifier Bridge in 1903 that showed an ESP removing particulate with barbed wire electrodes and plate collectors

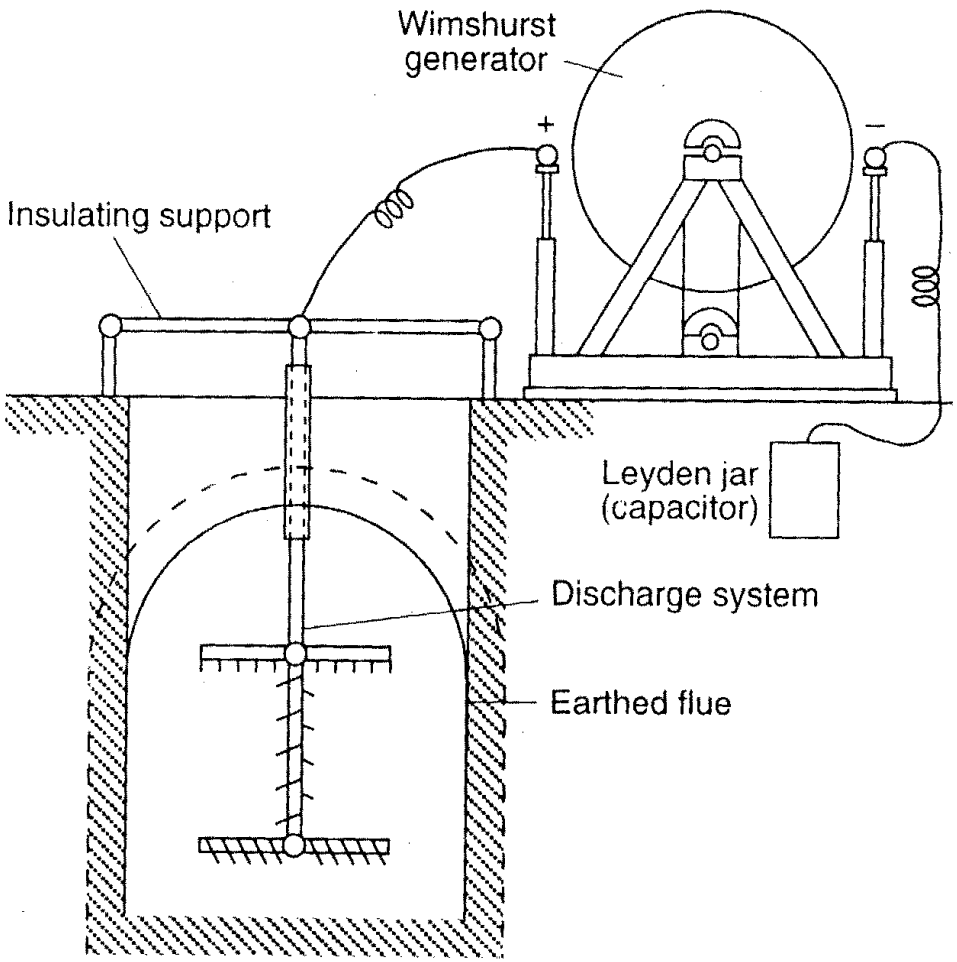
Lodge Cottrell



Sir Oliver Lodge

The first attempt at an ESP
Lead Fume Removal

Lodge Cottrell



The Contribution by Cottrell & Schmidt

Lodge Cottrell

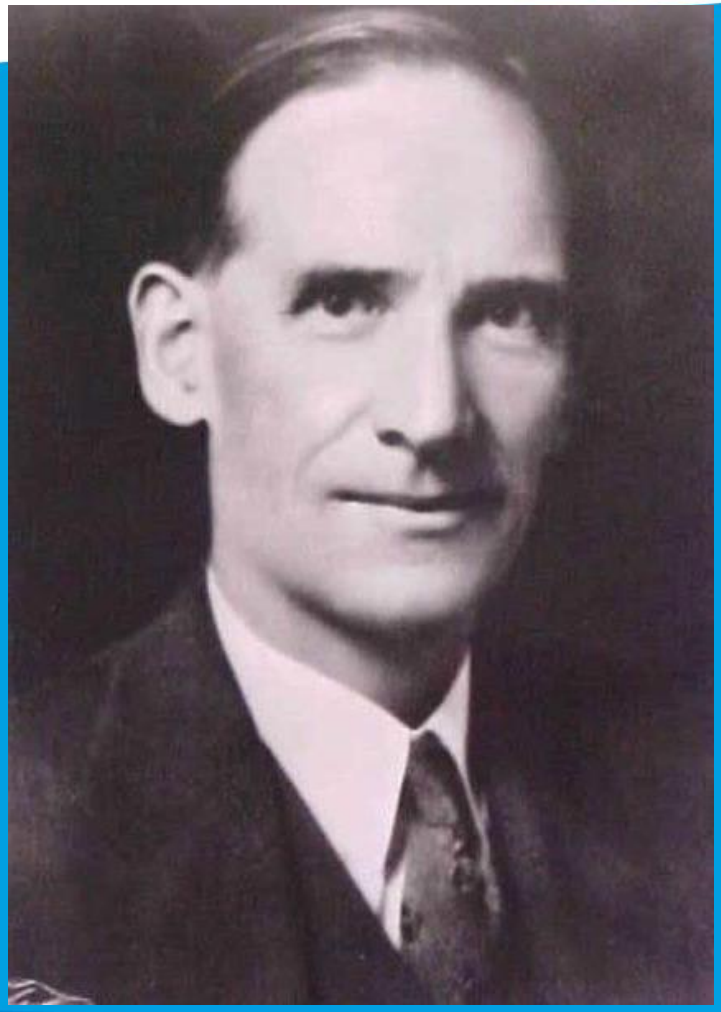
- **Major Break through by Dr Frederick Cottrell in 1906 with the development of a High Voltage AC Transformer coupled with a Synchronous Mechanical Switch Rectifier.**

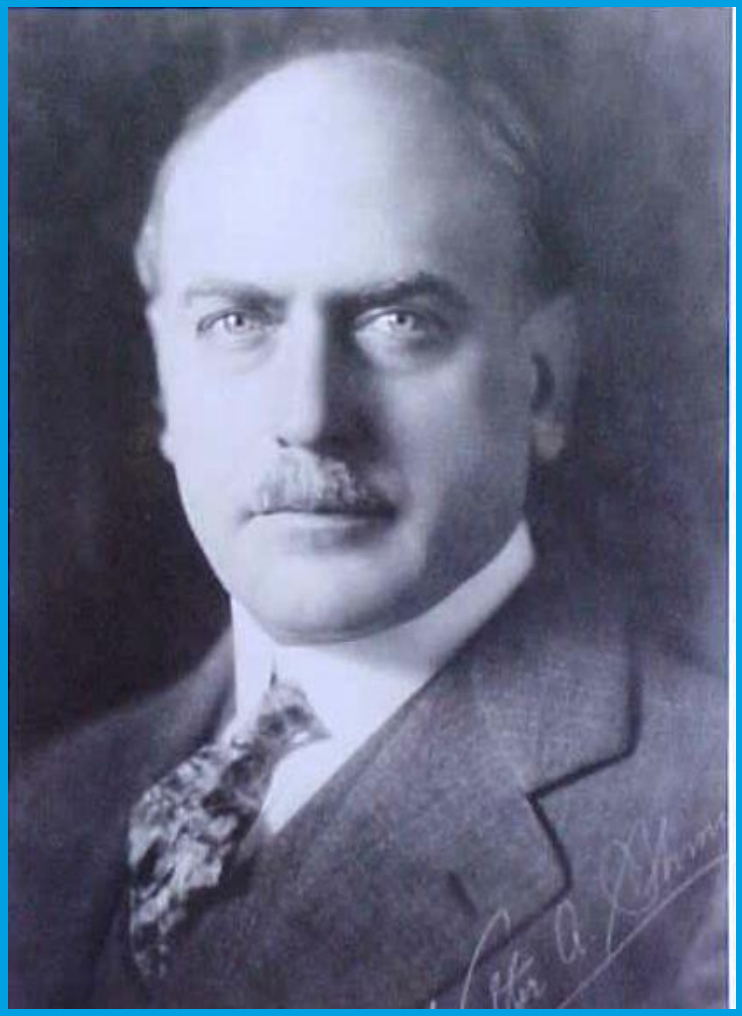
- **Vastly superior to earlier equipment and led to an ESP to collect Sulphuric Acid Mist at Pinole California in 1907 – 200 cfm**

- **ESP development was enhanced by Walter Schmidt's development of the fine wire Discharge Electrode – In 1912 an ESP was installed at the Riversdale Portland Cement Works handling 1,000,000 cfm – 50 yrs life**

Frederick Cottrell & Walter Schmidt

Lodge Cottrell





Early Installations

1884	Lead fumes – roaster	Bagillt, Wales, UK
1907	Sulphuric acid mist – contact process gases	Pinhole, CA, USA
1910	Lead zinc – smelter	Balaklala, CA, USA
1912	Cement kiln dust	Riverside, CA, USA
1912	Lead fume – converters	Garfield, UT, USA
1913	Bullion recovery-slimes	Niagara Falls, NJ, USA
1914	Lead – Dwight Lloyd sinter	Tooele, UT, USA
1914	Lead – blast furnace	Trail, B.C., Canada
1914	Cleaning roaster off gases – sulphuric acid production	Germany
1915	Lime inj. chlorine collection	Niagara Falls, USA
1915	Tar removal – towns gas	Portland, OR, USA
1915	Carbon from calcium carbide furnaces	Germany
1915	Ventilation air cleaning	New Haven, CT, USA
1915	Dehydration crude oils	CA, USA
1916	Paper pulp alkali salt	Canada
1917	Hot BF gas cleaning	Skinningrove, UK
1918	Copper smelter plants [19]	Japan
1919	Copper smelter – central gas cleaning. 2 000 000 cfm	Anaconda, MT, USA

- **Many designs used 5 inch Tubes (following Cottrell)**
  - **Garfield Smelter had 2520 x 10 ft Tubes with 10G wire DE handling 200,000 cfm**
- **Anaconda Smelter – experiments with 12 and 36 inch tubes – kV's up to 150 Kv. Final arrangement was Vertical flow Corrugated Plates – 700,000 cfm**
- **48 inch Dia was also investigated but had operational problems.**
- **Wide spacing is not a new concept !**

The Wet ESPs is a Unique application for ESPs.

Lodge Cottrell

No other Saturated Gas particulate removal system can achieve the low Emissions that are capable of being achieved by WESPs

Applications include:-
Acid Gas Particulate removal from Utility Boilers

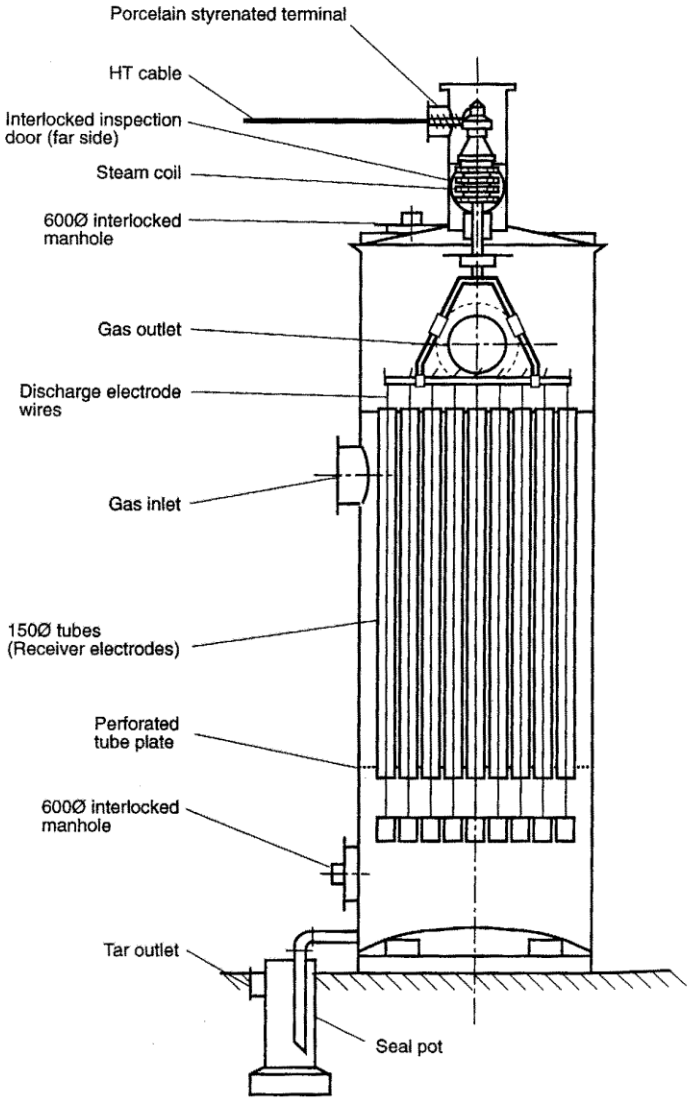
Acid Gas Particulate removal from Industrial Processes such as non Ferrous Smelters, MSW and Industrial Waste Incinerators.

Particulate removal from Toxic Explosive applications in Steel works

TYPICAL ARRANGEMENTS OF WESPS

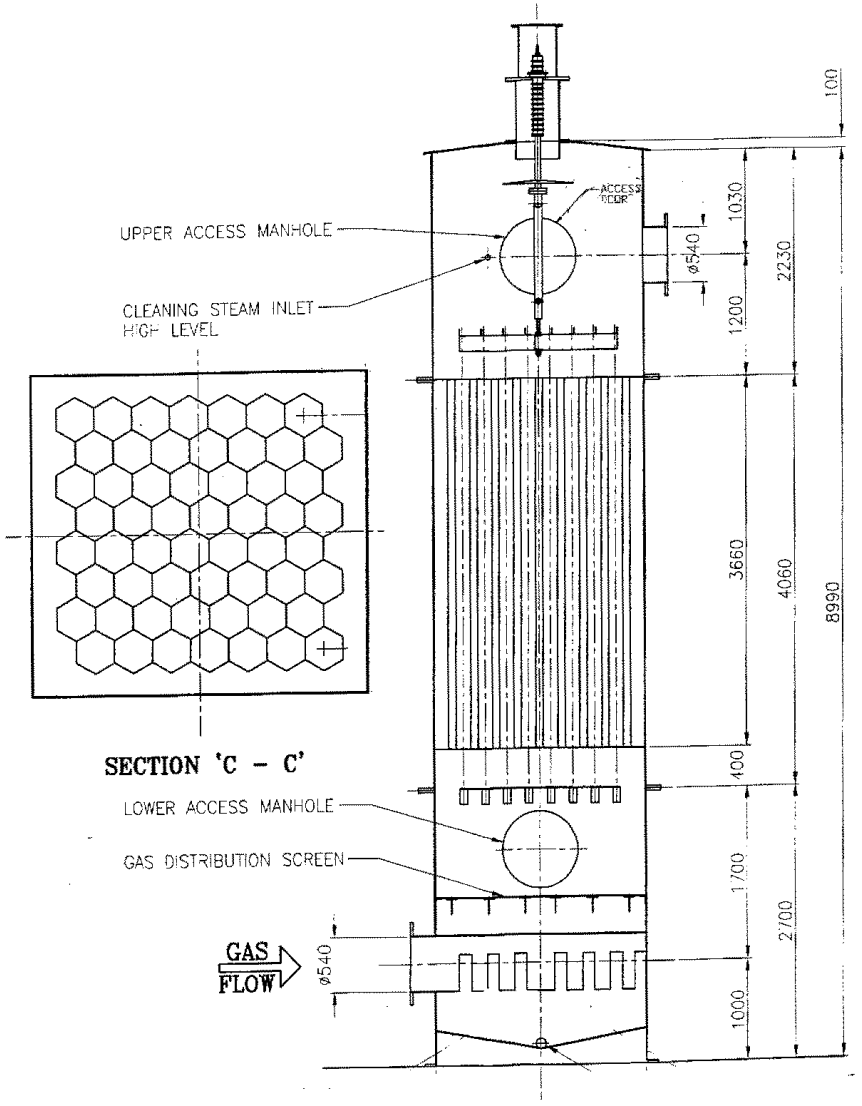
Typical Vertical Tube ESP - Detarrer

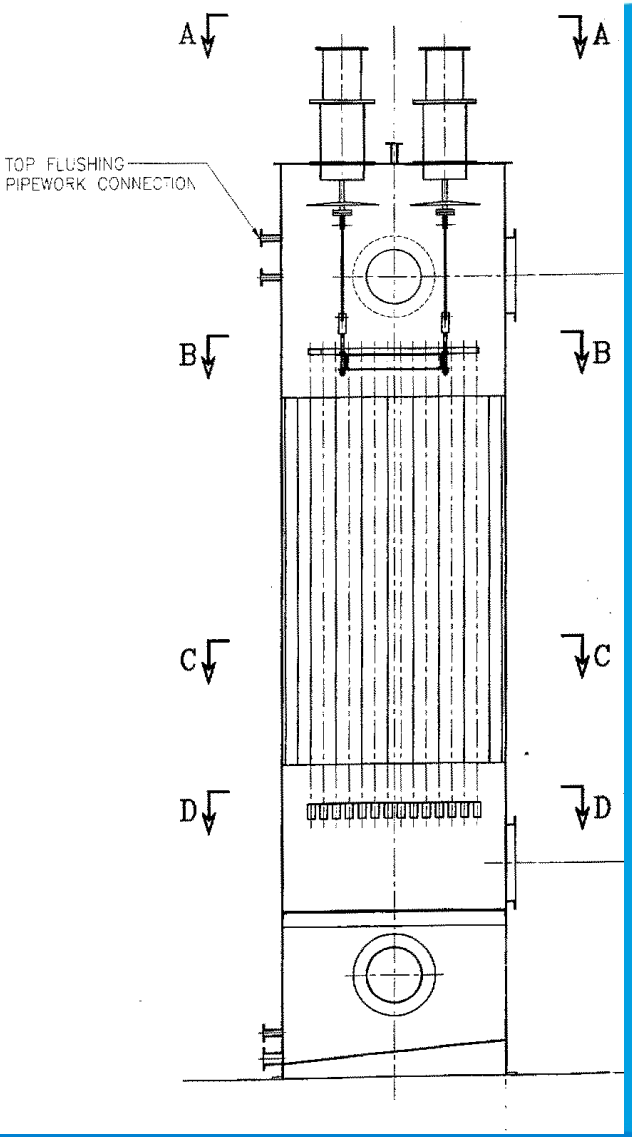
Lodge Cottrell



Hexagonal Tube Vertical Flow WESP

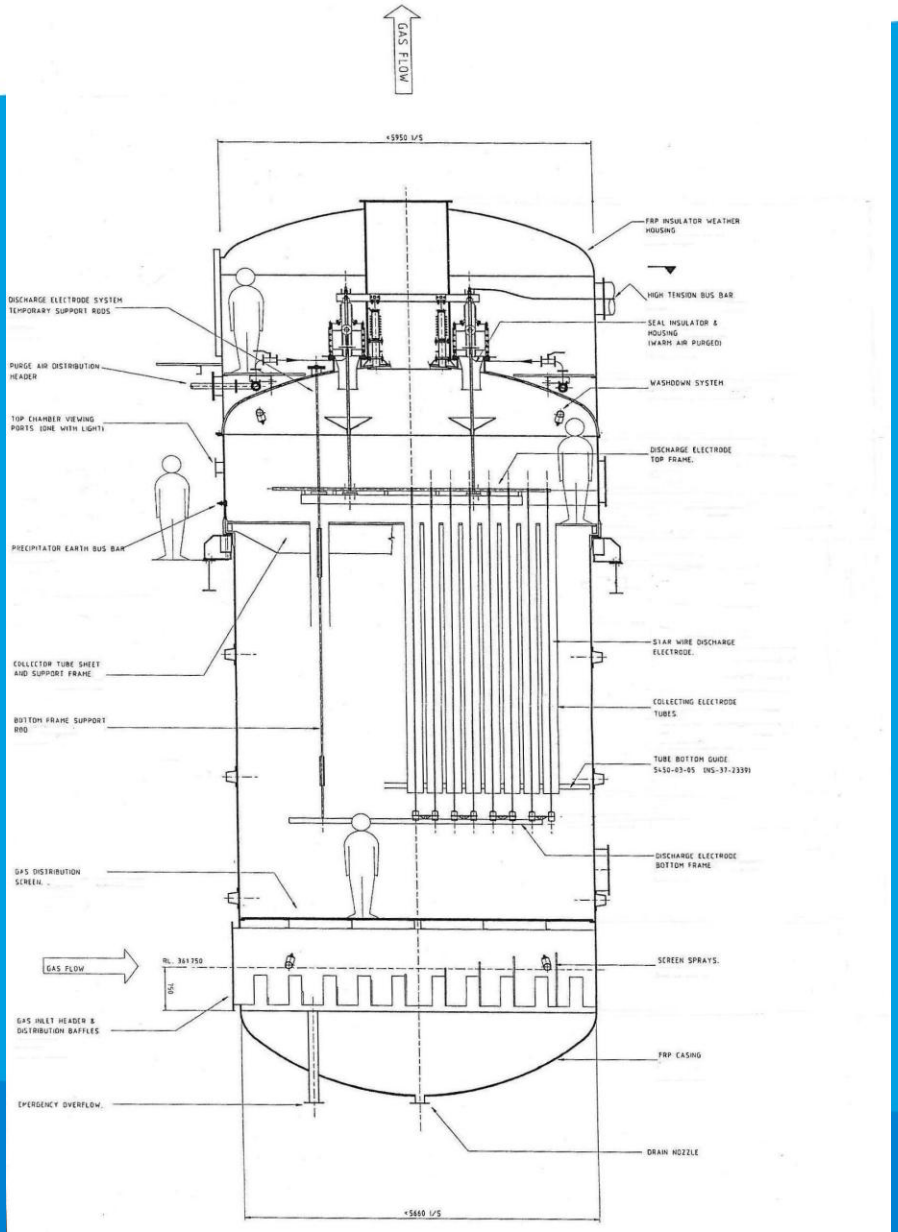
Lodge Cottrell





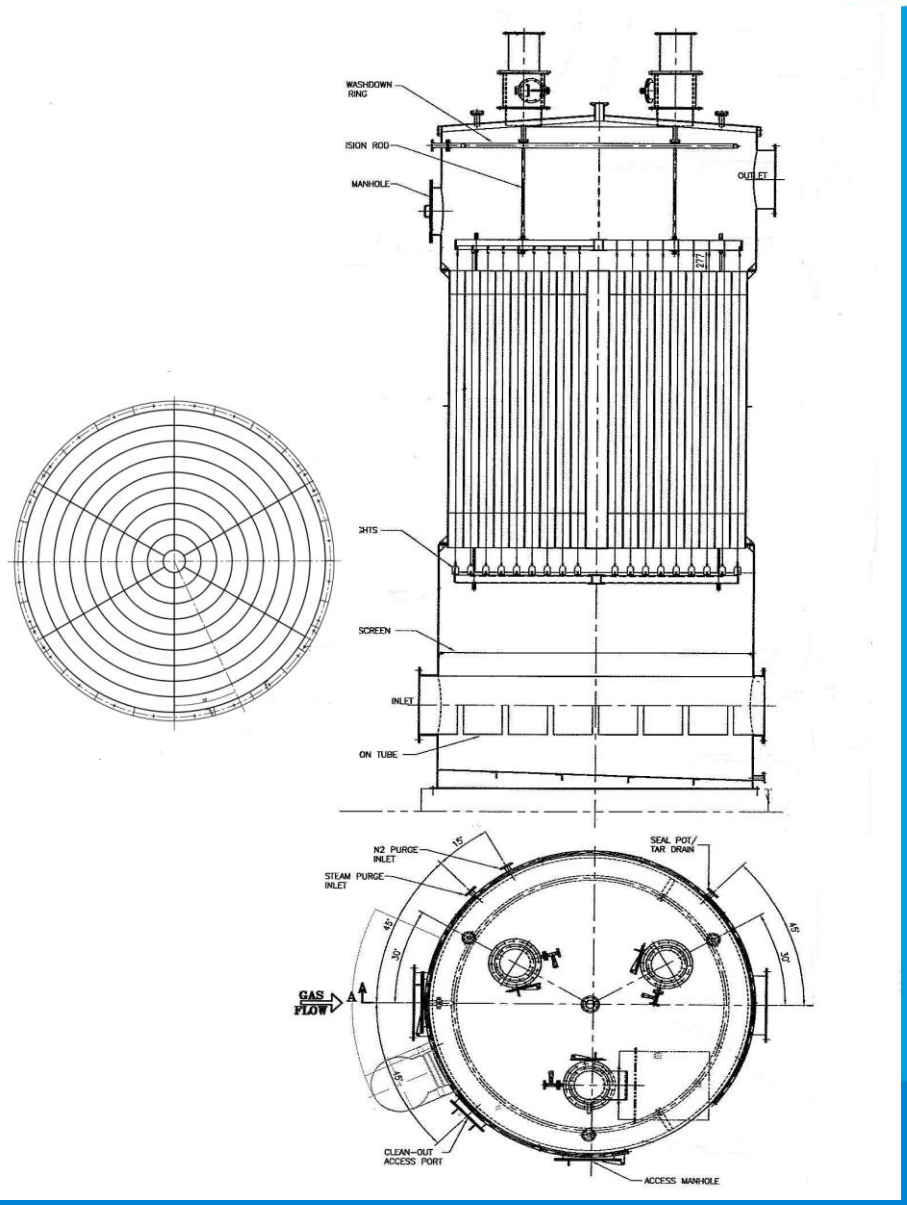
Vertical Flow Round Tube Acid Mist WESP

Lodge Cottrell



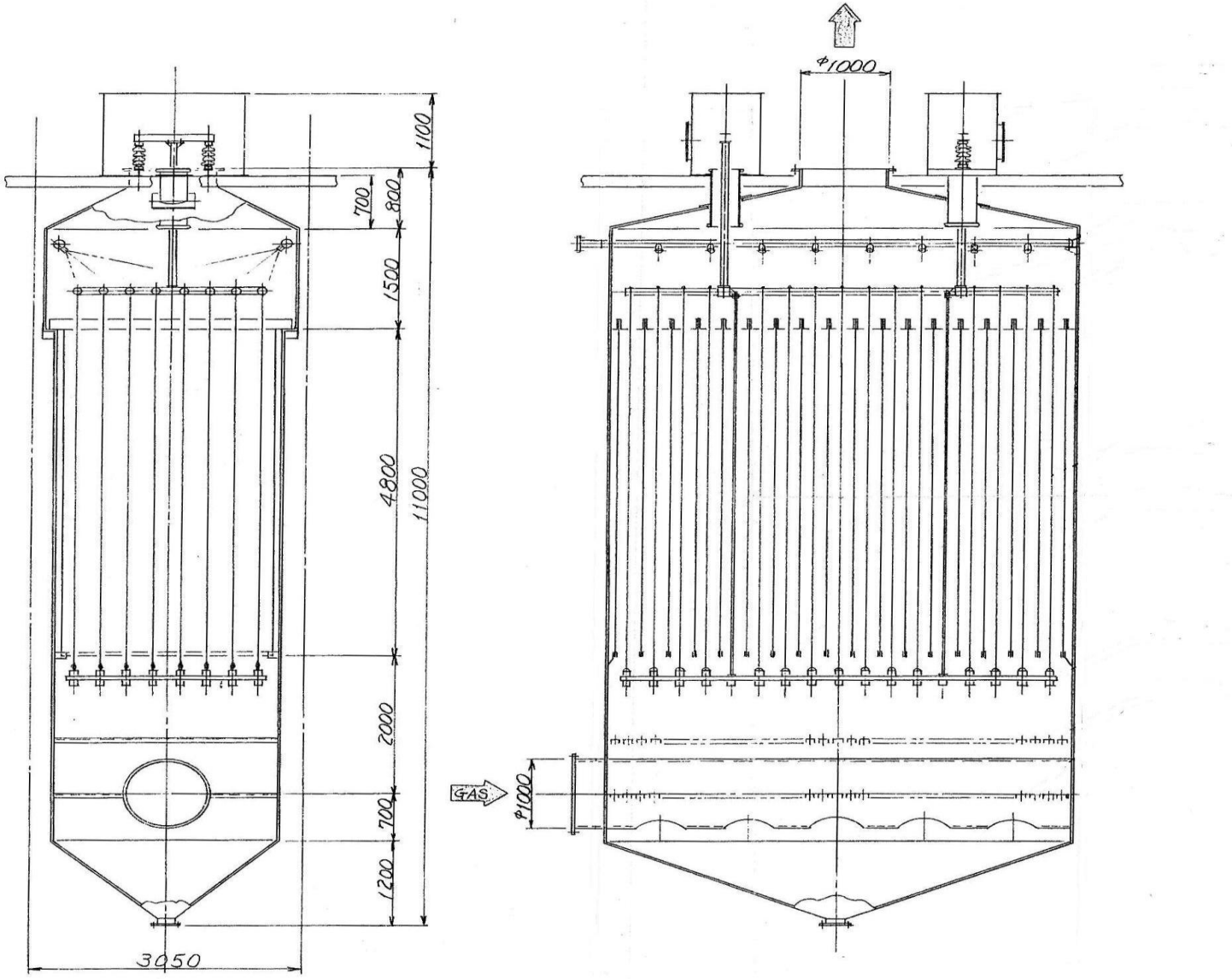
Vertical Flow Concentric Ring Tar removal WESP

Lodge Cottrell



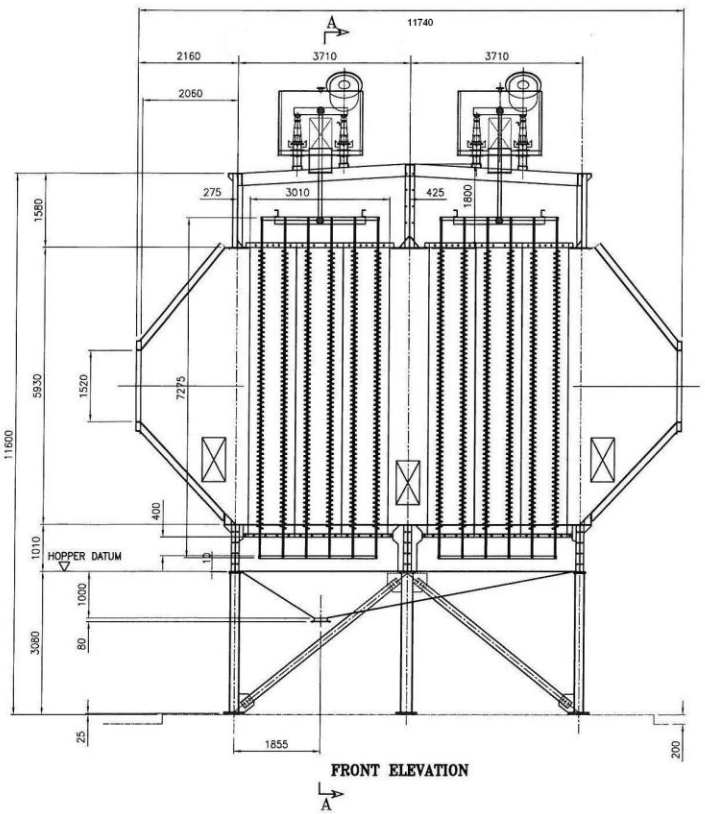
Vertical Flow Flat Plate Acid Mist WESP

Lodge Cottrell

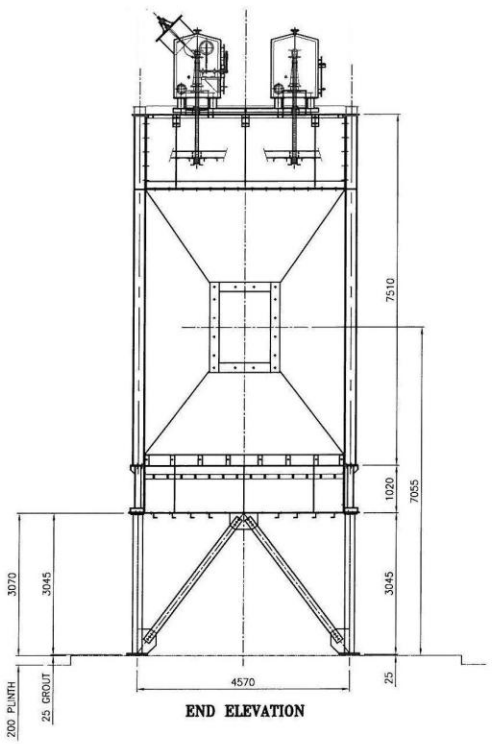


Horizontal Flow WESP Arrangement

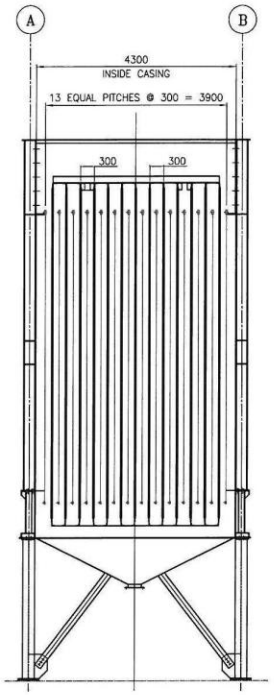
Lodge Cottrell



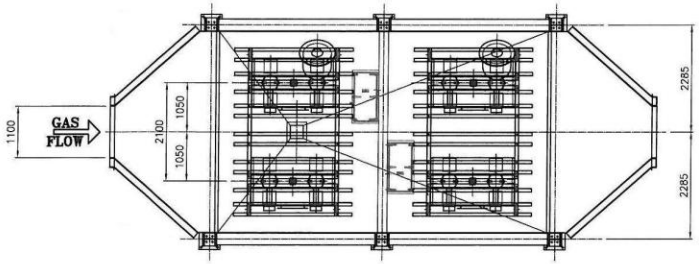
FRONT ELEVATION



END ELEVATION



SECTION A–A



PLAN VIEW

Comments on Arrangements

Lodge Cottrell

Horizontal WESPs are probably the most popular arrangement for Utility Applications.
Large Gas Volumes have to be Treated and this configuration results in a simpler arrangement.

The large Gas Volumes and relatively small Treatment Times – not unlike Heavy Fuel Oil applications - results in wide and short configurations at relatively high Gas Velocities.

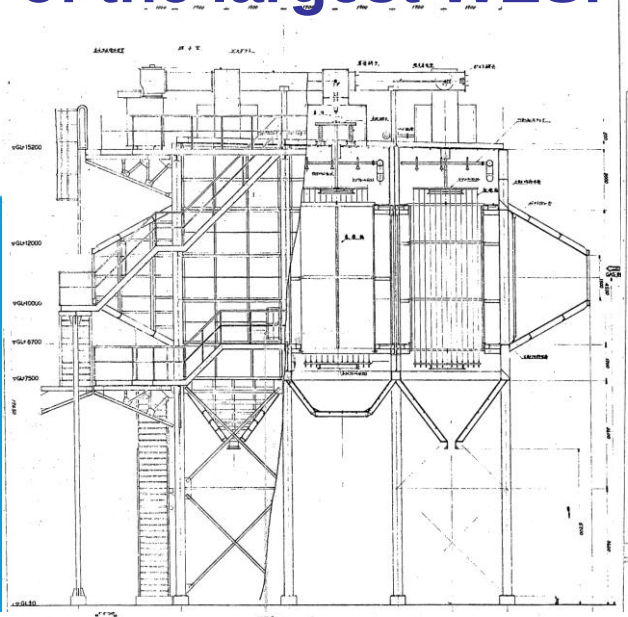
This is made more difficult as the Collecting Plates are restricted in height to 30 ft (9m).

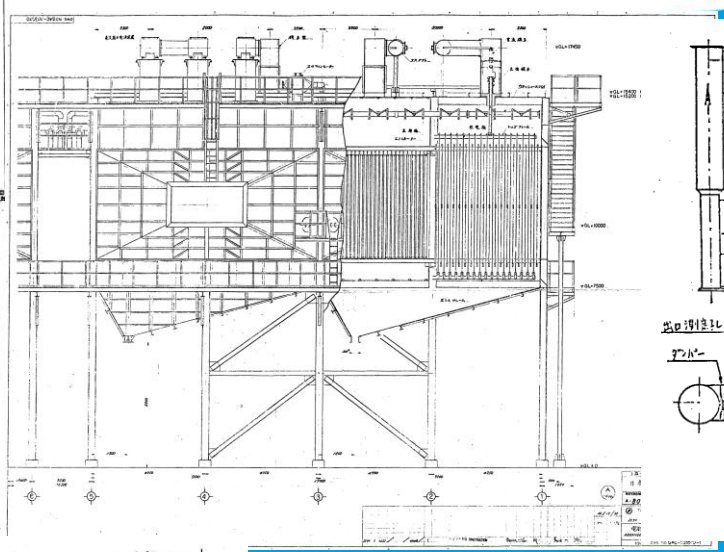
Large Gas Volume WESP - 778,000 ACFM. Ammonia Scrubber on Steel Sinter Strand

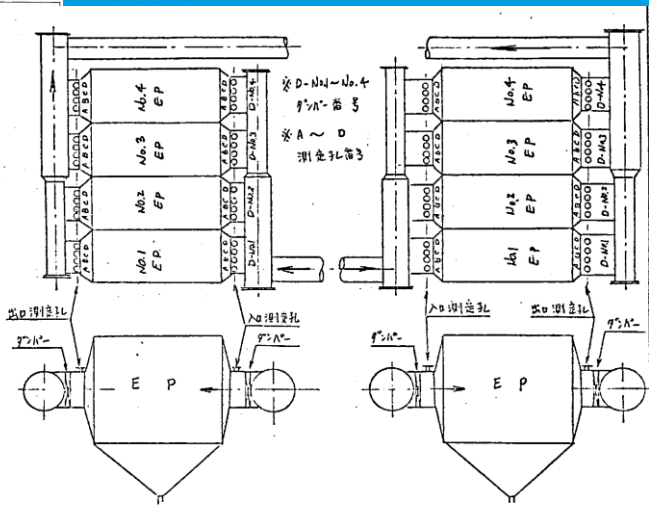
Lodge Cottrell

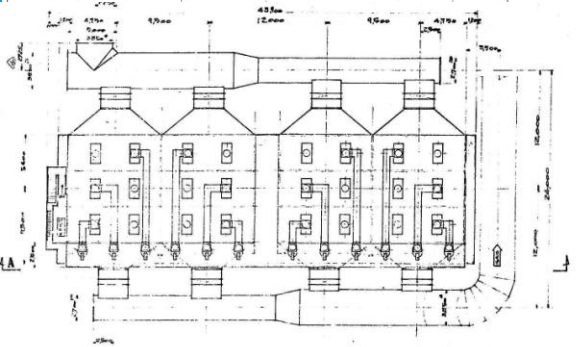
Configuration of Ogashima Mist WESP, One of the largest WESPs in the World in 1976

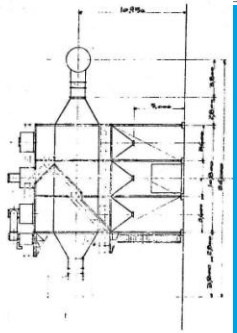
Lodge Cottrell

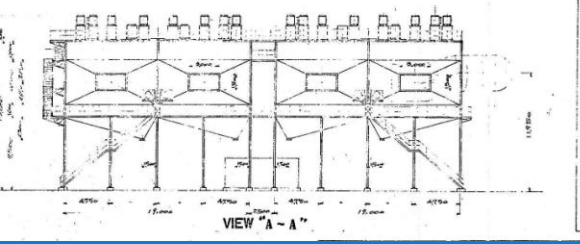


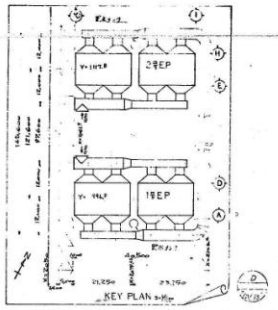








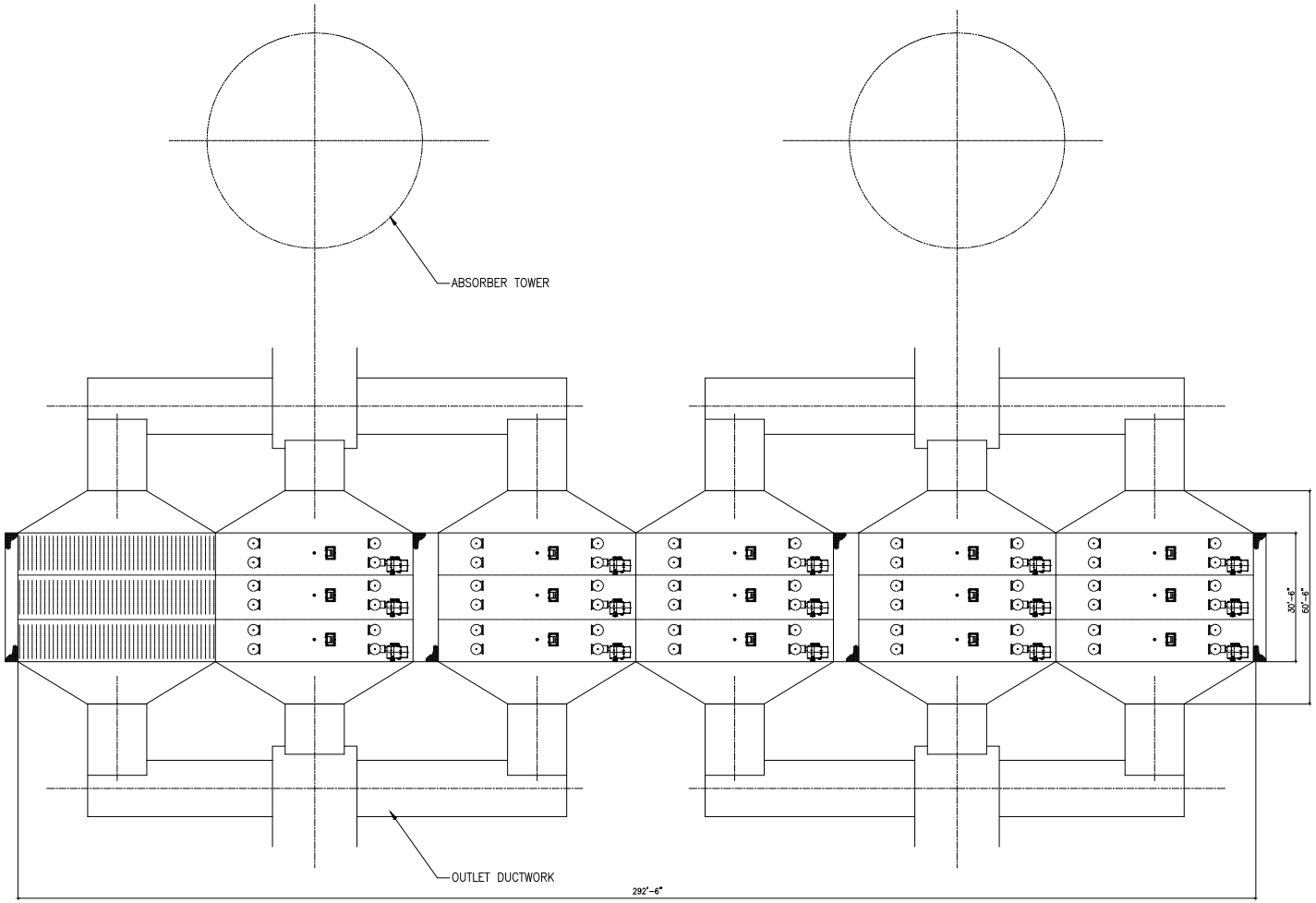




Commissioning Date	Sept 1976
Gas Volume	367 Am^3/s (778,000 ACFM)
Design Effy	92.5%
Configuration	4 x M250 3F 2.4 X 4.8 – 72
TR Sets	24 x 85kV(Peak) 400 mA

Typical Horizontal Flow WESP Arrangement

Lodge Cottrell



Alternative Arrangement for Restricted Space

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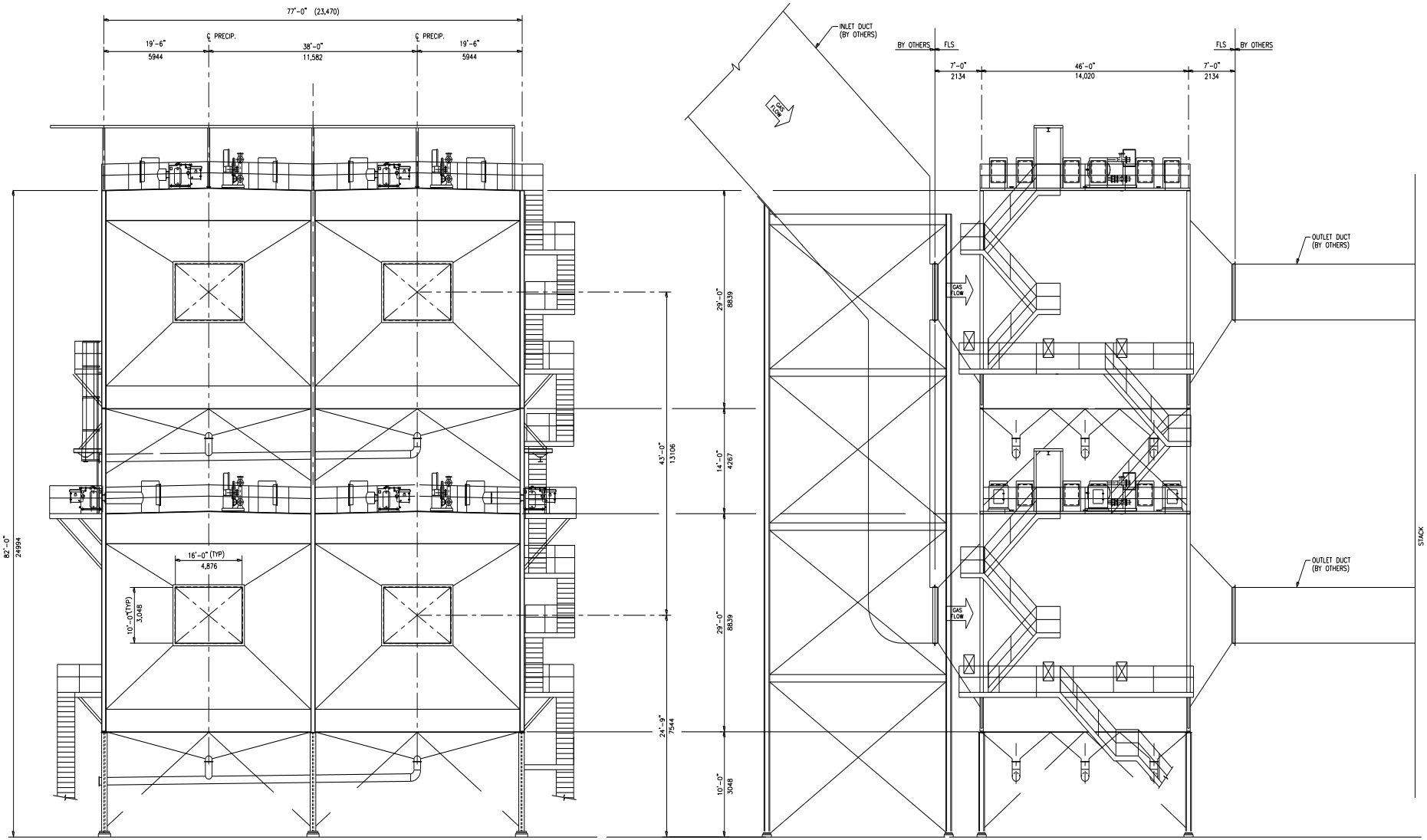


Early Application in the USA
AES Deepwater

Lodge Cottrell

This was a Contract won by Fluid Ionic Systems in the 1980's. Lodge Cottrell Inc (Dresser Industries) bought FIS.

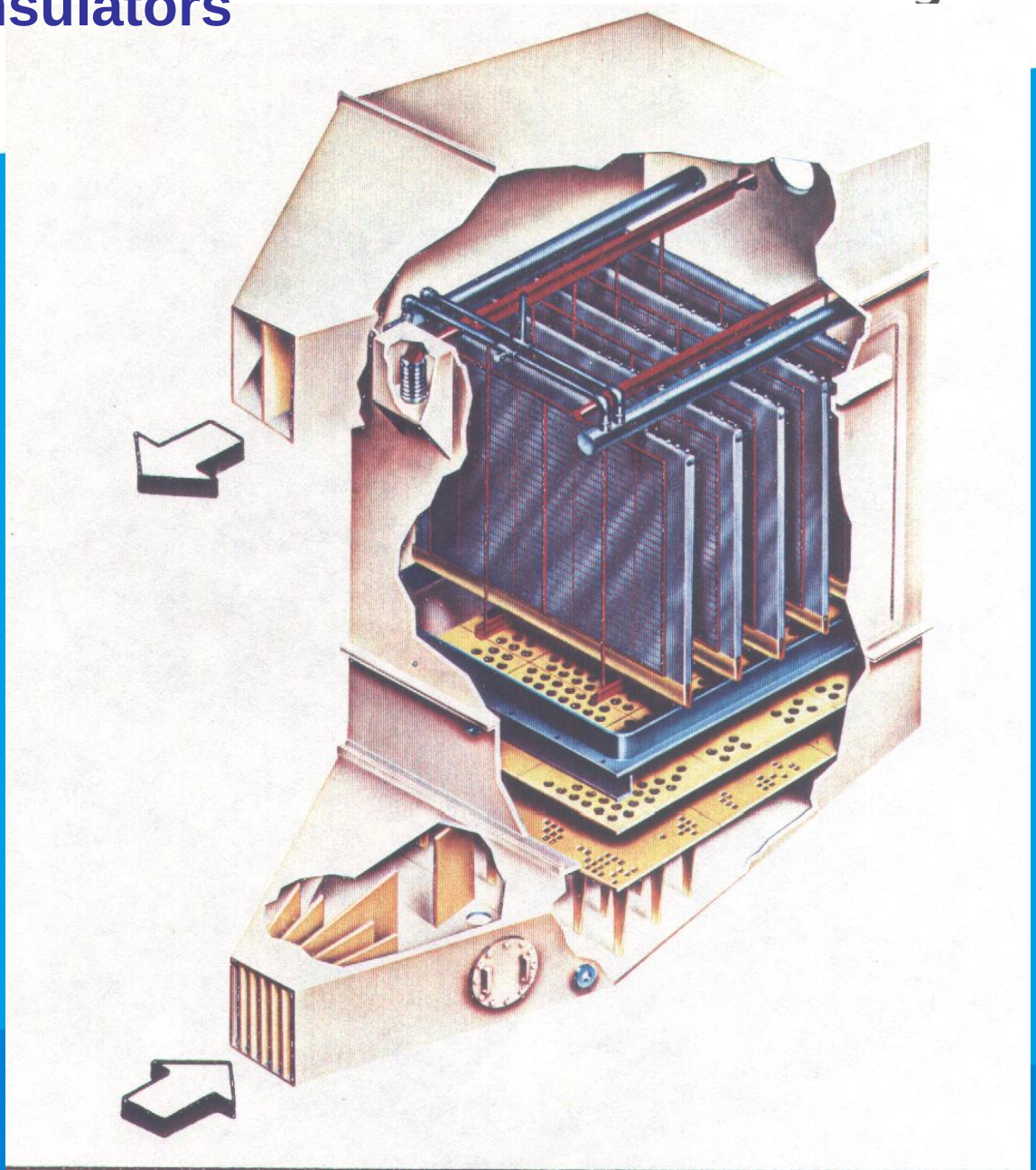
In the early 2000's FLS (Lodge Cottrell's owners) sold the FIS Technology to B&W.

The FIS Design was a Vertical Flow Flat Plate configuration. The collector Plates were continually washed with a weir type System.

Collector Plates were Balsa Wood with FRP Coating. Some problems occurred with delamination of the FRP & Wood. Some changes made with Alloy Collector plates & Spray type washing system.

Vertical Flow Flat Plate Outrigger Insulators

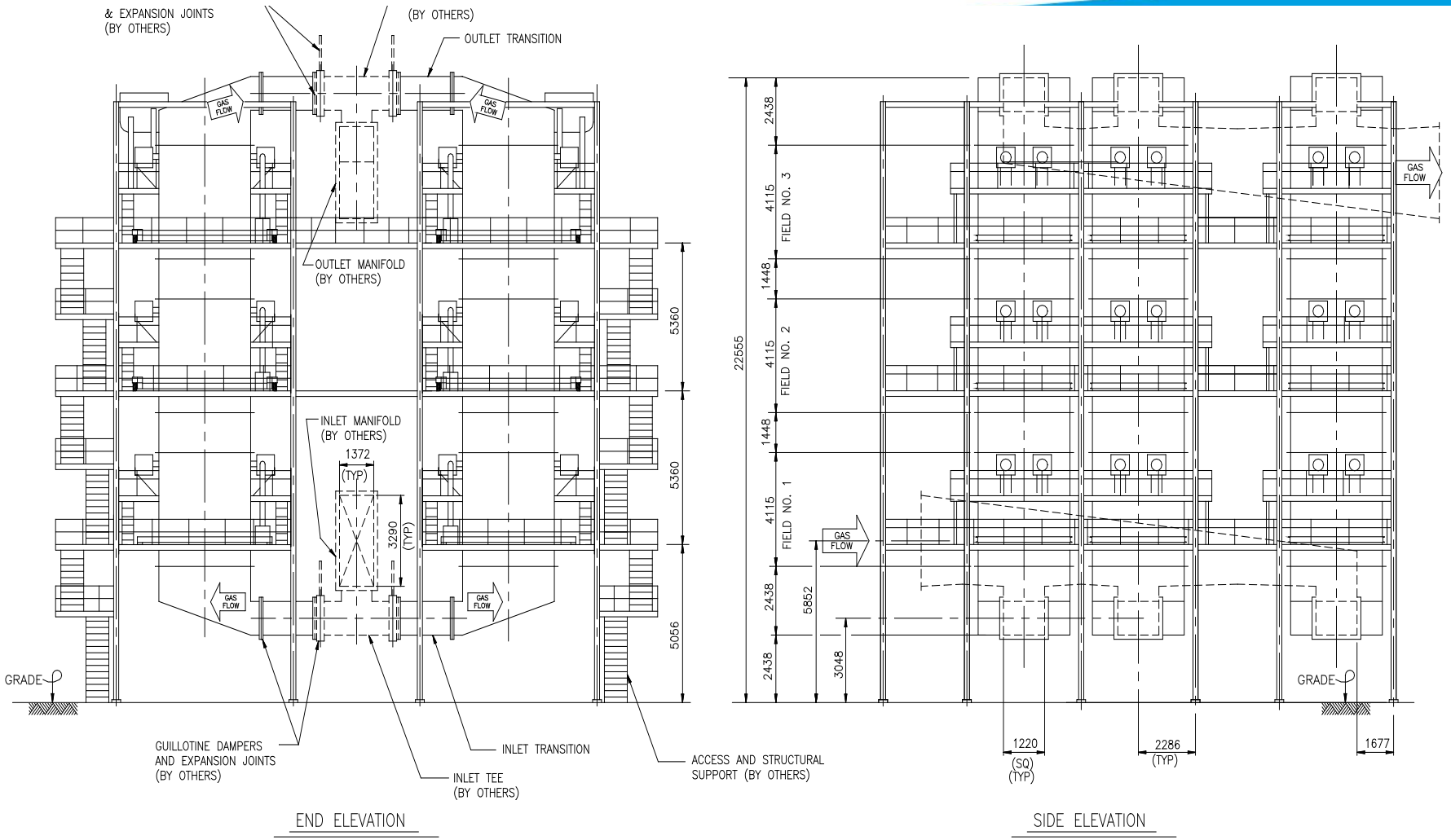
Lodge Cottrell



AES Deepwater – Vertical Flow WESPs

Lodge Cottrell

Vertical Flow stand alone Arrangement - Stacked Modular Units



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COLLECTING ELECTRODES

Requirements for Collecting Electrodes

Lodge Cottrell

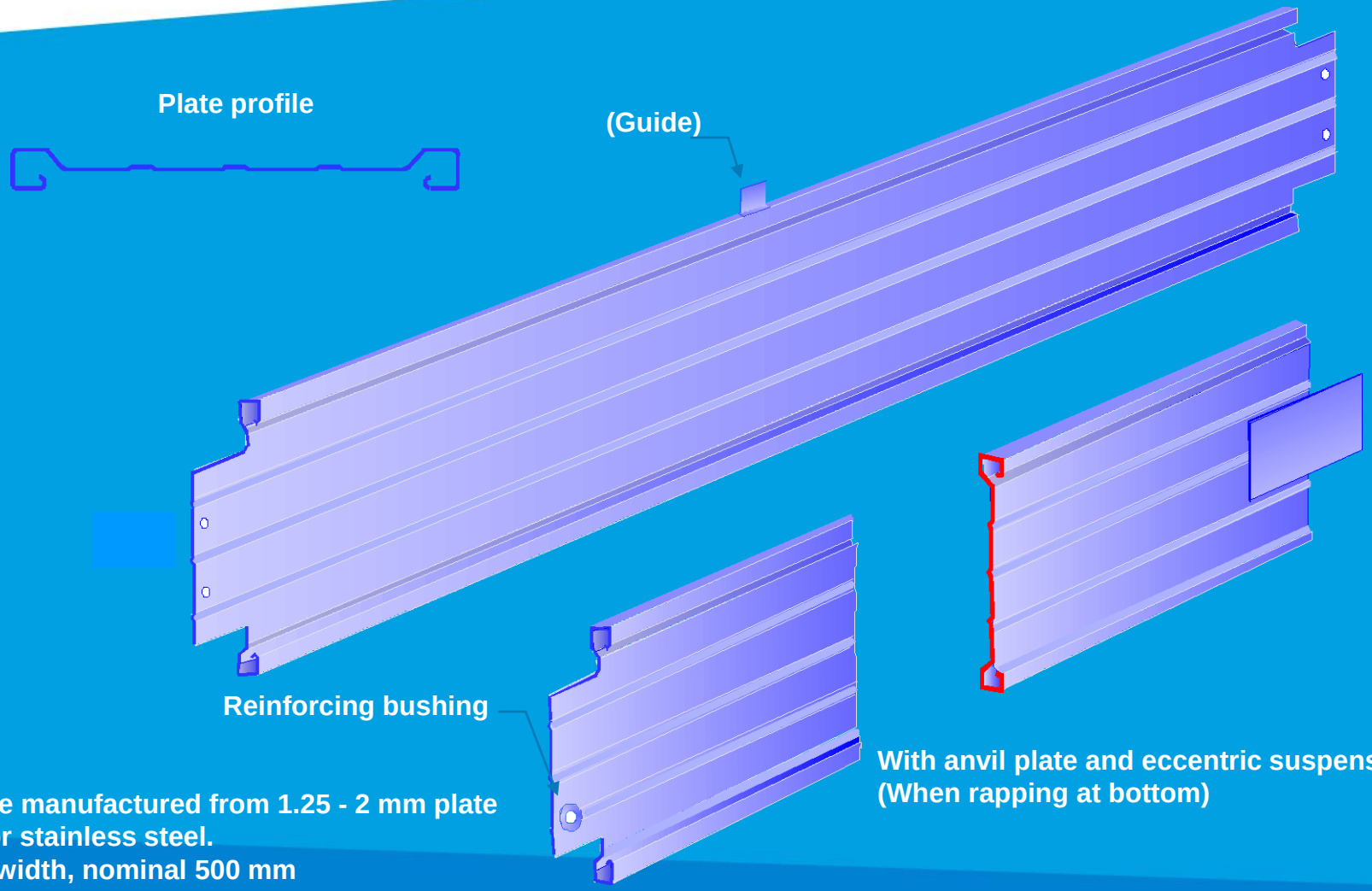
- Collector plates for Dry ESPs are a compromise between providing a relatively flat profile for the uniform electrical field, while being mechanically stable under conditions of Gas Flow, Temperature and Rapping Forces. Anti Reentrainment is also a consideration.

- Most Dry ESP CEs are cold rolled profiled plates and range in height up to 50 ft.

- WESPs still have some of the Dry ESP considerations, but they need a profile that is easily washed. For Alloy plates Cost is a major factor. – Many designs have been used. Reentrainmnet is not a consideration.

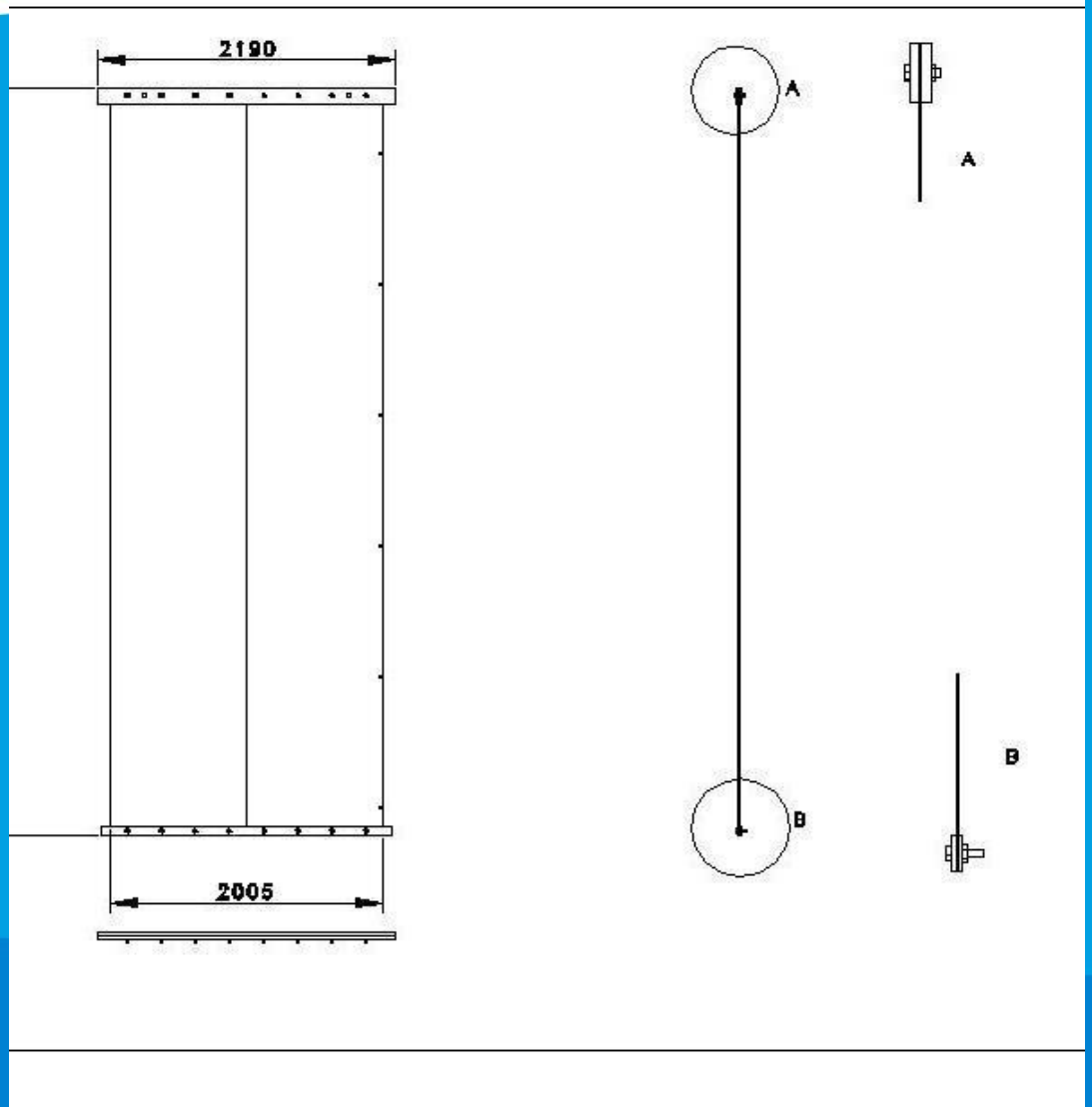
Cold Rolled Strip Plate Collecting Electrode
As used on Dry ESPs.
Similar configuration can be used for WESP

Lodge Cottrell



Can be manufactured from 1.25 - 2 mm plate
Mild or stainless steel.
Plate width, nominal 500 mm

Typical WESP Collector
Non Corrosive Gas



Collector Plate has to be made from 5 mm Material for stiffness. So too expensive for Alloy.

OK for Carbon Steel applications

Lodge Cottrell

DISCHARGE ELECTRODES

Factors Influencing Discharge Electrode Design

Lodge Cottrell

- The basic requirement of a Discharge Electrode is the same for the Dry and WESP designs.
  - When electrically energised they promote ionization of the process gas.
- In order to do this effectively under different operating conditions DEs have to have different Discharge Characteristics.
  - Dry – High Dust Loadings and/or Fine Dust require high emission DEs – Design of emitter.
  - Dry – Withstand Rapping forces and maintain straightness.
  - Wet – Dust removal can be carried out with simple wire DE. – No Rapping so strength not so important. But stability is important.
  - Wet – Removal of Acid Mist requires high emission design – High Current. This is also required in High Velocity situations (10 ft/s), to withstand Corona Suppression.

High and Standard Emission Electrodes

Lodge Cottrell

Corona Suppression

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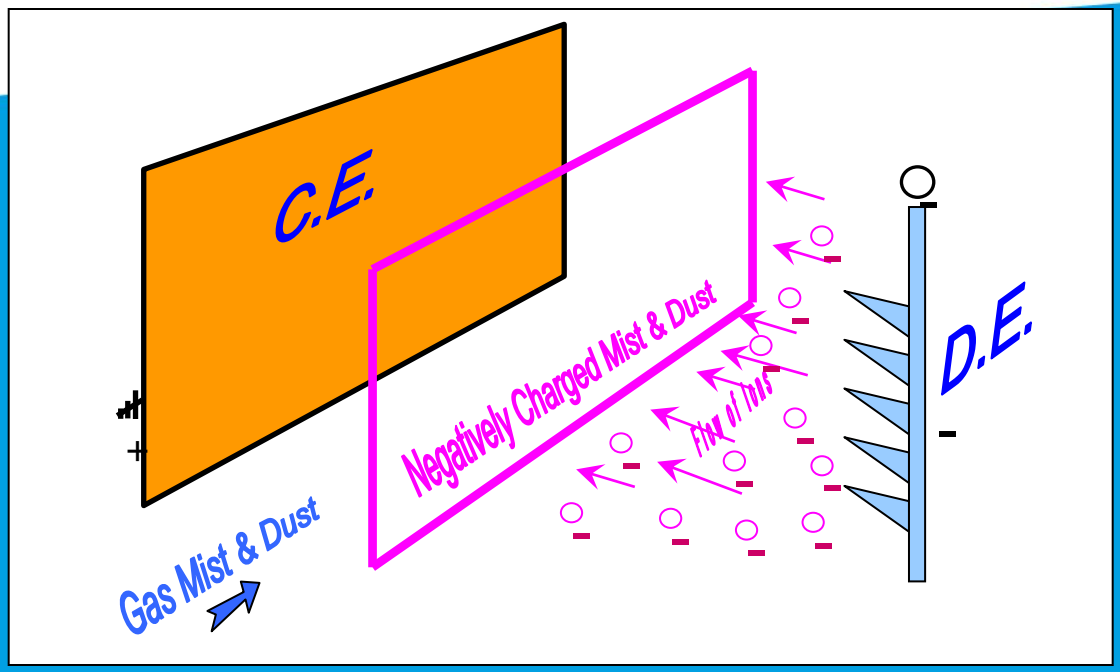
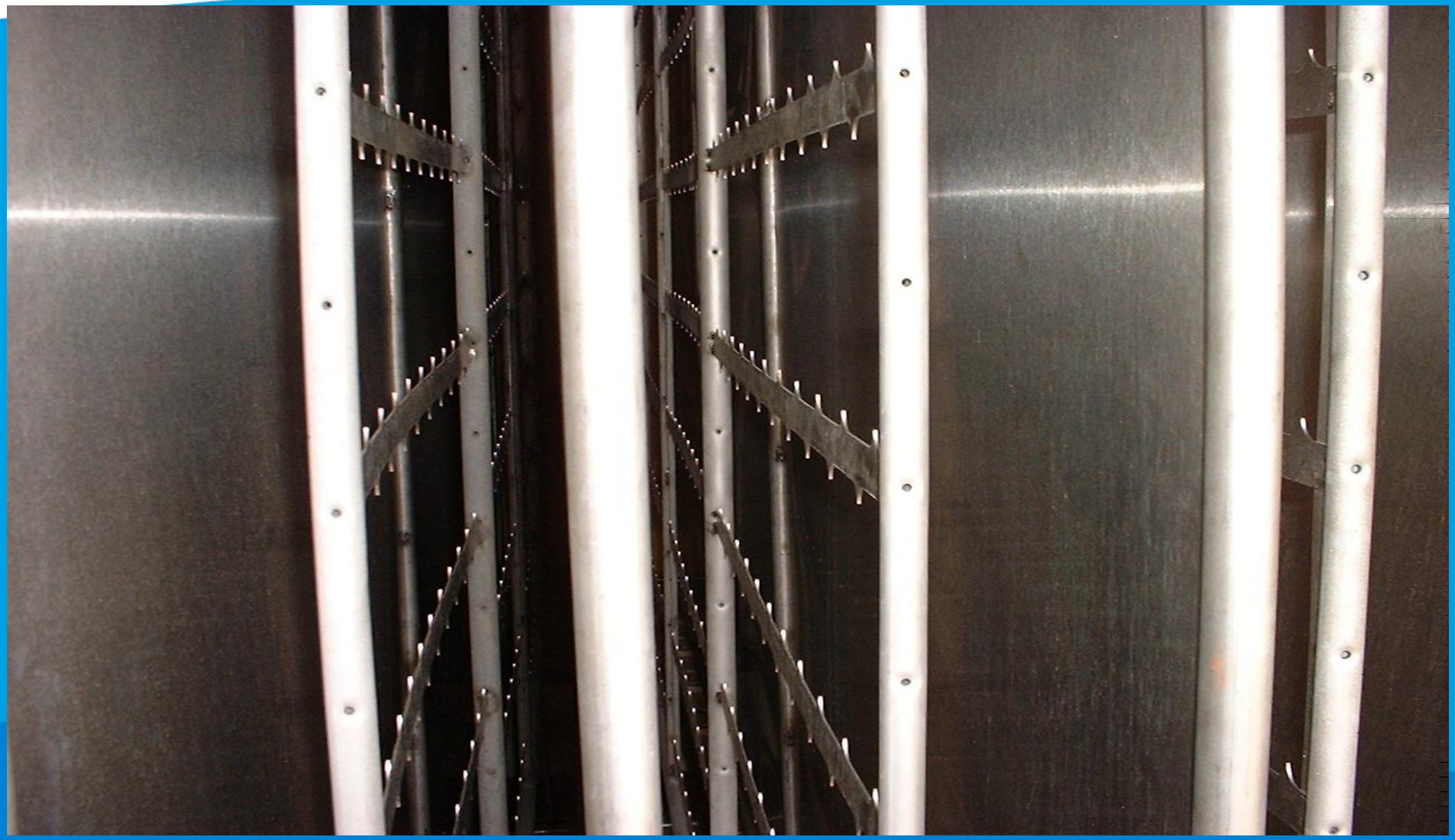


For Current to Flow, DE needs to 'See' +ve earthed CE.
Negatively Charged Mist & Dust Create a –ve 'Fog' that reduces Current Flow.
Effect increases with Fine Particles, due to larger surface area.
More Intense Corona Discharge required

High Emission DEs & Alloy CEs as Retrofitted into AES Deepwater

Lodge Cottrell



CE & DE Arrangement as used on Rectangular Alloy Tube WESP

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CLEANING THE ELECTRODES

Cleaning of Electrodes – Dry ESP

Lodge Cottrell

- Rapping of CE & DE system by hammers.
  - Dust removal to prevent reduced Electrical Clearances and maintain optimum Power Input.
  - Dust Reentrainment is inherently a problem
  - Correct Rapping sequencing is critical to efficient performance.

Cleaning of Electrodes - WESP

Lodge Cottrell

- Washing takes the place of Rapping.
  - Dust removal to prevent reduced Electrical Clearances
  - Remove Chloride build up which can cause excessive corrosion in a Sulphuric Acid environment.
  - Intermittent Washing can be used if Chlorides are not a problem – reduced water consumption.
- Water quality is important
  - Must not add to Chloride Burden
  - Solids (including dissolved Solids) could potentially add to the particulate emissions
  - Ph should be close to neutral

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INSULATORS

Some types of WESP Insulators

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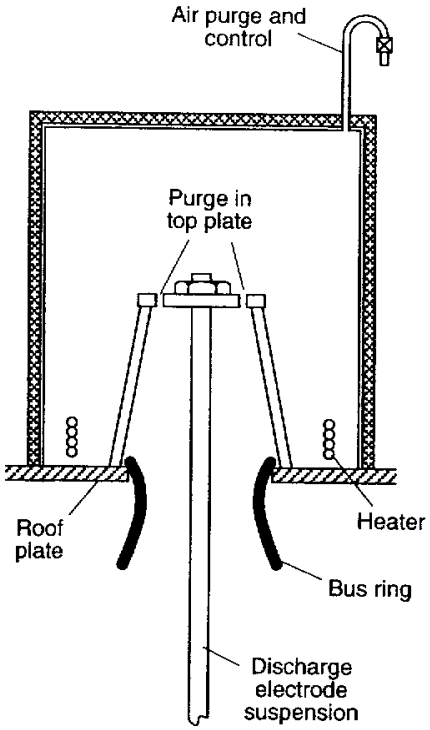
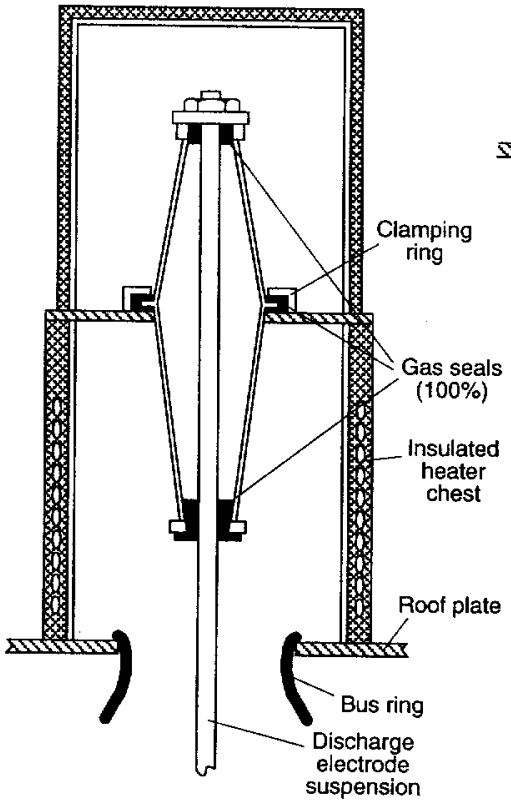
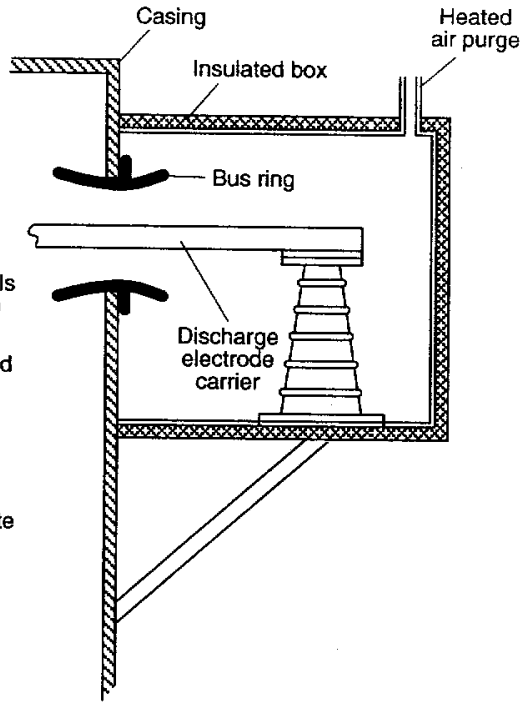


(a) 'Flower pot' insulator general application



(b) Lead through bushing toxic gas/pressure application



(c) Outboard post insulator general application

Insulators for Dry and WET ESPs

Lodge Cottrell

- **Function for Dry ESP and WESP is the same**
  - **Insulate the negatively charged DE system from the positively Earthed CE system. Can also act as a Gas Seal.**
  - **Insulator design is a compromise between functionality and cost.**
- **Insulators on Dry ESPs are working in a ‘dry’ environment but detailed design considerations are required to ensure trouble free operation.**
  - **Insulator is an interface between hot gas and warm ambient and is therefore potentially vulnerable to Dew Point.**
  - **Most processes requires heating to ensure there are no Acid and Water Dew Point problems.**
  - **Very aggressive processes require air washing (Purging) of the inside of the Insulator. This is usually Heated Air.**

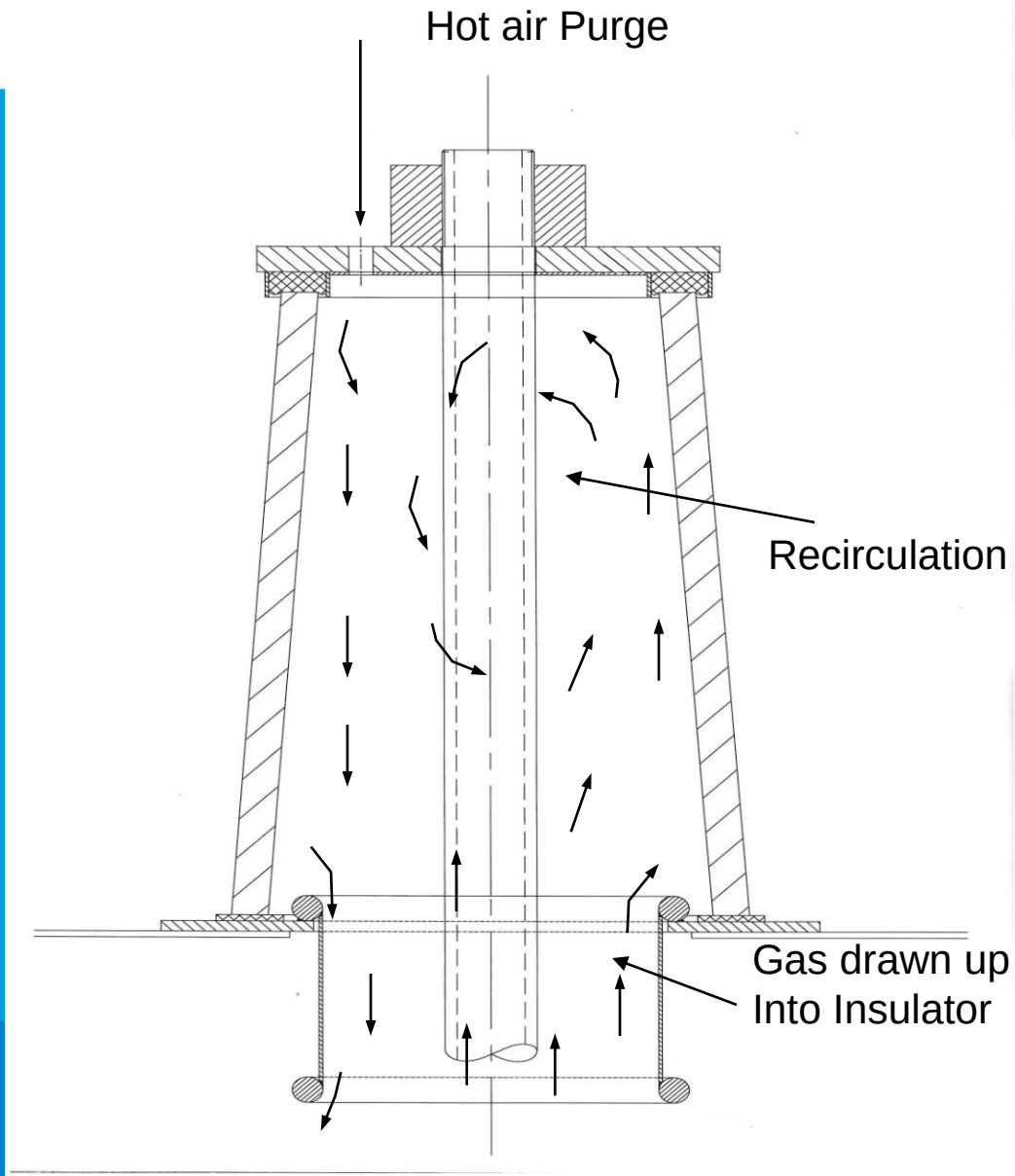
Insulators for Dry and WET ESPs Continued

Lodge Cottrell

- WESPs are always operating in a Saturated environment so Hot Air Purging is normally specified.
- This is acceptable for Acid Particulate removal but cannot be used for Explosive Gas applications.
- Heated Box system is acceptable for all applications and does not require purge air.

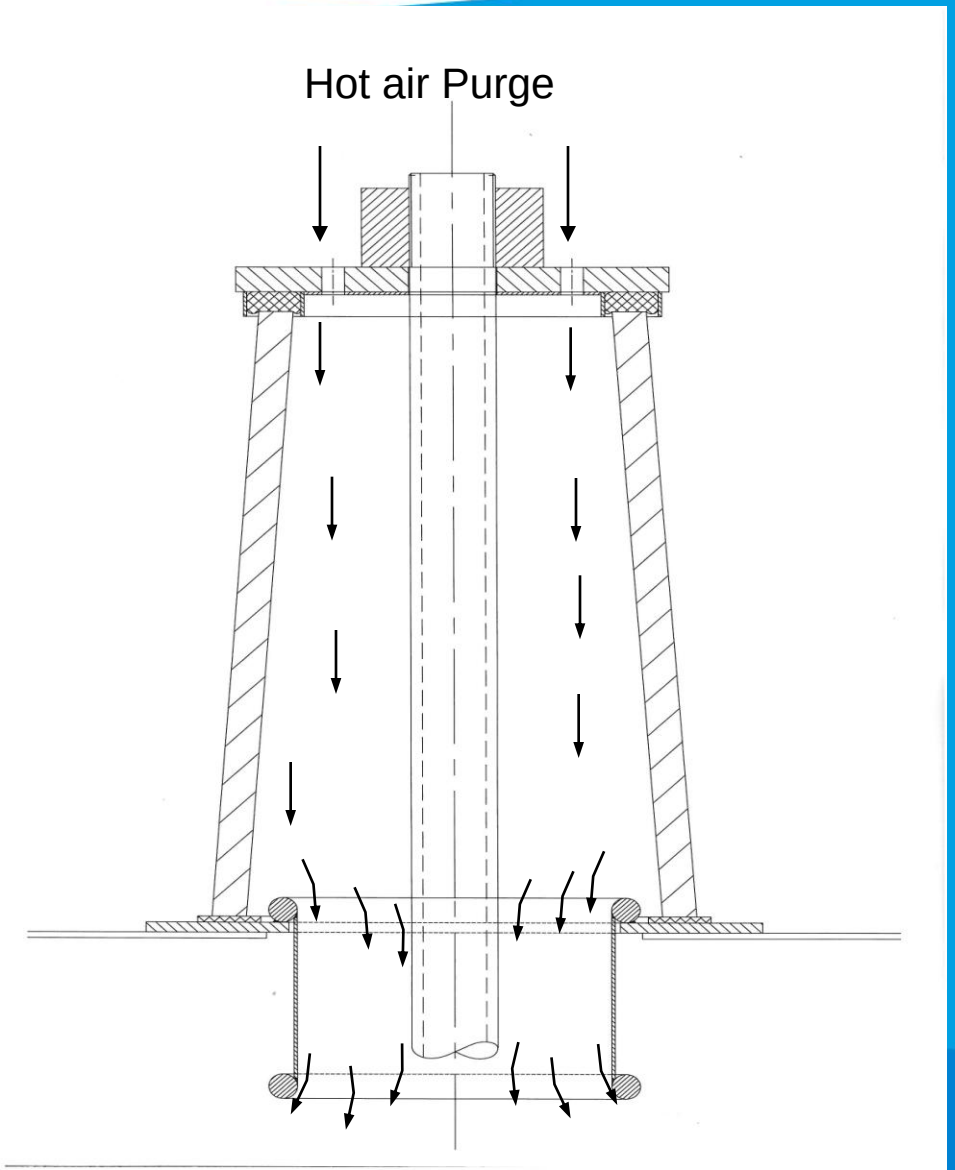
Typical Air Purged Insulator
Bad Purge Air Distribution

Lodge Cottrell



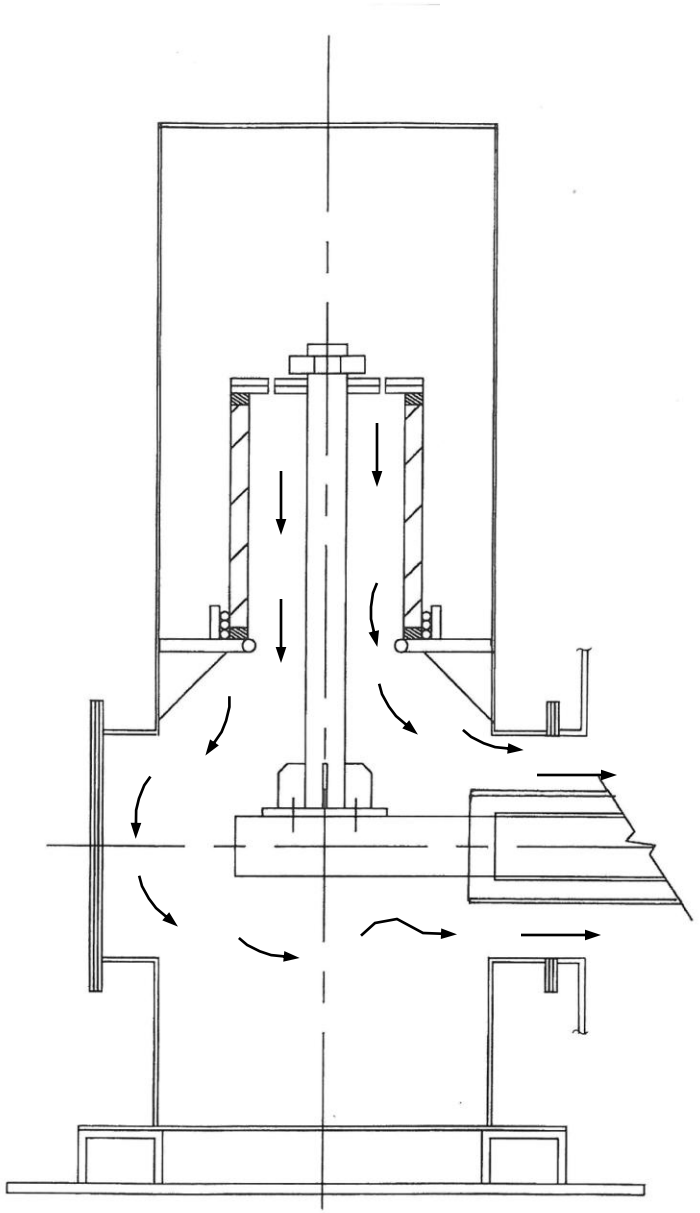
Typical Air Purged Insulator
Good Purge Air Distribution

Lodge Cottrell



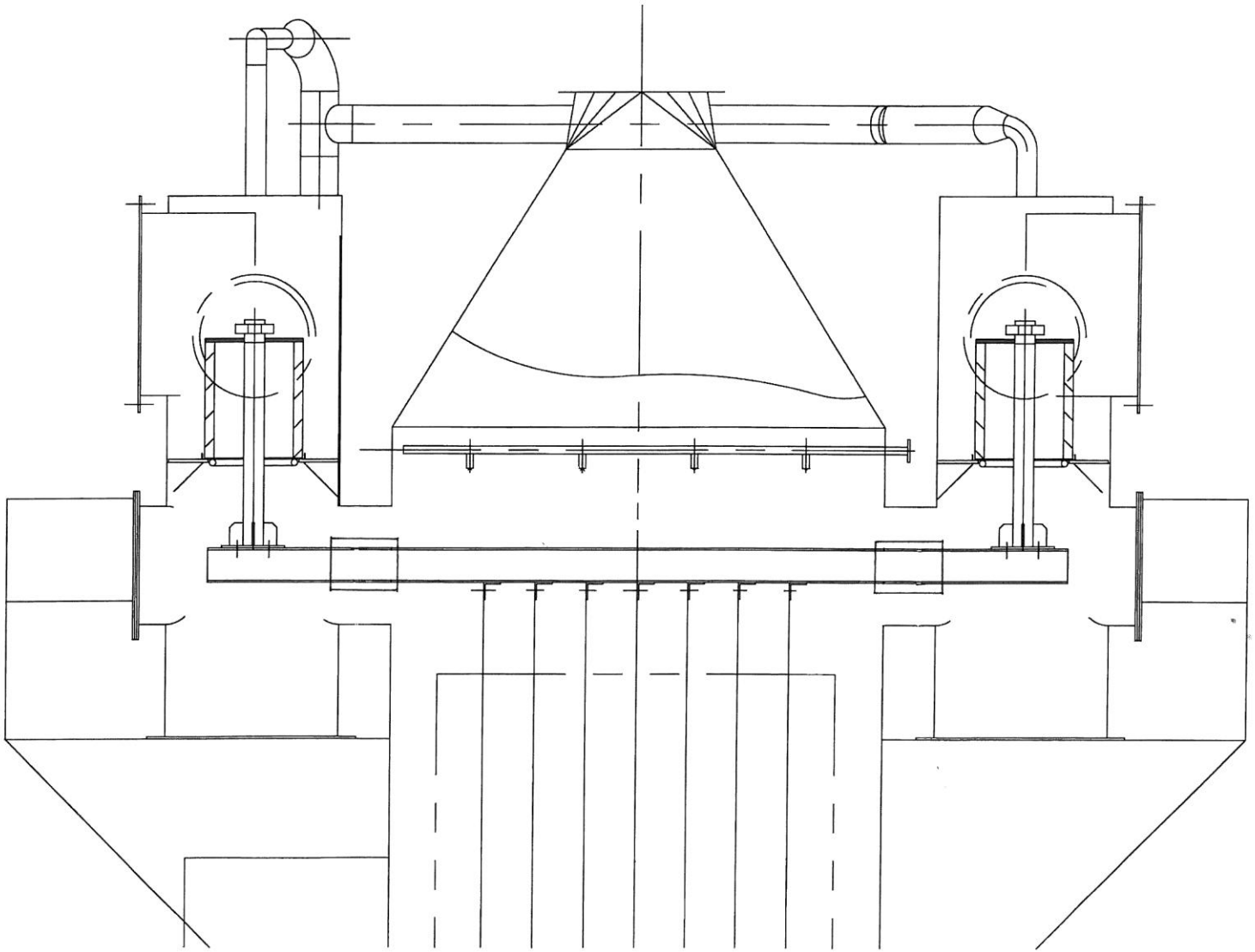
Typical ‘Outrigger’ type Support Insulator

Lodge Cottrell



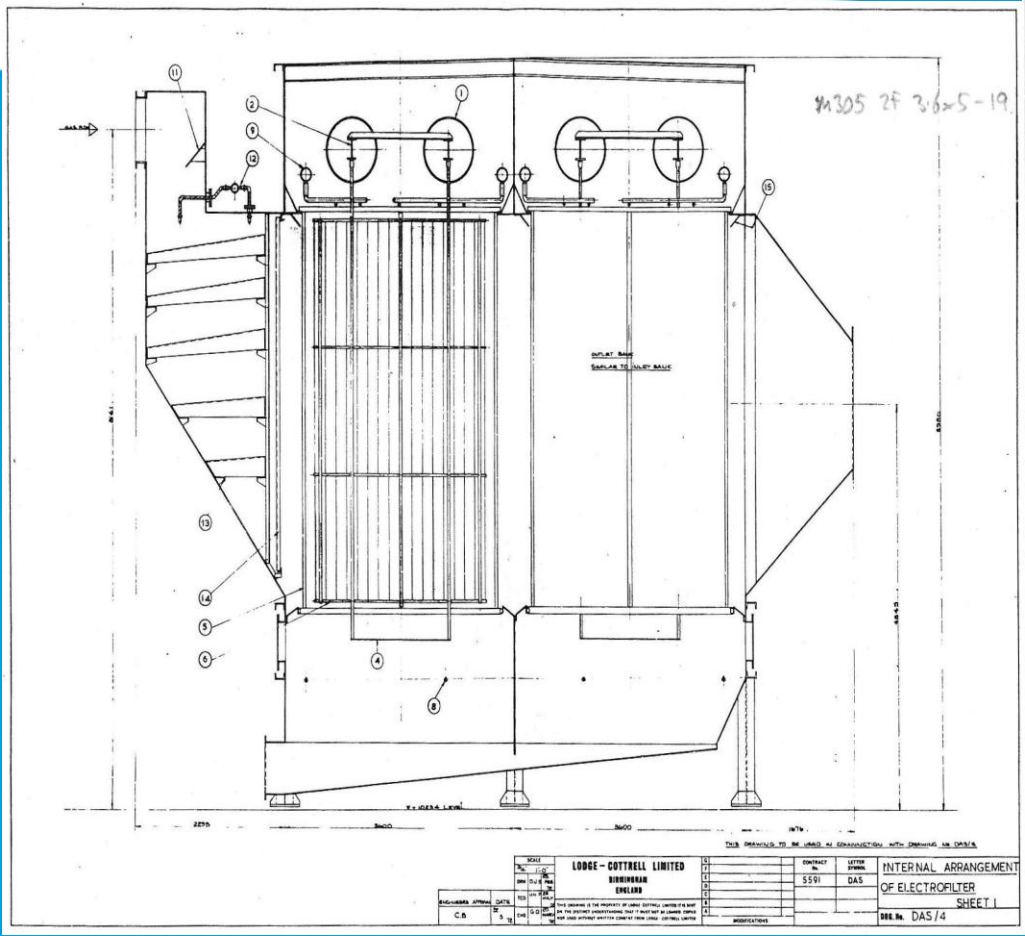
Typical Vertical Flow WESP With 'Outrigger' Insulators

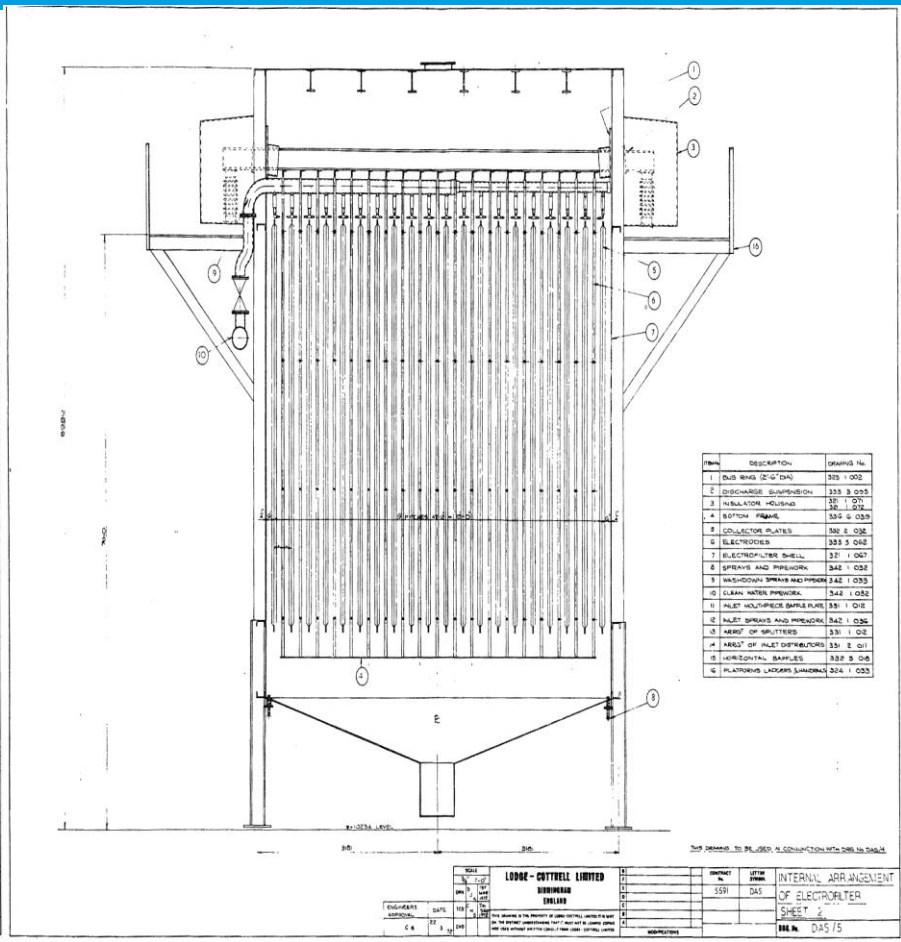
Lodge Cottrell



Horizontal WESP
Outrigger Insulators

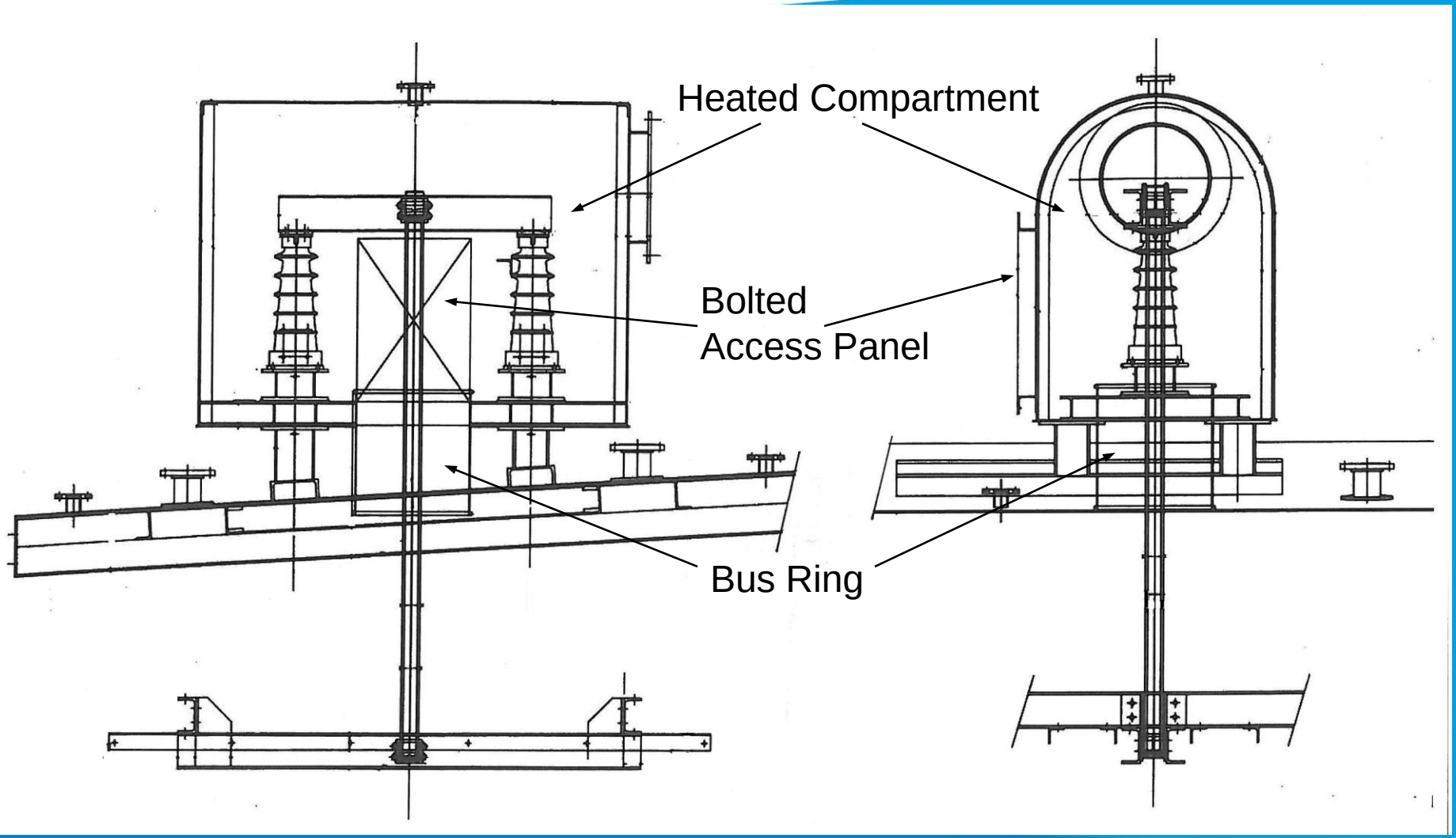
Lodge Cottrell





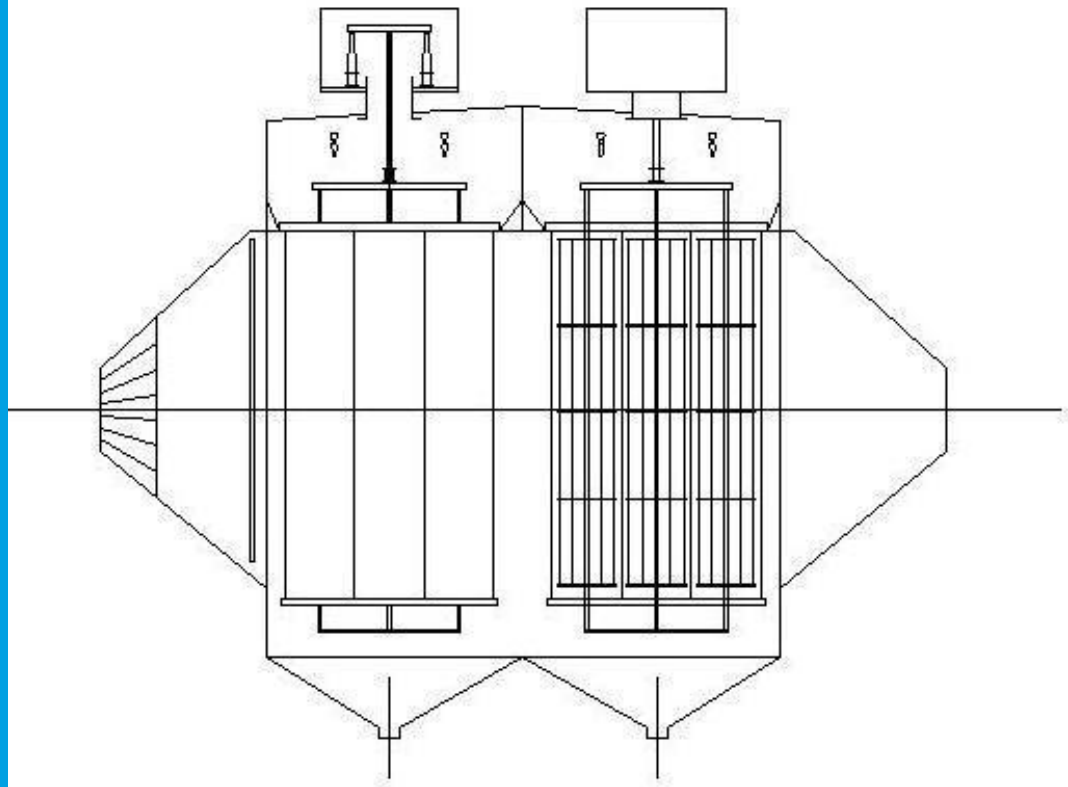
Non Purged Insulator arrangement as used On Acid Mist and Explosive Gas Applications

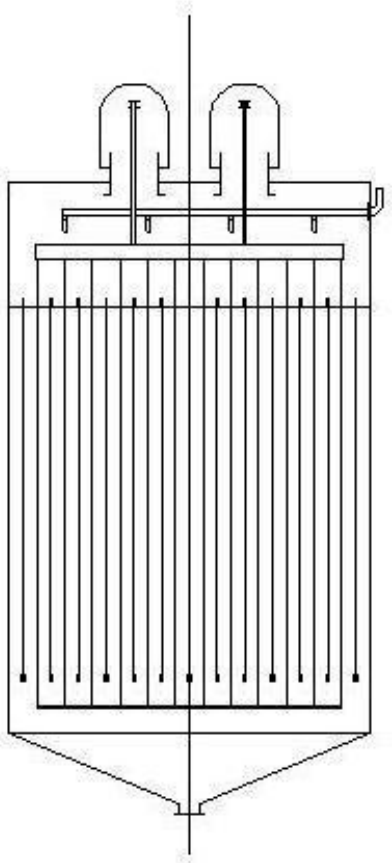
Lodge Cottrell



Horizontal WESP
Non Corrosive Explosive Gas

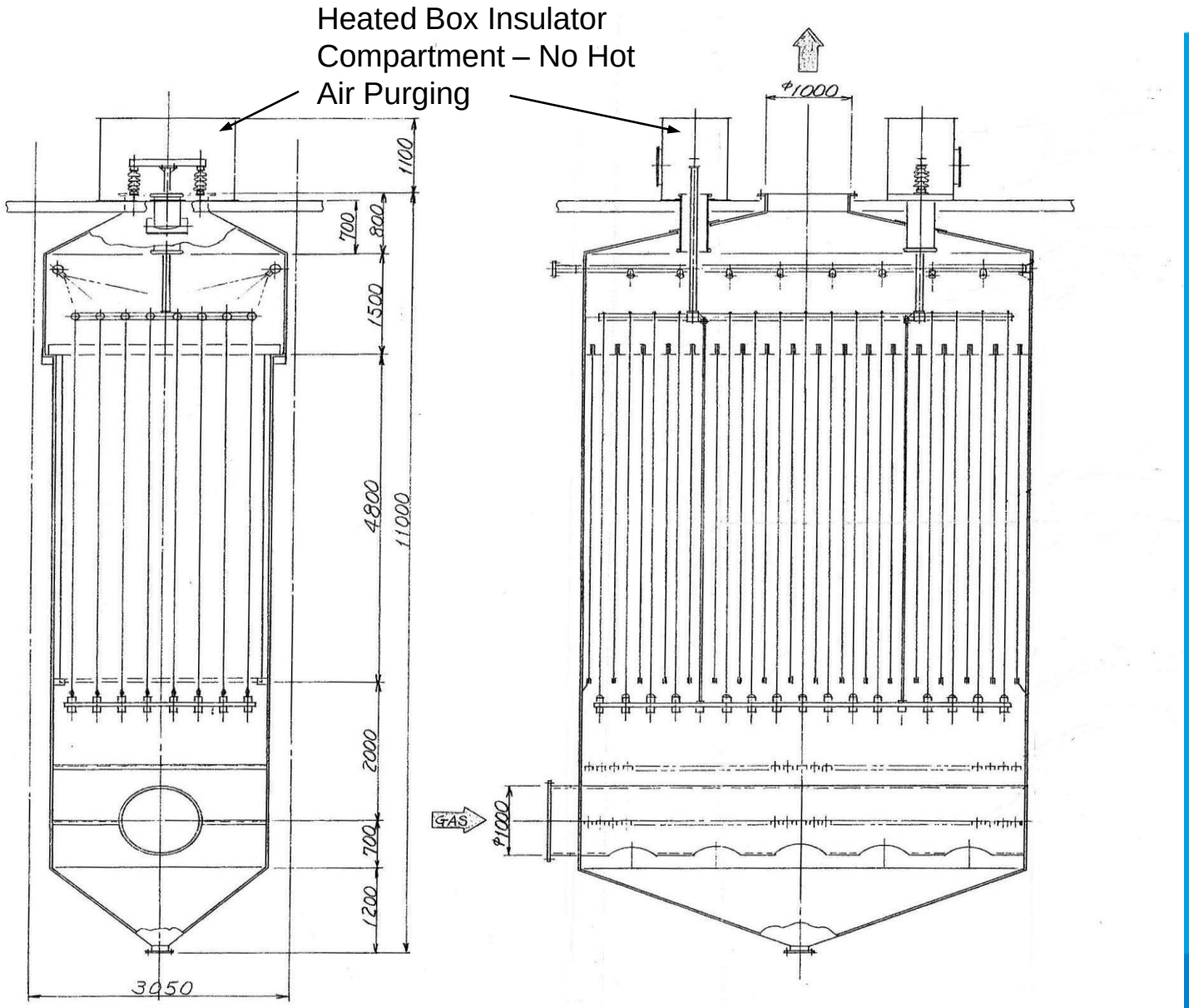
Lodge Cottrell





Vertical Flow Flat Plate Acid Mist ESP

Lodge Cottrell



Vertical Flow Tar Removal WESP
Concentric Ring Type – Explosive Gas

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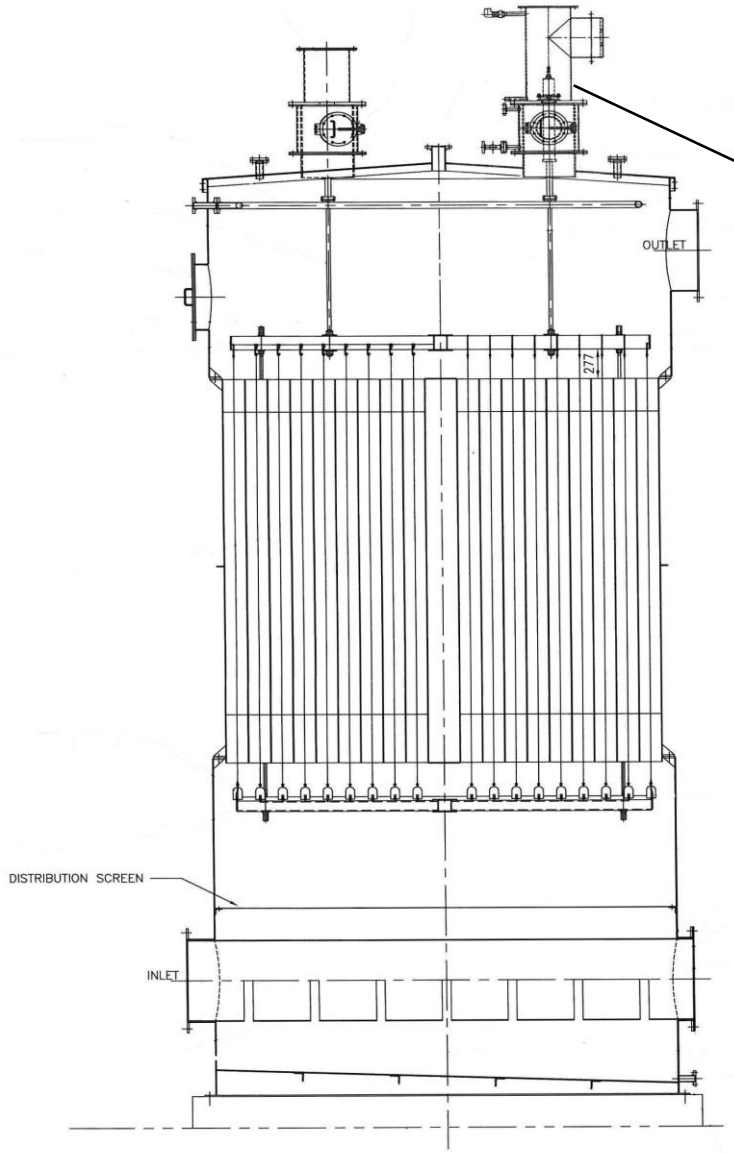
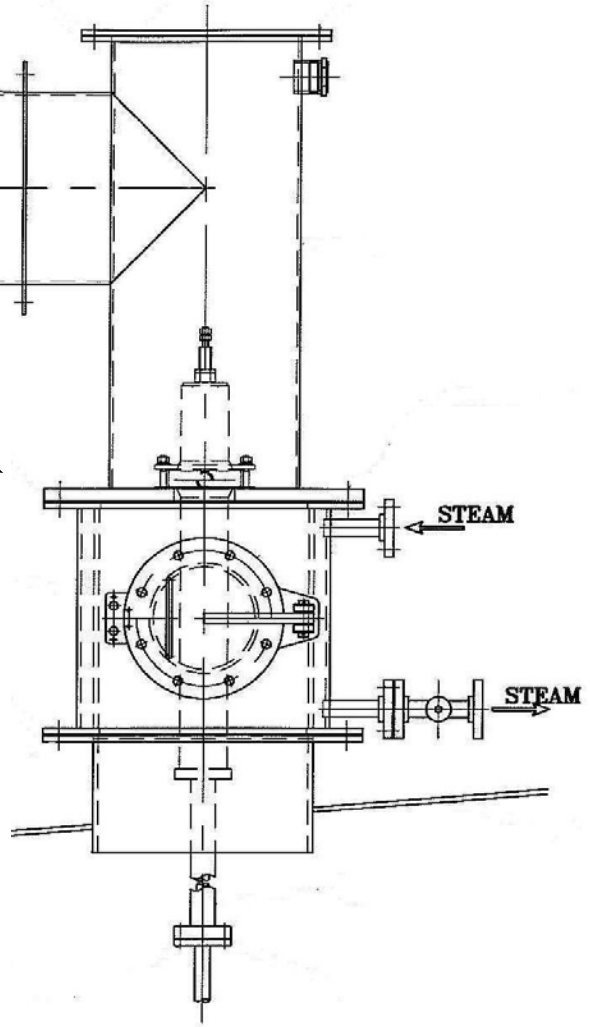


Insulator is 'Solid'. The part of the Insulator exposed to the Gas is inside a Heated Chamber. This Heat Barrier stops Process Gas from contaminating the Insulator



WESP for Nuclear Reprocessing Plant.
Oil Filled Isolation Chamber for 100% seal

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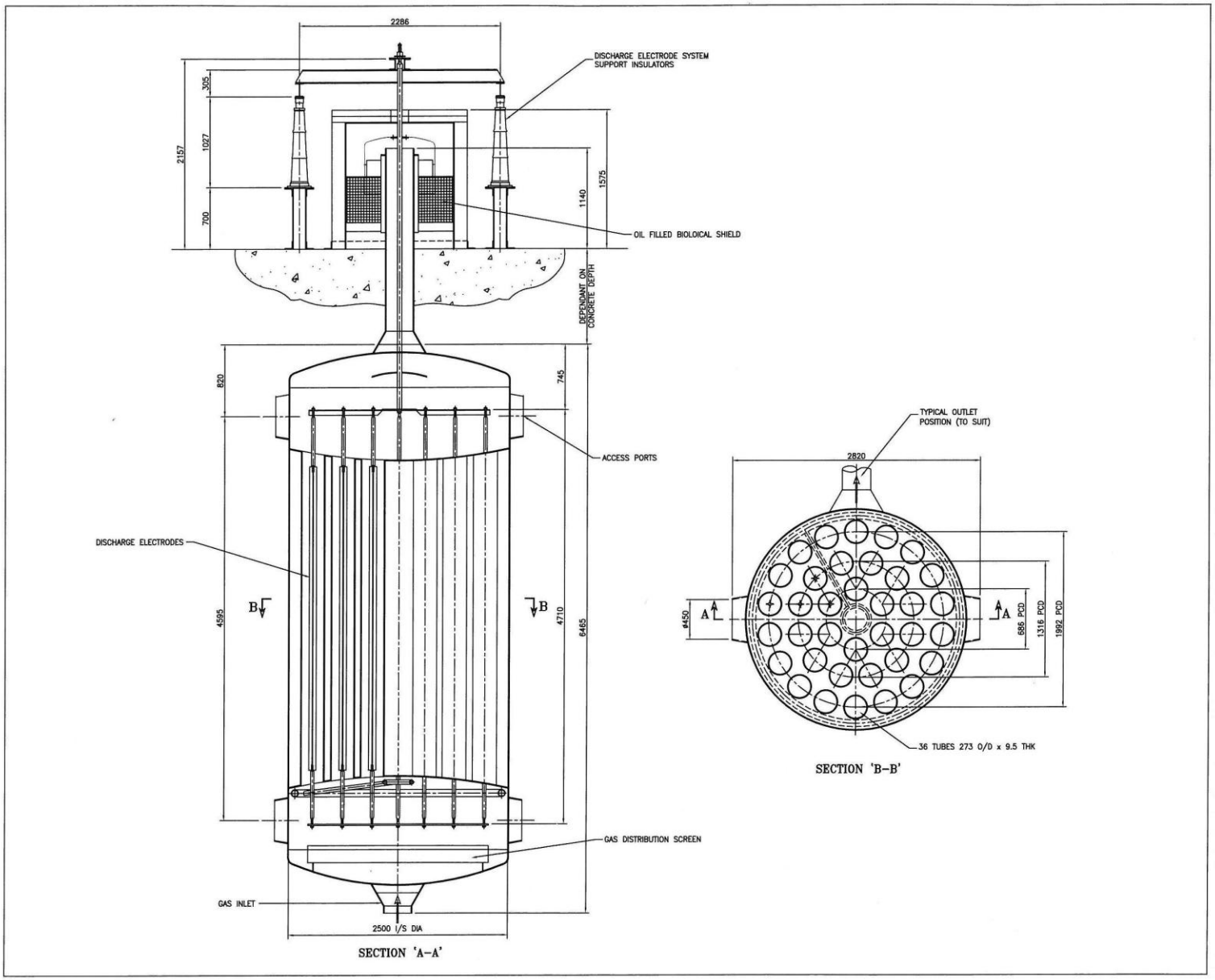

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GAS DISTRIBUTION

Importance of gas Distribution

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- Gas Distribution is an important factor in ESP Performance.
- Applies equally to Horizontal & Vertical Flows.
- Velocity profile should be less than 20% RMS to ensure adequate flow distribution.

Typical Horizontal Flow Gas Distribution

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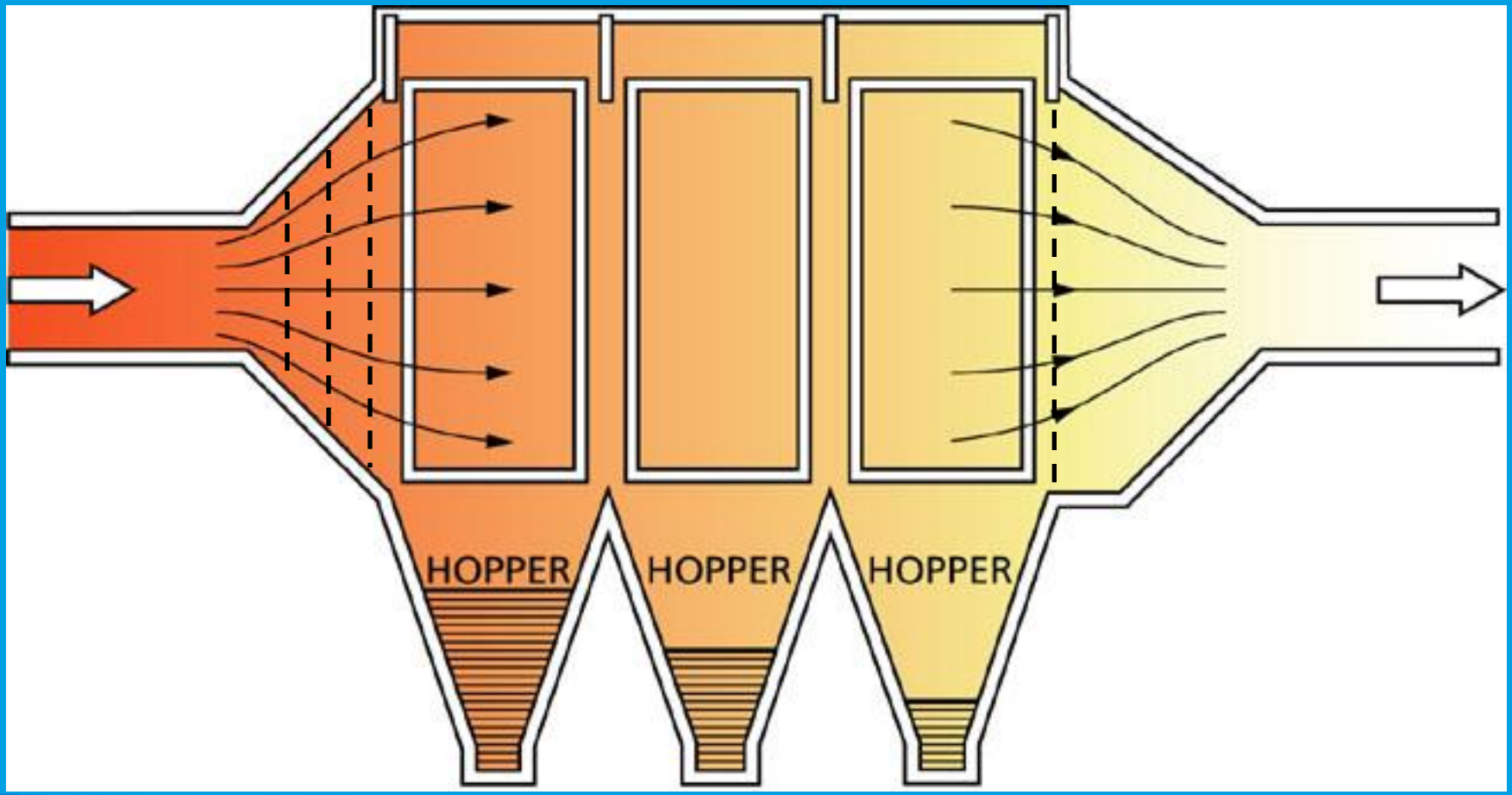

Gas Distribution – Important with Horizontal Flow, Critical with Vertical Flow

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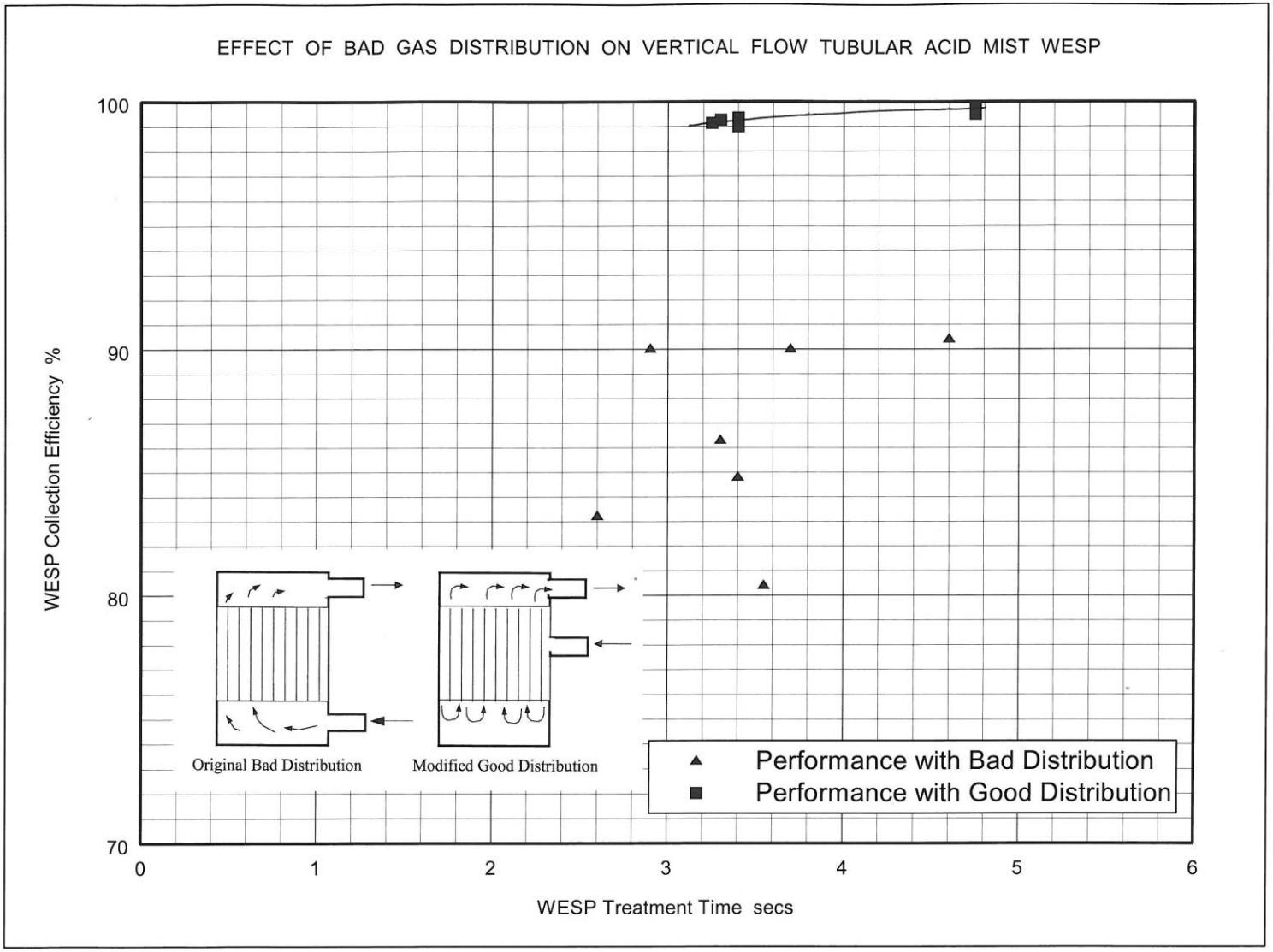

Hexagonal Tube Vertical Flow Inlet Distribution

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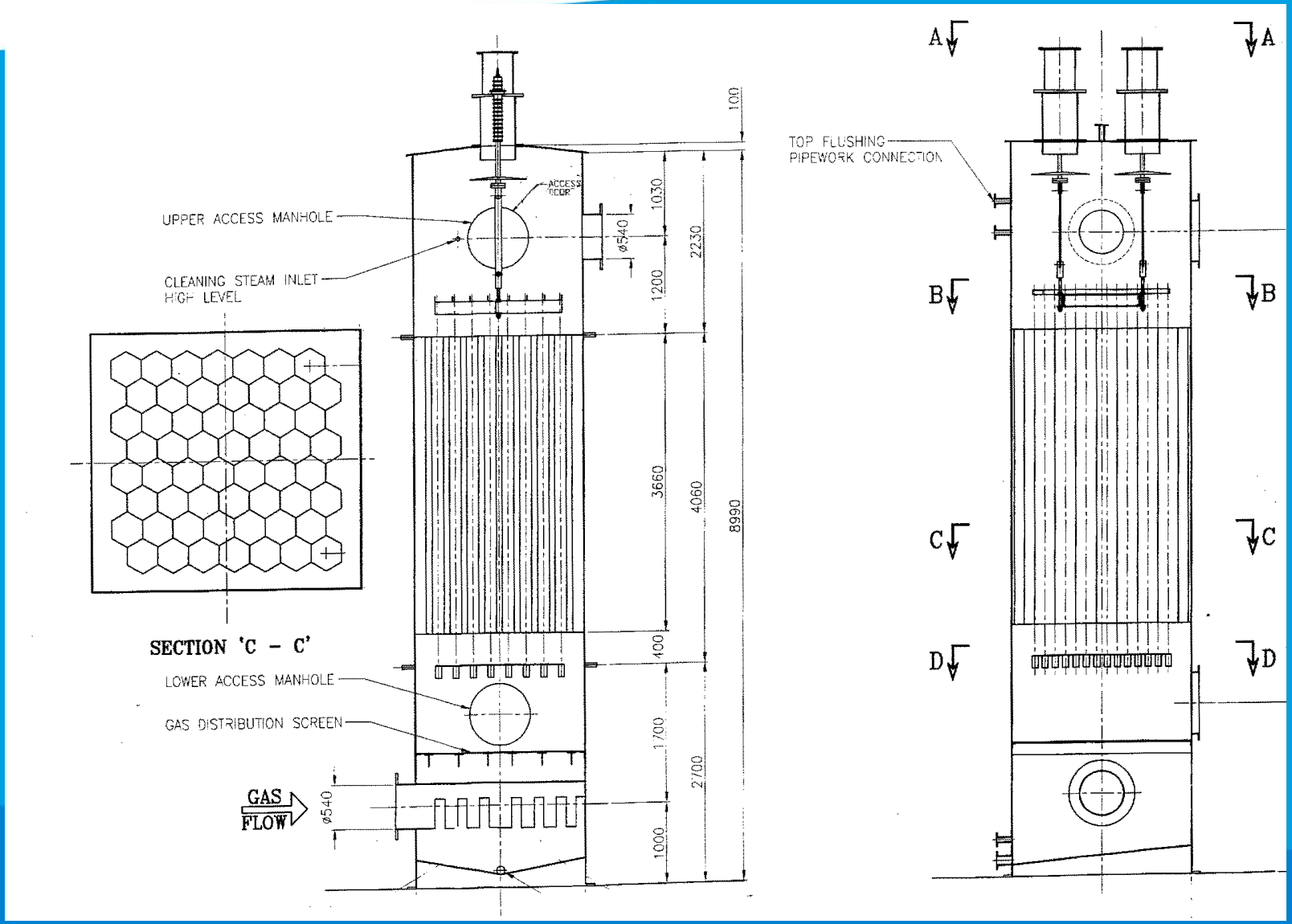

Gas Flow Modelling
Min 1/12 Scale Typical 1/10

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Do not let air into WESP Treating Explosive Gas!

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