TECHNICAL SPECIFICATION

DRY ELECTROSTATIC PRECIPITATORS

DEP 31.27.21.30-Gen.

July 1998
(DEP Circular 18/99 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of:

Shell International Oil Products B.V. (SIOP)
and
Shell International Exploration and Production B.V. (SIEP)
and
Shell International Chemicals B.V. (SIC)

The Hague, The Netherlands,

and other Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements.

3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

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All administrative queries should be directed to the DEP Administrator in SIOP.

NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the design, fabrication, assembly, erection, inspection, testing and commissioning of dry electrostatic precipitators (ESPs).

This DEP covers hot and cold ESPs of both horizontal and vertical construction. Wet collection ESPs are excluded from the scope of this DEP.

This DEP is a revision of the DEP of the same number dated December 1992; *a summary of the main changes is given in Section 1.3.*

The installation shall comprise the equipment listed on a sheet entitled 'Scope of Supply'. The limits of supply shall be listed and defined on a sheet entitled 'Terminal points'. For guidance, typical examples of a 'Scope of supply' and 'Terminal points' are given in Appendix 1.

To facilitate exchange and assessment of information by the Principal and the Supplier, use shall be made of data/requisition sheets DEP 31.27.21.94-Gen.; the purpose of these sheets is described in Section 14.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is primarily intended for use in oil refineries but may also be used for applications in chemical plants, gas plants and exploration and production facilities. In the latter cases, redundancy aspects associated with a shutdown frequency of 3 to 4 years in refinery applications should be considered.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 SUMMARY OF MAIN CHANGES

A summary of the main changes since the last revision of this DEP are as follows:

Section	Description
1.1	Distinction between hot-side and cold-side removed. Same in Section 2, description reworded.
2.	Section on dust disposal added.
3.1	Design not limited to rigid frame construction.
3.1	Requirement for flow model study added.
3.3	Section on gas distribution devices rewritten.
3.6.1	Minimum plate thickness requirement removed for FCCU applications.
6.2	Section replaced by reference to DEP 33.64.10.10-Gen.
6.3	Section replaced by reference to DEP 33.64.10.10-Gen.
6.4	Paragraph on control circuit protection removed
6.7	Relevant standards added for motor protection in dusty atmospheres.

6.9	Section replaced by reference to DEP 33.64.10.10-Gen.
6.10	Most of this section replaced by reference to DEP 33.64.10.10-Gen.
10.3	Section on structural welding replaced by reference to DEP 34.28.00.31-Gen.
10.4	Duplication with 3.10 removed
13.2	New section for air load test
16	References updated
Appendix 4	Air load test procedure included
Appendix 8	Danger notice updated

1.4 DEFINITIONS

1.4.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4.2 Specific definitions and abbreviations

aspect ratio	ratio of the total collecting plate length over height
bus section	ESP portion that is independently energized
cells	bus sections arranged perpendicular to the gas flow
chamber	gas-tight longitudinal subdivision of the ESP
collecting electrode	particulate collecting surface
crest factor	ratio of the peak value to the rms value of the periodic wave form
discharge electrode	emitting and corona-establishing surface
efficiency	weight fraction of collected particles divided by the total particulates entering the ESP, as a percentage
electrodes	both the discharge and collecting electrodes
ESP	dry electrostatic precipitator
FCCU	fluidised catalytic cracking unit
fields	bus sections arranged in the direction of the gas flow. Each field is fully separated both electrically and mechanically from any adjacent field
IPF	instrumented protective function. A function comprising the initiator function, logic solver function and final element function for the purpose of preventing or mitigating hazardous situations. See DEP 32.80.10.10-Gen.
IPS	instrumented protective system. The electromechanical, electronic

	and/or programmable electronic logic solver component of the instrumented protective function, complete with input and output equipment.
T-R set	transformer and rectifier unit
velocity, face or gas	average velocity of the gas across the ESP

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (16).

2. ESP DESCRIPTION

2.1 ESP FUNCTIONALITY

ESPs are used to control air pollution (e.g. flue gas cleaning) by collecting solid particulates typically in the range of 10 µm and smaller.

ESPs are used for exhaust gas cleaning of boilers, incinerators and regenerators of catalytic cracking units.

The electrostatic precipitation process can be either dry or wet. Dry collectors have certain advantages over wet collectors in that dry collection simplifies handling and saves costs of processing the particulates. Handling and disposal of the collected material shall be planned with account being taken of the need for cooling, ventilation or other precautions. Without cooling, the temperature limits of equipment will have to be considered and dry dusty material, if hygroscopic, may cause caking. Also, the precipitate may be pyrophoric.

Depending on the nature of the particulate in question (e.g. a liquid residue), wet collection may be required. Wet collection ESPs are not covered by this DEP.

Although ESPs are available in many types and configurations, they all work on the same principle, i.e.:

- electrical charging of the suspended particulates;
- collection of the charged particulates in an electric field;
- removal of the precipitated material.

The ESP efficiency depends on a number of variables including particulate resistivity, gas composition, plate area, gas residence time, electrical field strength and particle migration velocity. The migration velocity is an important parameter for the degree of efficiency and size of particles to be collected. The migration velocity of the particle is the result of the balance between the attracting Coulomb and retarding Stokes drag forces. It increases with particle diameter, particle charge and collecting field strength. Efficiencies are usually in the range of 85% to 95%.

Dry ESPs contain the following basic components, refer to Appendix 2.

- casing;
- gas distribution screens (inlet and outlet);
- high tension T-R set(s);
- field(s) with discharge electrodes and collecting electrodes;
- rappers;
- hoppers.

In refinery applications, ESPs are described either as ‘hot’ or as ‘cold’, depending on the temperature operating range. ESPs operating at temperatures above approximately 220 °C are classed as hot ESPs.

Since each type has its specific requirements and serves a particular purpose, selection shall be based on the process and particulate properties.

Where appropriate, further explanations are included in the general sections of the individual component descriptions.

2.2 DUST DISPOSAL

Depending on the nature of the separated dust, disposal of the dust shall be considered before commissioning the unit. In some cases a market for the dust may exist (e.g. the cement industry) as an alternative to disposal as chemical waste.

3. DESIGN AND ENGINEERING

3.1 GENERAL DESCRIPTION

For design, engineering, fabrication, inspection and testing, the Supplier shall adhere to internationally accepted industry standards and practices, supplemented by the requirements of this DEP. Specific standards or codes may be specified by the Principal if local conditions so dictate.

SI units shall be used throughout the design.

The ESP shall be of the dry plate type, suitable for continuous outdoor operation. Both 'European' and 'American' designs may be employed.

The design shall be proven in practice, robust and reliable. Safety, ease of operation, inspection, maintenance, repair and cleaning are of particular importance.

The design of the equipment shall be both technically and economically justified in such a way that the absolute minimum of operating personnel and maintenance is required for continuous operation.

The ESP shall be designed for the maximum specified throughput, i.e. shall be designed for the combined peak flowrate and dust load specified by the Principal, and the equipment configuration shall have sufficient flexibility to cope with a fluctuating dust load and/or soot load, if applicable.

The aspect ratio of the ESP shall be at least 1.0.

The applicable local and national regulations shall be stated by the Supplier on the data/requisition sheets. The Supplier shall obtain all local approvals and certificates as needed.

The Supplier shall give full details of the chemical and physical properties of the construction materials.

All metal surfaces in contact with flue gases shall be at a higher temperature than the highest dew point (acid or water, as applicable) which may occur during any of the operating conditions in combination with any of the flue gas compositions specified in the data/requisition sheets.

There shall be sufficient space and access for inspection, cleaning, removal and maintenance of such parts as rapping gear, electrodes, insulators, T-R sets, valves, fans and electric motors.
Arrangements and written procedures for the removal of emitting electrodes and rapping gear shall be provided.

There shall be adequate protection to prevent personnel touching surfaces hotter than 70 °C.

Before the contract is awarded the Supplier shall satisfy the Principal that, at all loads, an even distribution of flue gas over the ESP passages is achieved and ESP efficiency is equal to or better than the specified emission limit. Flue gas flow model studies should be performed where limited available plot space requires difficult inlet and outlet configurations.

Under adverse conditions the flue gases entering the ESP may contain or consist of flammable mixtures. Although ESP operation is aimed at the non-sparking condition, regular sparks will occur and in combination with these flammable mixtures may present a potential explosion or fire hazard in the ESP. Any need for specific safety precautions shall be reviewed by the Supplier in consultation with the Principal.

3.2 ESP CASING, INCLUDING INLET AND OUTLET TRANSITIONS

The casing shall be designed for a combination of gas design pressure and temperature, and wind/snow/seismic loads, see DEP 34.00.01.30-Gen. The design pressure shall be based on the maximum operating pressure and/or vacuum in the casing.

The casing shall be all-welded and gas-tight, minimum 6 mm thick steel sheeting material, stiffened by steel sections. A corrosion allowance of 2 mm shall be included in the design.

There shall be no restriction to the free expansion of internals or insulation/sheeting.

The materials shall be adequate for the medium and temperature of service.

All elements and panels shall be sufficiently stiffened against damage during transport, erection, and mechanical vibration. Stiffening shall not interfere with the free expansion of the casing.

The casing design and construction shall facilitate the removal and/or installation, at site, of internals. The design shall further allow convenient access for removal and installation of discharge electrodes.

Thermal insulation of the casing shall be external (see Section 5).

3.3 GAS DISTRIBUTION DEVICES

An even gas flow distribution over the entire cross-section is critical in the design and operation of the ESP.

Gas velocities in the upstream duct may generally range from 6 m/s to 25 m/s and are too high for adequate particle separation. A swaged inlet plenum with gas distributors shall be used to create a uniform inlet flow profile. Gas velocities in the ESP passages are typically between 0.5 m/s and 2.5 m/s; the optimum gas velocity to achieve an efficiencies of 90% and better is approximately 1.0 m/s.

Inlet and outlet plenums (transition sections) contain perforated plates and flow distribution devices, to guarantee even gas velocities throughout the treatment zone. Deviation from the average gas velocity at any point in a gas passage shall be not more than 20%. The inlet plenum shall be designed so that collected particles will be discharged into the first ESP hopper. Also, dedicated rappers for the inlet gas distributors should be considered.

3.4 ELECTRODE ASSEMBLIES

3.4.1 General description

The discharge electrodes ionise the flue gas, which charges the particulates and creates the electric field. The corona is established between high voltage fine wire or strip electrodes and the collecting plate electrodes at ground potential. A high voltage pulsating direct current produces a uni-directional but non-uniform electric field. The particulates passing through the corona field are subjected to intense bombardment by negative ions and become charged in 0.01 seconds or less, and are attracted to the collecting electrodes.

The resistivity of the particulates is such that a portion of the charge is retained. This contributes to the adhesive and cohesive forces which retain the particulates on the collecting plates. Dust layers can build up to a thickness of several millimetres. However, if the layers become too thick they will act as an insulator and reduce the strength of the field. Therefore, it is necessary to periodically remove deposited particulates from these collecting plates.

Precipitator performance is optimised by segregating the electrodes into fields. The need for separate fields occurs due to the differing power requirements in the ESP. High dust concentrations at the front end of the ESP tend to suppress corona current, therefore demanding high voltage inputs for particle charging. Further downstream in the ESP, where dust concentrations are lower, corona current flows more easily. Any excessive sparking in the downstream section would, when equipped with only one power set, limit the power input to the entire ESP. Therefore, ESPs shall have two or more fields and shall have some redundancy to cope with outages. The degree of sectionalisation of the high tension sections shall be advised by the Supplier.

Collecting electrode spacing shall be minimum 200 mm and maximum 400 mm.

3.4.2 Electrodes

Discharge electrodes shall be made from stainless steel strip or wire.
In vertical ESPs these discharge electrodes may be secured by screws, with individual weight tensioning.
In horizontal ESPs the discharge electrodes may be fitted with points and keyed into a tubular frame.

Collecting electrodes shall be made from cold or hot rolled thin plates with stiffeners, refer Appendix 3.
In vertical type ESPs these collecting electrodes may be made as sections and welded in a frame as double sections.
In horizontal type ESPs the collecting electrodes are normally executed as single plate sections.

The collecting electrodes shall have an 0.6 mm corrosion allowance, i.e. 0.3 mm on either side. The discharge electrodes do not require a corrosion allowance.

Electrodes shall be suspended from the roof, discharge electrodes shall be supported from insulators, refer Appendix 5.

Electrode types and supporting arrangements shall be selected for ease of construction, repair and access. The supporting construction shall ensure that electrode alignment is optimal during all specified operating conditions.

All internals shall be supported in a satisfactory manner so as to prevent distortion of electrodes. Internals shall not rest on cladding or any internal insulation.

The distance between collecting electrode edges and the inner walls of the casing shall be minimal and by-passing shall be eliminated.

Gas passages and the collecting electrode surface shall be so designed that re-entrainment of particulates will be kept to an absolute minimum and will not be a source of vortex shedding.

3.5 ELECTRODE CLEANING MECHANISM

3.5.1 General

Dust build-up on the collecting electrodes and also on the discharge electrodes has to be removed. Dust can effectively be dislodged from these surfaces by the shearing action of a sharp impulse.

Impact rappers or hammers shall be used to shock or vibrate both the collecting and discharge electrodes, thereby dislodging the precipitated dust.

Zonal control of rapping shall be provided as precipitation near the inlet zone will be much higher than that near the outlet zone.

The rapping frequency shall be adjustable and "impact" rappers shall also be provided with adjustable rapping intensity.

3.5.2 Rapping Gear

Rapping equipment, for cleaning the collecting and discharge electrodes, may be executed as:

- pneumatic impulse rappers;
- mechanical rappers, e.g. cam driven hammers, refer Appendix 6;
- electromagnetic impulse rappers, refer Appendix 7.

For both the collecting and discharge electrodes, the electrode supplier shall indicate the following:

- number, arrangement, type, and size of rapping devices required;
- power requirements per rapping device and the installed power;
- frequency control (timer or pressure drop);
- range of frequency and intensity settings;
- typical filtration cycle with respect to the frequency of cleaning;
- time required for cleaning (downtime/year).

3.6 DUST HOPPERS AND DISCHARGE SYSTEM

3.6.1 General

The agglomerated dust drops into hoppers from where it will be removed via a dust discharge system.

Hopper plate thickness shall be not less than 6 mm. A corrosion allowance is not required for FCCU applications. For all other applications, a 2 mm corrosion allowance shall be applied.

Hoppers shall be equipped with baffles to prevent gas by-passing and dust re-entrainment. Hopper insides shall be smooth (e.g. no weld beads) and clear from obstructions (e.g. no internal rungs).

Hoppers shall be adequately sized with sufficient over capacity to allow for maintenance and disturbances in the ESP operation. Hoppers shall provide for a 3 day storage capacity. Hopper sizes of ESPs fitted with continuous dust removal equipment may provide for shorter storage capacities subject to agreement by the Principal.

The free space beneath the hopper flanges shall be minimum 3 m, in order to create sufficient access for particulate removal.

Depending on the type of dust, hopper configuration and equipment layout the dust discharge system may be executed as a:

- screw conveyor system;
- chain conveyor system;
- gravity dropout system;
- pneumatic conveying system.

The Supplier shall state his recommendation and full details of the dust discharge system in the tender and shall specify:

- hopper type and geometry (e.g. valley angle and angle of repose), size, storage capacity for collected dust, number and location;
- dust removal system (type, capacity, protection against air in-leak and dust blow-back).

The Supplier shall describe all special features and precautions taken to avoid exposure to air when dealing with pyrophoric dust.

3.6.2 Flushing assembly for dust hopper

Depending on the particulate properties, bridging may occur. The Supplier shall review the need for any of the following systems and state his recommendation or design standard in the tender:

- ring flushing system to fluidize particulates;
- rappers;
- poke holes.

3.6.3 Heating for dust hopper

Hopper tips shall be fitted with electrical heat tracing, or heated by other means if agreed by the Principal or if otherwise specified in the data/requisition sheets.

For electric heating systems see (6.8).

3.6.4 Dust hopper outlet valves

Each pyramid hopper outlet shall be equipped with a manually operated slide valve and rotary star valve. Rotary star valves shall not be applied if condensation cannot be prevented (e.g. due to climatic conditions).

For all rotary star valves, data/requisition sheet DEP 31.25.40.93-Gen. shall be completed by the Manufacturer.

3.7 OBSERVATION AND ACCESS

Observation windows shall be provided at the ESP outlet and be equipped with high intensity illumination to allow light rapping puffs to be seen.

Windows shall not be provided on the ESP casing or particulate hoppers.

Where necessary, gas purging shall be provided to keep observation windows sealed, clean and cool. The glasses shall have external covers to prevent cracking.

There shall be a sufficient number of access and inspection doors. Adequate access space shall be provided for each zone or field in the ESP (with a maximum distance of 800 mm between fields). Each particulate hopper shall be provided with an access door. These doors shall be provided with a security catch to prevent unloading of the hopper contents if inadvertently opened.

Access doors shall have a free opening of at least 400 x 400 mm and shall be located on both sides of access spaces.

All access and inspection doors shall be key-interlocked for safety reasons. Padlock systems shall not be used.

3.8 SUPPORT STRUCTURE AND FOUNDATION

3.8.1 General

The ESP foundation shall not be included in the scope of supply and shall be provided by the Principal. The Supplier shall provide the Principal with all necessary information to allow proper foundation design and shall approve the foundation drawings.

The Supplier shall submit sufficient information regarding:

- foundations/piling;
- thermal expansion allowances;
- steel structure;
- access/platforms/stairs;
- access/inspection doors.

3.8.2 Steel structures

Supporting steel structures, platforms, stairs, ladders and railings shall be in accordance with DEP 34.00.01.30-Gen. and DEP 34.28.00.31-Gen.
The general arrangement of stairways shall be in accordance with Standard Drawing S 28.001 and the handrail design should be as shown on Standard Drawing S 28.006.

The steel structure design shall take into account testing and access positions as well as any restrictions imposed by manufacturing, transport or erection.

Further to the above requirements, stairs and platforms shall provide easy access to all valves, gauges, instrument process connections, observation points and access doors, and for all other operational purposes. Ladders may only be used for creating extra means of escape. All stairs, platforms and walkways shall be adequately safeguarded with handrails and toe plates.

All main platforms shall be provided with an emergency means of escape leading down to ground level.

Railings shall be mounted around the roof or roof sections of the ESP where no platforms are required but where access is possible or necessary.

3.9 DESIGN OF DUCTING

3.9.1 General

Ducting, including bends, shall be designed for the maximum operating conditions in the ducting, including vacuum, and a combination of wind/seismic/etc. loads, see DEP 34.00.01.30-Gen.

All ducting shall have a plate thickness of not less than 6 mm, and a 2 mm corrosion allowance shall be included in the design. For FCCU applications no corrosion allowance is required.

The ducting shall be gas tight and smooth, and bends shall have rounded profiles and, if necessary, be fitted with guide vanes. Guide vanes shall be designed to avoid resonance and the formation of eddies in the gas stream; hence they shall have a smooth tapered leading edge. Guide vanes shall be attached to the ducting by welding, and allowance shall be made for differential thermal expansion.

Ducting shall be sufficiently stiffened against mechanical vibration and distortion. Stiffening shall not restrict the free expansion of the ducting in any direction. Effective vibration isolation (e.g. from the ESP) shall be provided where necessary.

All ducting shall be designed such that the free cross sectional area provides stable, uniform, gas flow and acceptable pressure loss. For noise limitations, see (8).

For the design of ducting the average gas velocity shall be limited to a maximum of 25 m/s.

Flanged connections shall be in accordance with Standard Drawing S 24.301.

It shall be possible to drain all ducting.

Transition pieces between duct sections of different cross-sectional area shall be provided as necessary. They shall be designed to prevent flow detachment from the duct wall and provide the most economic pressure loss.

Diverging sections shall have an included half angle of less than 7.5 degrees. If necessary, guide vanes shall be considered.

Expansion joints shall be provided in the flue gas ducting as necessary; they shall be of the bellows type and shall be gas tight. Expansion joints may be of high temperature fabric, multi-layered and reinforced with stainless steel wires, or steel-bellows type, both with inner sleeves. Adequately ventilated rain shields shall be fitted to all expansion joints.

Access doors shall be provided in all sections of the ducting. Access doors shall have a free opening of at least 400 x 400 mm, and shall be in accordance with Standard Drawing S 24.304.

The duct floor shall be sufficiently strong to allow access by maintenance personnel.

Duct supports shall be designed to remove all loads from the ESP casing. Sliding supports shall be designed to allow lateral and axial expansion movements of the ducting.

Thermal insulation of flue gas ducting shall be external, see (5). Where insulation is for personnel protection only, heat shields are an acceptable alternative.

The ducting wall temperature shall be above the highest calculated dew point temperature of the gas for any of the specified operating conditions.

3.9.2 ESP inlet ducting

The ESP inlet ducting shall comprise the complete ducting from terminal point to ESP inlet and, if applicable, bypass ducting or ducting to the bypass stack.

3.9.3 ESP outlet ducting

The flue gas ducting shall comprise the complete ducting from ESP outlet to terminal point and, if applicable, bypass or stack.

3.10 PIPING AND PIPING CONNECTIONS

Piping shall be in accordance with DEP 31.38.01.11-Gen.

Piping nozzles on the ESP and ducting shall be in accordance with Standard Drawing S 10.101.

Instrument process connections shall be in accordance with DEP 31.38.01.12-Gen. unless stated otherwise in the data/requisition sheets.

Piping and piping components shall not be threaded.

Lap joint flanges (including special stub ends) and socket weld flanges shall not be used.

Pipe sizes such as 1.25", 2.5", 3.5" and 5" shall not be used.

All connections shall extend at least 100 mm beyond the insulation.

3.11 DAMPERS AND ISOLATORS

3.11.1 General

Where required or specified, (bypass) dampers and isolators shall be provided.

If safe access to the ESP is required for shut-down maintenance during normal operations, a plate type isolator shall be provided downstream of the damper. Safe access isolation of the ESP is defined as 100% sealing efficiency at all operating conditions.

Where a damper sealing efficiency of 100% is not specified, a vent valve and standpipe shall be provided on top of the ducting between the damper and the isolator. The standpipe outlet shall be at least 2 m above adjacent platforms or walkways. It shall be effectively protected against the ingress of rain water.

For all isolators and dampers, data/requisition sheet DEP 31.38.01.93-Gen. shall be completed by the Manufacturer.

3.11.2 Dampers

The damper shall be of a type and make accepted by the Principal.

Special attention shall be given in the design to the prevention of any vibration or fluttering at any blade position and during any operating condition.

The damper operating gear shall be outside of the ducting so as to be accessible for inspection and maintenance during normal ESP operation.

The shaft shall be marked to indicate the blade position and shall be efficiently sealed to prevent gas leakage.

Damper shaft bearings shall be external and of the self-aligning and non-lubricating type.

It shall be possible to lock the damper blade in its closed position.

The damper blade shall not move under the effects of gravity or vibration. In addition, the damper shall be designed such that in the event of an explosion, when the damper is in the "open to bypass" position, movement of the damper blade is restricted.

Blade seals shall be all metal, non-permeable and flexible so as to accommodate thermal or other normal movements of the damper casing. Their sealing efficiency shall be assisted by the pressure difference across the blade.

The Principal shall specify in the data/requisition sheets whether single seals or double seals with air purging are required. The degree of gas flow isolation provided by the closed damper shall be stated by the Supplier on the data/requisition sheets as a percentage of the maximum flow.

Dampers shall be both electric motor and manually operated. Equipment for manual operation shall be easily accessible and a shaft-mounted position indicator shall be included. A disengaging clutch shall be incorporated to facilitate manual operation of the damper. Shaft drives shall be protected by a rigid and firmly mounted guard.

Electric motors shall be capable of developing at least 110% of the power required by the damper under the most severe operating condition.

The damper drive shaft shall be capable of transmitting at least 110% of the maximum motor torque.

The maximum blade travel in both directions shall be controlled by limit switches. The mounting brackets of the limit switches shall be adjustable so as to allow the optimum closing positions of the damper blade to be set. The Principal shall specify the make and type of the limit switches.

3.11.3 Spade plate isolators

The isolator shall be of a type and make accepted by the Principal.

The spade plate shall provide 100% gas-tight isolation.

The spade plate shall be thick enough and sufficiently stiffened to avoid distortion, and to withstand at least 1.5 times the design pressure of the ducting.

Unless otherwise specified, spade plates shall be of carbon steel and shall have a minimum corrosion allowance of 2 mm. They shall be provided with sufficient protection against corrosion.

Manual insertion of the spade plate shall be done from the top of the ducting by means of a chain block which shall not normally form part of the supply. The chain block shall be supported from a suitable overhead beam. Facilities shall be provided for storing the spade plate securely while not in use.

3.12 STEEL STACKS

Steel stacks shall be in accordance with DEP 34.24.26.31-Gen. If the stacks are excluded from the ESP supply scope, the Principal shall provide all necessary design information as requested by the ESP supplier.

Stacks shall be provided with sufficient protection against corrosion, subject to acceptance by the Principal.

The bypass stack shall be protected against the ingress of rain by a water gathering rain hood complete with adequate drainage facilities.

3.13 FANS

Fans which are intended to overcome ESP and/or flue gas system draft losses are normally not included in the supply scope of the ESP. The Principal shall specifically state any such requirement in the data/requisition sheets.

Fans should be located in the ESP outlet ducting.

Due consideration shall be given in establishing a design basis for capacity and head generation.

Fans shall be in accordance with DEP 31.29.47.30-Gen. and shall be of the single suction centrifugal type with a stiffened casing having a minimum thickness of 5 mm.

The casing shall be of a design to facilitate removal of the rotor without dismantling the connecting ducting. The casing shall allow for thermal expansion without affecting the alignment of the equipment.

The combined performance, mechanically and thermodynamically, of the fan and drive shall be the responsibility of the fan supplier.

The following information shall be provided and submitted with the tender:

- performance curve (guaranteed by supplier),
- torque speed curve,
- fan mass and its inertia of rotation,
- minimum required flow rate to avoid surging,
- installation and cross-sectional drawings.

3.14 CHEMICAL DOSING INSTALLATION FOR FLUE GAS CONDITIONING

Particularly for high resistivity particulates, flue gas conditioning may be considered to improve ESP efficiencies. The Principal shall state in the data/requisition sheets whether this is an acceptable means of efficiency improvement and/or the Supplier shall state his reasoning in the tender.

An installation suitable for dosing the necessary chemicals for the ESP may comprise, for example:

- a dosing installation for sulphur trioxide (SO_3)
- a dosing installation for ammonia (NH_3)
- a dosing installation for water (H_2O)

Each dosing installation shall be provided with a dosing pump complete with installed spare. The stroke of the pumps shall be adjustable during operation and standstill. Dosing pumps shall be in accordance with DEP 31.29.12.30-Gen.

The above installations shall be complete with lines, valves, pumps, vessels, mixers, mountings, heaters, if necessary, and arrangements to avoid health and safety hazards.

3.15 GAS FLOW INDUCED VIBRATIONS

The Supplier shall include in the design all measures necessary to ensure that no part of the ESP installation and ducting shall be subject to any vibrations which are induced by gas flow and which may reduce the design lifetime of any part of the ESP and ducting, or create equipment noise exceeding the limitations (see 8).

The design measures shall include, if necessary, provision for the installation of damping equipment after the initial start-up of the ESP. Baffles shall be installed in line with the direction of gas flow.

The Supplier shall take care in the design to ensure that the frequencies of gas vortex shedding from internals do not excite or resonate with the natural frequencies. Also, such vortex shedding frequencies shall not excite or resonate with the acoustic frequencies of the ESP casing or ducting.

Following the start-up of the ESP, any corrective measures which may be required to dampen any unacceptable gas flow induced vibrations or to eliminate noise, shall be the sole responsibility of the Supplier. Such corrective measures shall be approved by the Principal and shall be applied by the Supplier prior to hand over of the ESP to the Principal.

4. SURFACE PREPARATION, PAINTING AND COATING

Painting shall be in accordance with DEP 30.48.00.31-Gen.

Components not corroding under ambient atmospheric conditions, such as galvanized steel, stainless steel and non-ferrous metals, need not be painted. Zinc containing paint shall not be applied on stainless steel.

Flange facings shall not be painted; in general, surfaces in contact with process streams need also not be painted.

All machined surfaces and threads shall be thoroughly cleaned and protected with Shell Ensis Fluid 'G' (or equivalent if approved by the Principal).

5. INSULATION

The ESP shell, roof and hoppers shall be provided with insulation material and sheeting to provide thermal insulation and weather protection.

Insulation shall be in accordance with DEP 30.46.00.31-Gen. The Supplier shall give in his tender full specifications of the insulation materials to be used together with any deviations from the above standard.

The installation of insulation shall be in accordance with standards accepted by the Principal and shall have been proven in practice to meet the operating conditions.

Internal insulation shall be avoided. For temperatures below 500 °C a bare steel surface (of appropriate grade) with external insulation shall be used. If internal insulation is required, details of such systems shall be agreed by the Principal.

External insulation shall be covered with sheeting installed in such a way that the insulation remains perfectly dry and free from ingress of water and has sufficient allowance for expansion.

The insulation cladding material for the ESP roof shall be steel with a minimum thickness of 5 mm.

Manholes, access doors, etc. shall have their own separate insulation so that they can be opened without damage to the insulation.

All vertical surfaces to be provided with insulation shall have insulation support rings, as shown on Standard Drawing S 20.003.

6. ELECTRICAL INSTALLATIONS

6.1 GENERAL DESCRIPTION

The electrical equipment forming part of the ESP package generally comprises the following items:

- Control cubicle;
- T-R set(s);
- Electric heating;
- Drives of ancillary equipment.

In addition, if requested by the Principal, the electrical equipment requirements may also be extended to include a dust disposal system.

The electrical systems shall be designed, constructed and installed in accordance with the requirements, DEP's and standards referred to in this section. Additional requirements specified by the Principal, such as for selected makes and types of electrical equipment, shall be adhered to.

All electrical equipment mounted on the ESP or located within the hazardous area designated for the installation shall be selected in accordance IEC 60079. Additionally, electrical equipment shall meet the requirements for enclosure protection IP 55 (Zone Y) or IP 65 (Zone Z) for a combustible dust environment, as determined from BS 6467.

6.2 MAINS ELECTRICITY SUPPLY

See DEP 33.64.10.10-Gen.

6.3 MAINS VOLTAGE DISTORTION

See DEP 33.64.10.10-Gen.

6.4 ELECTRICAL CONTROL CUBICLE

The electrical control cubicle shall house the control switches and protection for the transformer rectifier unit, control relays for the rapping system and heating system and the microprocessor supervisory and control unit for the ESP system.

A common cubicle may only be used to serve more than one ESP system when these systems serve a single processing unit.

The electrical control cubicle shall be located indoors and shall meet the requirements for enclosure protection IP 41 to IEC 60529. Enclosures shall be designed to be self supporting and suitable for floor mounting.

The layout, operational front panel and location of the components of the assembly shall be arranged in a logical and systematic sequence and standardised throughout. Operational equipment or metering shall not be located at levels below 200 mm and above 2 000 mm. The door width shall not exceed 800 mm and the floor shall not form part of the enclosure.

All components mounted inside enclosures shall be accessible from the front. Live parts shall be protected by barriers or shrouds meeting a minimum degree of protection IP 20. Barriers shall be constructed from a rigid transparent insulating material allowing screened components to be identified.

All components shall be identified by permanent labels manufactured from a durable material located adjacent to the component.

The Manufacturer shall provide, as part of the documentation, a component layout drawing and a schematic wiring diagram indicating component ratings and settings.

Components operating at low voltage and extra low voltage shall be segregated by means of barriers.

All internal wiring shall be distributed via flexible plastic piping. Wires shall be identified at

each end by embossed codes on the insulation or by means of code numbered ferrules.

Control equipment requiring routine adjustment during normal operation shall be accessible from the front of the cabinet allowing adjustment to be made without opening the cabinet door.

Enclosure doors shall be lockable, using padlock type key locks.

Each control cabinet shall be provided with a main electrical supply isolator interlocked with the door(s) such that the supply is disconnected prior to access being allowed. The isolator shall be provided with padlocking facilities in the OFF position.

DIN fuses of the D-type shall only be applied up to a maximum 63 A and when backed up by short-circuit current limiting devices of maximum 350 A rating to reduce the short-circuit level. Fuses shall be of the low loss type.

Anti-condensation heaters for the cubicle, if requested by the Principal, shall be electrical and supplied from a separate source connected between the system phase and neutral. The heating system shall be separately protected and switched for isolation purposes by means of a miniature circuit breaker in combination with an earth leakage protecting device of 30 mA sensitivity. When the heating system is live, this shall be indicated by means of a prominently positioned red indicator lamp. The heating system shall be designed in such a way that the heat is adequately distributed over all functional units.

A copper earth bar shall be mounted within the enclosure for termination of earth conductors. The earth bar shall have a minimum cross sectional area of 70 mm^2 and shall have sufficient termination screws for the connection of all incoming and outgoing cable earthing leads.

Cabinets shall be pre-wired and wiring requiring connection to external circuits shall be marshalled in terminal blocks with circuit identification.

Cable entry shall normally be arranged at the bottom via an un-drilled gland plate, and means shall be provided to support the ends of cables at the point of entry.

6.5 TRANSFORMER RECTIFIER UNITS (T-R SETS)

The T-R sets form an integral part of the ESP and are mounted on the ESP main housing in close proximity to the high voltage discharge electrodes.

T-R sets shall be suitable for mounting outdoors and shall be designed to withstand the environmental conditions, including modes of vibration, applicable at its location.

T-R sets shall be designed for an operational life of 20 years.

Each T-R set shall normally be installed in a single tank in which all components are immersed in mineral insulating oil. The unit shall be hermetically sealed and designed in accordance with the applicable requirements of IEC 60076. The tank cover shall be fixed by means of bolts allowing removal for maintenance and repair .

The rectifier shall be of a full-wave silicon controlled type.

T-R sets shall be designed for occasional operation where frequent sparking occurs in the discharge system. The Manufacture shall advise the purchaser of any limits in this mode of operation.

The T-R sets shall be provided, as a minimum, with the following electrical protection equipment which shall be located in a separate accessory box mounted on the unit and in an immediately accessible position:

- Oil temperature measuring device (two level 'Alarm' and Trip');
- Over pressure switch (arranged to trip the unit);
- Oil level switch (arranged to alarm on operation).

The transformer rectifier unit shall be protected by fuses in combination with a separate isolating switch or by circuit breaker arranged to break all poles of the power supply. Protection against short-circuits, overload and earth fault conditions shall be included. These control and protective devices shall be installed in the control cubicle.

The high voltage output circuit shall be provided with a manually operated isolating switch arranged to disconnect all output circuits. In addition a circuit switch shall be provided to discharge the high voltage circuits connected to the unit. If a single switch is used to provide positive isolation it shall have three positions as follows:

- OPERATIONAL POSITION : Isolator Closed.
- MID POSITION : HV Output Isolated.
- EARTHED POSITION : HV Output Isolated and Circuits Earthed.

If separate isolating and earthing switches are provided then mechanical interlocking shall be installed such that the output of the unit is isolated prior to earthing the connected circuits.

The isolator and earthing switch shall have positive action such that intermediate positions are not possible. Each position shall be clearly identified by a non-removable label. The switch shall be provided with an electrical interlock arranged to trip the low voltage power source before the high voltage output is isolated. Padlocking facilities shall be provided for all positions.

Where an ESP installation comprises multiples of single transformer rectifier units then the electrical interlocks, associated with the high voltage isolator, shall be arranged to trip all transformer rectifier supply sources. A trip of all T-R supplies shall be caused by the operation of any isolator switch when operated independently.

The high voltage output bushing from the unit shall be protected by an enclosure to IP 55 or IP 65. If a metal enclosure is used then flexible equipotential bonding leads shall be provided between the enclosure and the casing of the ESP. All joints shall be provided with sealing against environmental conditions.

For the T-R sets the Supplier shall provide the following information:

- number, make, type, and rating of the units;
- power consumption (kW);
- rectifier voltage (average at load and peak) (kV);
- rectifier current (arithmetic/effective) (mA).

6.6 HIGH VOLTAGE DISCHARGE SYSTEM

The HVDS comprises distributed high voltage bushing insulators which support and supply the discharge electrodes and are connected to the transformer rectifier unit via a bus-duct mounted on the ESP casing, see Appendix 5.

The bushing insulators and bus-duct shall be protected by an enclosure(s) with enclosure protection IP 55 or IP 65. If metal enclosure(s) are used then equipotential bonding shall be provided at all joints.

High voltage insulators shall be manufactured from porcelain or quartz glass, with a minimum alumina content of 85% and, if required to support a mechanical load, shall have a mechanical strength equal to the design mechanical loading with an added minimum factor of safety of 2.0.

High voltage insulators shall be dimensioned such that the distance between surfaces of different polarity are sufficient to avoid flashover at the peak operating voltage for the design environmental conditions. The insulator arcing distance shall not be less than 2.5 times the nominal spacing between the discharge and collecting electrodes in the ESP.

To keep the HV insulators clean from particulate deposits, a purge (cleaning) system is normally acceptable. The Supplier shall advise the Principal accordingly.

Electrical connections between parts of the unit subject to differential expansion shall be provided with flexible joints.

The components of the high voltage system shall be accessible for maintenance purposes. At each point of access a danger notice shall be installed stating as shown in Appendix 8. Access covers/doors shall be provided with a key-interlocking facility, see (3.7).

6.7 ELECTRIC MOTORS

Electric motors shall meet the requirements of DEP 33.66.05.31-Gen. and shall have a method of cooling as specified in IC 0041 of IEC 60034-6.

Where motors are subject to frequent starting, e.g. rapping system motors, then the rating of the motor shall be selected such that a lifetime of 20 years is maintained.

Motors shall be selected in accordance with the requirements for the hazardous area classification and shall have type of protection Ex(e) or Ex(n).

For an area with classification Y (dust explosion may occur due to the presence of combustible dust) the degree of protection shall be IP 55. For an area with classification Z (dust explosions may occur due to the frequent presence of combustible dust), the degree of protection shall be IP 65. See BS 6467.

Motor circuits will be supplied from the Principal's low voltage motor control centre but the Supplier shall provide means of control from the control cubicle in accordance with Standard Drawing S 67.004.

Motors shall be provided with a Remote Control Unit (RCU) installed local to the motor. The RCU will be provided by the Principal for installation by the Supplier.

For all electric motors data/requisition sheet DEP 33.66.05.93-Gen. shall be completed by the Manufacturer.

6.8 ANTI-CONDENSATION AND HEATING SYSTEMS

If an anti-condensation system is specified by the Principal it shall be electrically operated. When metal sheathed heaters are used the sheathing material shall be resistant to any corrosive effect in the operating environment.

Heaters shall be controlled by capillary type thermostats. The temperature setting accuracy shall be at least 95% of the set value and the maximum difference shall not be more than 10 °C. The hysteresis shall be between 5% and 10 % of the actual setting or between 4 °C and 10 °C, whichever is the more stringent.

Local thermostats shall only be adjustable by means of a tool.

Electrical heat tracing for the particulate hoppers shall comply with the requirements of DEP 33.68.30.32-Gen.

Heater circuits will be supplied from the Principal's supply but the Supplier shall provide means of control from the control panel in accordance with Standard Drawing S 67.004.

Heaters shall be provided with a safety switch installed local to the heater. The safety switch will be provided by the Principal for installation by the Supplier.

6.9 LIGHTING AND POWER INSTALLATION

See DEP 33.64.10.10-Gen.

6.10 EARTHING SYSTEM

A separate protective earth conductor shall be installed to connect the electrical items of equipment. The protective conductor shall be PVC insulated, coloured green/yellow and have a minimum cross sectional area of 70 mm^2.

See also DEP 33.64.10.10-Gen.

7. INSTRUMENTATION AND CONTROL

7.1 GENERAL DESCRIPTION

Amended per Circular 18/99

The scope of supply for instrumentation and control for the ESP shall be selected from the options given in DEP 32.31.09.31-Gen.

Whether the instrumentation is supplied with the ESP installation or not, all necessary instrument process connections shall be provided by Supplier.

Their requirements shall be in accordance with DEP 32.31.00.32-Gen. All equipment therein indicated as 'forming part of mechanical engineering' shall be supplied with the ESP.

The Supplier shall be responsible for the correct input data and for the sizing calculations for flow measuring elements. The sizing calculations shall be subject to the approval of the Principal.

The Supplier shall provide, and include in the tender, schematic diagrams for automatic control, start-up and instrumented protective function (IPF) of the ESP. PEFS symbols shall conform to DEP 32.10.03.10-Gen.

The Supplier shall include any provisions deemed necessary for satisfactory operation of the ESP under the conditions specified in the data/requisition sheets.

The diagrams etc. shall also include the additional requirements, if any, specified in the applicable local and national regulations. In case of conflict between such regulations and the requirements specified above, the Supplier shall state this in the tender.

7.2 INSTRUMENTATION

The Supplier shall review the instrumentation requirements for the ESP and state his recommendation or design standard in the quotation. For guidance, the following are typical on an ESP:

- opacity meter, to measure optical density of the emission stream;
- analysers for carbon monoxide and oxygen;
- temperature, to monitor/control hopper temperatures and flue gas temperatures in the ESP;
- pressure, to monitor/control pressure profile across the ESP;
- level, instrumentation to monitor/control hopper levels (preferably gamma ray detectors);
- microprocessor to control T-R sets and electrical field conditions;
- insulator compartment purge air system;
- instrumentation to control rapping mechanisms.

7.3 AUTOMATIC CONTROL UNIT

In order to obtain the optimum collecting performance (efficiency), each T-R set shall be fitted with an automatic control unit. The control system shall be equipped with power thyristors as final control elements (as an alternative to transductors). Triggering shall be effected via a voltage regulator, which shall operate fully electronically and shall be without contacts. This will permit the fastest possible adaptation to the operating conditions in the electrical field at any given moment.

The automatic control unit shall detect sparks in the flash-over range and adapt the voltage to the maximum admissible flash-over limit, which depends on the process variables.
Adaptation shall be achieved by setting the rate of voltage increase and the extent of voltage reduction. By further setting a limitation on current, the voltage height can be limited and flash-overs reduced to a minimum.

The following instrumentation shall be provided as part of the controller:

- voltmeter a.c. T-R input and kW input;
- milliammeter and kilovoltmeter for the d.c. output of the T-R unit;
- provisions for alarm signals;

- spark counter (cumulative).

7.4 INSTRUMENTED PROTECTIVE FUNCTION

If flammable mixtures can enter the ESP, facilities shall be provided for automatically tripping the ESP. A trip of the ESP's power supply shall include earthing of the discharge system. The details of the tripping and purging scheme shall be subject to the approval of the Principal.

A hard-wired trip button shall be included at the operator console for manual emergency shutdown.

8. NOISE LIMITATIONS

8.1 GENERAL DESCRIPTION

EEMUA 140 shall apply with regard to definitions, notations, measuring equipment and procedures, test reporting, calculation methods and procedures.

8.2 NOISE LIMITS

The maximum allowable sound pressure level shall be 85 dB(A) in the work area, i.e. any position accessible to personnel at a distance not less than 1 m from the equipment surface.

If more stringent noise limits apply, this shall be indicated by the Principal on the data/requisition sheet, DEP 31.10.00.94-Gen.

If the equipment produces impulsive and/or narrow band noise, the above limit shall be 5 dB(A) lower than the value stated above or in the data/requisition sheets.

The above requirements apply in the absence of reverberation and background noise from equipment other than the ESP installation, for all operating conditions. The requirements refer to the overall noise level produced jointly by all components of the installation.

Start-up, shut-down and testing situations are to be considered as normal operation. If in such situations higher noise levels are produced for only short periods, the equivalent (average) sound pressure level over an 8 hour period shall not exceed 85 dB(A) in the work area. However, the maximum (peak) level shall not exceed 95 dB(A).

8.3 NOISE ABATEMENT

Excessive equipment noise should be eliminated by low noise design. Where other noise control measures, such as acoustic enclosures, are required, they shall not in any case obstruct operational or routine maintenance activities. Where noise hoods are proposed, prior approval of the Principal shall be obtained regarding construction, materials and safety requirements.

Acoustic insulation of pipes, valves and flanges shall be in accordance with DEP 31.46.00.31-Gen.

8.4 INFORMATION TO BE SUBMITTED WITH THE TENDER

The Supplier shall submit the sound power levels and/or sound pressure levels of the equipment, together with any other relevant information as requested in the equipment noise limitation sheet DEP 31.10.00.94-Gen., in the silencer data/requisition sheet DEP 31.10.00.95-Gen., and the acoustic enclosure data/requisition sheet DEP 31.10.00.96-Gen.

Applicable noise levels, i.e. guaranteed sound power levels and sound pressure levels per octave band centre frequency at both minimum and maximum operating conditions, shall be specified for the following equipment parts:

- complete ESP, including rapping mechanisms;
- all electric motors;
- complete dust removal system, including valves;
- ducting, including dampers;
- fans.

9. ADDITIONAL REQUIREMENTS

9.1 NAMEPLATES AND RATING PLATES

Each ESP shall be provided with a nameplate made of corrosion resistant metallic material. Enamelled nameplates are not acceptable.

The nameplate shall be attached by means of rivets to a non-removable part of the frame and shall be clearly stamped with the following information:

- Manufacturer's name;
- year of fabrication;
- purchaser's order number;
- Manufacturer's work identification number;
- equipment item number;
- equipment type, model and serial number;
- design pressure, incl. vacuum, (kPa);
- design temperature, (°C).

The language on the nameplate shall be English, unless stated otherwise in the data/requisition sheets.

The rating plate of the motor shall be in accordance with DEP 33.66.05.31-Gen.

9.2 SPECIAL TOOLS

All special tools required for maintenance and operation which are not normally found in a workshop, shall form part of the installation.

9.3 MAINTENANCE MANUAL

A maintenance manual (at least 5 copies) shall be provided, the manual shall at least contain:

- schematic diagrams clearly showing all parts;
- a recommendation for the lubricants to be used;
- prospective problems (e.g. in case of emergency);
- precautions to be taken when ESP has to be shut down.

Where an existing ESP is to be modified, special precautions may be required to ensure that the modifications necessary are carried out safely and in accordance with the design code to which the ESP was constructed and tested.

9.4 SPARE PARTS

Supplier shall submit a list of recommended spare parts for both commissioning and 2 years of operation, showing quantities and unit prices of each item. Reference is made to DEP 70.10.90.11-Gen.

10. MATERIAL, FABRICATION AND CONSTRUCTION

10.1 GENERAL

The ESP installation shall be shop-fabricated to the maximum possible extent and shall be transported to site as one complete unit, or as a number of large sub-assemblies ready for, and requiring the minimum of, site assembly.

The extent of shop fabrication shall be clearly specified by the Supplier and shall be agreed upon between the Supplier and the Principal.

10.2 CONSTRUCTION MATERIALS

Construction materials of main components shall be selected by the Principal and are listed in the data/requisition sheets. Material selections and equivalent grades shall be in accordance with DEP 30.10.02.11-Gen.

10.3 WELDING

Structural welding shall be in accordance with DEP 34.28.00.31-Gen. (which makes reference to AWS D1.1).

10.4 PIPING FABRICATION

Piping component materials shall be selected for the applicable service requirements. The type and material specifications of the piping components shall be stated by the Supplier.

Piping shall be fabricated in accordance with DEP 31.38.01.31-Gen.

See also (3.10).

10.5 GASKETS AND PACKING

Jointing materials for bolted connections shall comply with the requirements of the applicable specification, code or standard and are subject to acceptance by the Principal.

All connections where gaskets are to be used shall have finished surfaces. Other flanges shall have machined surfaces in accordance with the appropriate standard requirement or as specified by the Principal. Where circumstances prohibit a finished or machined cut, the gasket contact surface shall be true within 0.5 mm and the adjoining surface shall be parallel.

11. PACKAGING, TRANSPORT AND SHIPPING

All external machined surfaces of the ESP shall be sprayed with one coat of Shell Ensis Fluid ‘G’, or equivalent (if acceptable to the Principal), before the equipment leaves the Manufacturer's works.

Prior to departure from the works, all openings shall be closed to prevent foreign matter from entering during transport or erection. All flanges and other connections shall be protected with blanks, caps or plugs.

To prevent damage of the ESP during lifting and/or transport, components shall be provided with adequate and proper lifting facilities. Also, pertinent lifting instructions shall be clearly indicated on the equipment concerned. For typical lifting facilities reference is made to Standard Drawings S 10.030 and S 10.115.

The Supplier shall submit final pro forma packing lists for the equipment and the spare parts ordered, showing number of packages with description, net and gross weights per unit and total weight, overall dimensions per unit and total measurement per unit.

12. INSPECTION AND TESTING

12.1 INSPECTION AND TESTING OF MATERIALS AND EQUIPMENT

Inspection and testing of individual items of equipment shall be done in accordance with this DEP and the data/requisition sheet.

Unless otherwise specified on the data/requisition sheets, performance testing of fans shall be in accordance with DEP 31.29.47.30-Gen.

Gas-tightness shall be tested up to the ESP terminal points, using a smoke bomb or a soap test at the maximum operating pressure.

The Supplier shall submit materials test certificates for the electrodes, casing plates, piping, valves, dampers, isolators and other equipment as specified in the data/requisition. These certificates shall be available at site before the initial start-up of the ESP. These test certificates shall satisfy the applicable code requirements.

The Principal shall specify if, and to what extent, he wishes to witness the Manufacturer's inspection and testing.

12.2 SCOPE OF INSPECTION WORK

To ensure compliance with specification, the tests and checks to be carried out at the Manufacturer's works shall include but are not limited to the following:

a) Materials:
A materials check to verify that the materials used for construction are in accordance with the material grade and quality specified in the purchase order and/or approved drawings.

b) Dimensions/tolerances:
A dimension and tolerance check to ensure that the equipment is fabricated in accordance with the latest revisions of the drawings.

c) Workmanship:
Welding:
All welds shall be subjected to close visual inspection as welding progresses. Any faults or bad practices shall be corrected immediately.

All preparations shall be in accordance with the specified profile(s). When a root gap is specified, the edges of butt welds shall be secured in such a way that the correct gap is maintained during welding. Particular attention shall be paid to joint preparation for those welds which cannot be back welded.

Type and size of electrode, welding current, direction of welding, etc., shall be in accordance with the procedure qualification test.
Welding and weld details shall be in accordance with the agreed drawings, specifications and procedures.

Finished weld inspection:
Welds shall be given a visual examination and shall comply with the relevant design code and/or as specified by the Principal. The Principal shall specify whether any non-destructive testing (NDT) is required and this shall comply with the relevant design code and/or as specified by the Principal.

d) Document review:
Verification of completeness of documentation covering the full scope of supply.

12.3 REPORTING

The Supplier shall report the following:

a) Material certificates according to ISO 10474 or as otherwise specified in the data/requisition;
b) Materials used for construction, including non-metallic materials, such as packing/gaskets etc.;

c) Weld preparation drawings;
d) Non-conformance's accepted by the Principal;
e) Results of pressure testing;
f) Results of running tests, including test certificates.

Such reporting shall be compiled in a manufacturing report. The supply of this manufacturing report, which should be checked and signed for acceptance by the purchaser's inspector or his nominee, is an integral part of the Manufacturer's obligation.

For correct completion reference is made to DEP 31.22.10.35-Gen. On the first page of the report a certificate of acceptance shall be inserted stating that all requirements indicated in the purchase order, any variation of the order and any attachments, have been adhered to.

Copies of the manufacturing report shall be supplied as specified by the Principal.

13. ERECTION, START-UP AND PERFORMANCE TESTING

13.1 MECHANICAL ERECTION

Plumb and level of ESP columns and framing shall be checked after erection.
Mechanical erection shall include any applicable tests and services such as cleaning, drying, electrode alignment, setting of instruments and the like, as may be required to prepare for start-up. Mechanical erection shall be carried out by the Supplier, or under his supervision, as agreed upon between the Principal and the Supplier.

The installation of rotating equipment shall be in accordance with DEP 31.29.00.10-Gen.

The ESP and ducting shall be mounted in such a way that free expansion is possible so that no undue stresses are caused to adjoining structures, equipment and foundations.

After completion of erection but before the discharge electrodes are installed, all extraneous material shall be removed from the ESP.

At this point all sub-systems should be energised for approximately 100 hours ('burn-in' period) to check for operational reliability. During the 100 hours test, air load tests should be performed. Secondary voltage and secondary current should be recorded and plotted for use as a baseline for future reference and performance testing.

All equipment and materials, including chemicals, necessary for the pre-start-up shall be provided by the Supplier.

13.2 AIR LOAD TEST

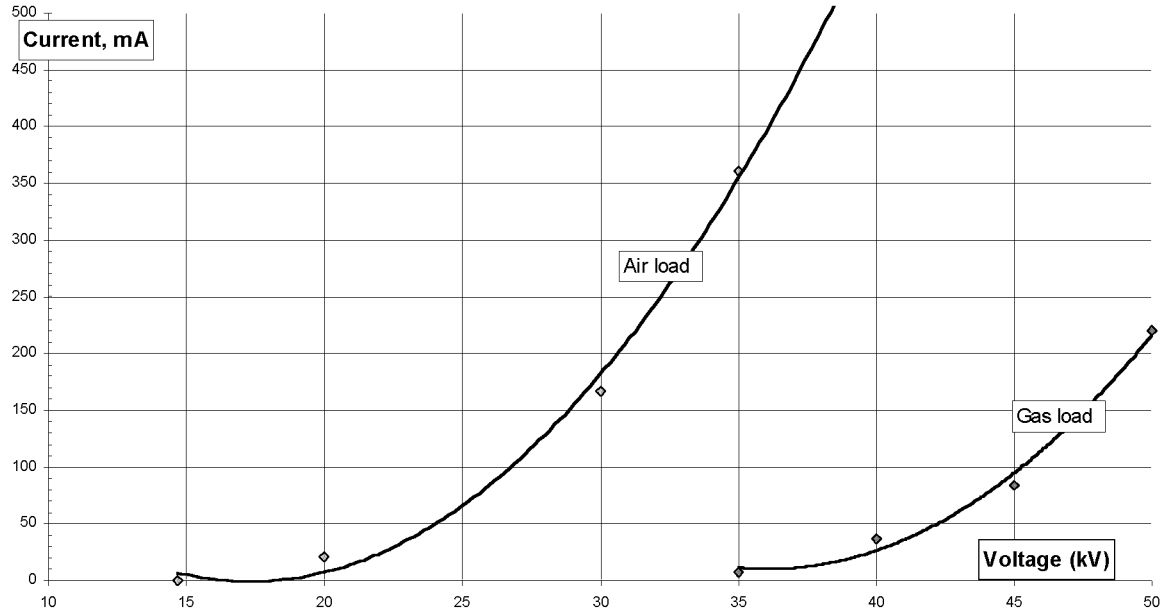
An air load test provides a unique opportunity to test a precipitator dynamically before committing it to high temperature operation, when personnel entry is no longer possible. The test allows maintenance personnel to gauge the quality of electrode clearances and to check for internal short circuits before start-up. Sparking during an air load test generally suggests poor clearances, assuming dry and clean insulators.

The precipitator is energised with just a slight draft and no gas flow. Each section is energised independently. Power is generally raised by increments of 10%. All meter readings are documented at each increment. A plot of voltage and current curves of equal size loads and equal size T-Rs should be similar (differences are cause for investigation). Each test serves as a basis for succeeding tests. The curves are compared and analysed for characteristic changes. The electrical characteristics of a precipitator differ considerably on gas loads from that of air loads. In an air load test the voltage is relatively low and the current is at rated or near rated value.

Conversely, at gas load and high dust concentration voltage is high and current is low, assuming good T-R/load matching and good alignment. Figure 1 is a good illustration of typical voltage-current curves for air loads and gas loads of an inlet field. The curves illustrate that in a highly charged electric field ion mobility decreases as particle concentration increases. In an air load the negative gas ions travel further without collisions, hence current flow is high.

A procedure for an air load test is provided in Appendix 4.

Figure 1 Typical voltage-current curves for an inlet field



13.3 START-UP

After completion of mechanical erection and all pre-start-up tests of control and IPF systems, the ESP shall be put into operation by the Principal under supervision of and, if required, with the assistance of the Supplier.

The Supplier shall instruct the Principal's staff in the correct methods of start-up, operation, shutdown, emergency procedure and maintenance.

13.4 PERFORMANCE/ACCEPTANCE TESTING

Performance and acceptance testing shall start only after the installation has been operating satisfactorily at near design conditions for a consecutive period of 60 days. The Principal may, however, stipulate a lower load and/or period to suit conditions prevailing at the time. The performance guarantees made by the Supplier shall be met.

Two performance tests shall be required. The first test shall be 60-90 days after start-up and continuous operation of the precipitator equipment. The Supplier shall first make all the adjustments he deems necessary for proper precipitator performance. If the guarantee is not met in all aspects, the Supplier shall immediately take the remedial steps necessary and shall then re-test to demonstrate that the guarantee is met. The re-test shall be conducted by the same company and the cost of all re-tests shall be borne by the Supplier.

The second test shall be performed within 305 and 365 days after successful completion of the first test. During this period the precipitator shall be operated and maintained in accordance with the Supplier’s recommendations, providing there will be no interference to operations. If the guarantee is not met in all aspects, the Supplier shall immediately take the remedial steps necessary and shall then re-test until Supplier can demonstrate that the guarantee is met. The re-tests shall be conducted by the same company and the cost of all re-tests shall be borne by the Supplier.

At least the following tests shall be carried out:

- efficiency test, if inlet loading is greater than specified;
- pressure drop test;
- any additional performance test, as specified on the data/requisition sheets;

- tests for automatic control and load response;
- tests for operation of the instrumented protective system (IPS).

Tests shall be done by an independent third party engaged by the Supplier and agreed by the Principal.

Tests shall be performed in the presence of the Principal and Supplier. Any re-tests due to Supplier's failure to meet guarantee will be paid by Supplier.

Methods for the determination of the flue gas dust load shall be agreed between the Principal and the Supplier before the award of the contract.

Unless otherwise specified, the plant instruments may be used for the performance tests after agreement has been reached between the Principal and the Supplier on the calibration and accuracy of the plant instruments.

If it is specified that the plant instruments may not be used for the performance tests, or if the Supplier does not agree to the use of plant instruments, the Supplier shall provide the calibrated test instruments and apparatus for the tests.

Amended per Circular 18/99

Flow metering shall be in accordance with DEP 32.31.00.32-Gen.

Where the Supplier does not provide the instrumentation and control system, the ESP supplier shall remain responsible for the ESP performance guarantees, on the basis that the ESP supplier agrees with the principles of the instrumentation and control system which will be applied.

14. DOCUMENTATION

14.1 GENERAL

The English language shall be used throughout unless otherwise specified. However, descriptions on drawings may be in other languages, provided that English translations are given.

The Supplier shall provide all drawings, design details, operation and maintenance manuals, and other information necessary for the design assessment, erection, operation and maintenance of the installation. All information, especially the manuals for operation and maintenance shall be clear and not open to misinterpretation and shall apply specifically to the installation supplied.

14.2 DATA/REQUISITION SHEETS AND DOCUMENTATION REQUIRED AT TENDERING

For the exchange of information between the Principal and the Supplier, use shall be made of data/requisition DEP 31.27.21.94-Gen.

14.2.1 Data/requisition sheets

These sheets describe, in conjunction with this specification, the extent of the project and contain data provided by the Principal.

Utility data will be indicated on the data/requisition sheets. Where necessary, additional information on existing equipment will be given by the Principal, e.g. flue gas ducting system, furnaces/boilers/fans, chemical dosing systems and dust disposal system.

The sheets shall be completed by the prospective Supplier at the tendering stage.

It is accepted that, at this stage, certain data requested on the data/requisition sheets will not have been finalised. However, rather than giving no information in such cases, the Supplier shall give anticipated data so that a clear appreciation can be made of the equipment offered. This is necessary for the Principal to make a pre-selection of the tenders. The data may be updated later by the Supplier prior to the final selection stage.

The following drawings and information shall be submitted with the completed data/requisition sheets:

(a) Drawings of:
- dimensioned general arrangement, front and side elevations and plan of complete installation showing location of transformer/rectifier units, rapping gear, ducting including expansion joints, damper, isolator, platforms and stairs, ladders and stacks.
- dimensioned front and side sectional elevations and sectional plan of ESP showing; casing, hoppers, insulation, access and observation ports.

(b) Description of:
- general description of installation
- extent of shop fabrication
- extent of site fabrication
- casing
- gas distribution devices
- electrodes and T-R units
- rapping systems
- purging/flushing and heating systems
- ducting including expansion joints
- damper and isolator
- dust collection system
- insulation and sheeting
- materials selection scheme
- control schemes and description of all controls and start-up logic
- single line diagram of power supply system.

(c) Graphs showing:

- gas flow, temperature and moisture content correction curves
- dust inlet concentration correction curve

(d) The capital costs of:

- ESP casing
- structural steelwork
- T-R units
- dust removal system
- ESP flue gas ducting, stacks
- insulation and sheeting
- instrumentation
- miscellaneous items
- erection/supervision of erection
- start-up/performance testing.

(e) Period of delivery:

- time from award of contract to completion of fabrication and erection
- time from arrival at site to acceptance
- estimated man-hours and minimum time needed for erection.

(f) Lists of:

- reference ESPs of the same type, including location, capacity
- any deviations from the requirements of this specification
- sub-suppliers
- all instruments and their location (local, local panel, control room)
- major shipping weights and dimensions
- provisions made for safety and emergencies.

14.2.2 Revised data/requisition sheets

A revision of the data sheets shall be submitted by selected suppliers for the final evaluation and selection by the Principal. This revision shall reflect any changes arising from bid clarification discussions with the Principal and firm data which was previously submitted as anticipated data, see (14.2.1).

The following information shall be submitted together with the revision:

- details of the casing wall and roof construction, showing electrodes
- details of gas distribution devices, inlet and outlet
- dimensioned details of internals
- electrode support details
- hopper details, including baffles and externally attached devices
- insulator compartment air purge system
- ESP and ducting support and expansion details
- details of damper, isolator and expansion joint constructions
- construction materials
- fan characteristics (where applicable)
- list of drives, showing type, manufacturer, duty
- list of insulation materials, showing type and location
- dimensions and mass details for shipping and erection purposes.

14.3 DOCUMENTATION AND INFORMATIONS REQUIRED AFTER CONTRACT AWARD

The following shall be submitted after the contract has been awarded:

- all necessary information for the design of the foundation, e.g. mass, moments, location of foundation bolts, etc.
- mounting and foundations of fan and drive
- details of fans, drives and instruments
- list of manufacturers of all major equipment
- list of all spare parts, including list of initial spare parts necessary for start-up and first year of operation, with detailed prices and time of delivery
- list of all tools necessary for operation, maintenance, inspection and cleaning insofar as not normally found in a refinery workshop

- the mass of:
- ESP empty
- ESP full (working conditions)
- fans and drives
- ducting, stacks, damper and drive, and isolator
- six copies of the operation and maintenance manuals

NOTE: For certain items, e.g. electric drives, the Supplier will receive dedicated requisition sheets, partly filled in by the Principal.

15. GUARANTEE

The Manufacturer shall ensure that the equipment is designed and constructed in accordance with the specifications and codes referred to in the data/ requisition sheets and drawings. The Manufacturer shall make all necessary calculations for which he is fully responsible.

The Manufacturer shall ensure that the equipment supplied confirms to all applicable codes and national statutory regulations, and shall obtain all necessary approvals from statutory authorities.

The Manufacturer shall guarantee that the equipment furnished is free from any defects in design, workmanship and material, that the various parts are designed to operate correctly in conjunction with each other and that they will give proper and continuous service under the operating and design conditions specified.

The Manufacturers guarantee shall cover a minimum period of twelve months continuous day and night service, as from the day on which the equipment is installed and commissioned. The Manufacturer's guarantee shall in any case not be less than 18 months from the date on which the equipment is ready for delivery at the Manufacturer's works.

16. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

Amended per Circular 18/99

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Requisitioning binder	DEP 30.10.01.10-Gen.
Metallic materials selected standards	DEP 30.10.02.11-Gen.
Thermal insulation for hot services	DEP 30.46.00.31-Gen.
Painting and coating of new construction projects	DEP 30.48.00.31-Gen.
Manufacturing report for pressure vessels	DEP 31.22.10.35-Gen.
Installation of rotating equipment	DEP 31.29.00.10-Gen.
Reciprocating positive displacement pumps and metering pumps	DEP 31.29.12.30-Gen
Centrifugal fans	DEP 31.29.47.30-Gen.
Piping - general requirements	DEP 31.38.01.11-Gen.
Piping classes	DEP 31.38.01.12-Gen.
Acoustic insulation for pipes, valves and flanges	DEP 31.46.00.31-Gen.
Instrumentation symbols and identification on Process Engineering Flow Schemes	DEP 32.10.03.10-Gen.
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Instrumentation for packaged units	DEP 32.31.09.31-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Electric motors three-phase, cage-induction type	DEP 33.66.05.31-Gen.
Electrical heat tracing	DEP 33.68.30.32-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Steel stacks	DEP 34.24.26.31-Gen.
Steel structures	DEP 34.28.00.31-Gen.
Spare parts for initial and normal operation	DEP 70.10.90.11-Gen.
Data/requisition sheets:	
Data/requisition sheet for equipment noise limitation	DEP 31.10.00.94-Gen.
Data/requisition sheet for vent/blowdown/air flow/ in-line silencers	DEP 31.10.00.95-Gen.
Data/requisition sheet for rotating equipment acoustic enclosures	DEP 31.10.00.96-Gen.
Data/requisition sheet for rotary star valves	DEP 31.25.40.93-Gen.
Data/requisition sheets for ESPs	DEP 31.27.21.94-Gen.
Data/requisition sheet for isolators and dampers	DEP 31.38.01.93-Gen.
Requisition sheets for electric motors	DEP 33.66.05.93-Gen.

NOTE: Data/requisition sheets are contained in the requisitioning binder, DEP 30.10.01.10-Gen.

STANDARD DRAWINGS

Flanged nozzles to apparatus	S 10.101
Lifting lug	S 10.030
Lifting trunnions	S 10.115
Support ring for insulation	S 20.003
Flanged connection for flue duct	S 24.301
Access door for flue duct	S 24.304
Stairways - general arrangement	S 28.001
Handrailing, type 'A'	S 28.006
Schematic diagram of control circuits	S 67.004

AMERICAN STANDARDS

ASME Boiler and Pressure Vessel Code Welding and brazing qualifications — ASME IX

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA.

Structural welding code — AWS D1.1

Issued by:
American Welding Society,
550 NW Le Jeune Road
P.O. Box 351040, Miami FL 33130
USA

BRITISH STANDARDS

Electrical apparatus with protection by enclosure for use in the presence of combustible dusts — BS 6467

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK

Noise Procedure Specification — EEMUA 140

Issued by:
Engineering Equipment and Materials Users Association.
45 Beech Street
London EC2Y 8AD
UK

INTERNATIONAL STANDARDS

Rotating electrical machines; Part 6: Methods of cooling	IEC 60034-6
Power transformers	IEC 60076
Electrical apparatus for explosive gas atmospheres	IEC 60079
Degree of protection provided by enclosures (IP Code)	IEC 60529

Issued by:
Central Office of IEC (sales dept.)
3, Rue de Varembé
1211 Geneva 20
Switzerland

Copies can also be obtained from national standards organisations

Steel and steel products - Inspection documents	ISO 10474

Issued by:
International Organisation for Standardisation
1, Rue de Varembé
CH-1211 Geneva 20
Switzerland.
Copies can also be obtained from national standards organisations

APPENDIX 1 SCOPE OF SUPPLY AND TERMINAL POINTS

A list entitled 'Scope of supply' and a list entitled 'Terminal points' shall be provided by the Principal. These lists refer to the individual requirements of each project. To assist in the compilation of these lists, typical examples are given below.

A sketch may also be found useful in defining the 'Terminal points' (e.g. flue gas ducting terminal points), in which case such a sketch should be attached to the 'Terminal point' list.

SCOPE OF SUPPLY (Typical example)

ESPs, each ESP complete with:

1. Instrumentation and control system
2. Hoppers
3. Dust removal system
4. Fans and drives
5. Steel structures
6. Platforms, stairways, ladders
7. Piping
8. Mountings, valves and fittings
9. Steel stack
10. All ducting to/from ESP and to stack
11. Damper and isolator
12. Heating systems
13. Lighting
14. Foundation bolts
15. Gaskets, jointing materials
16. Special tools
17. Insulation
18. Flue gas chemical dosing installation

TERMINAL POINTS (Typical example)

See also Sketch ...(by the Principal)... attached to this list.

1. Flue gas in/outlet of the ESP

2. ESP flue gas duct from/to, by-pass stack

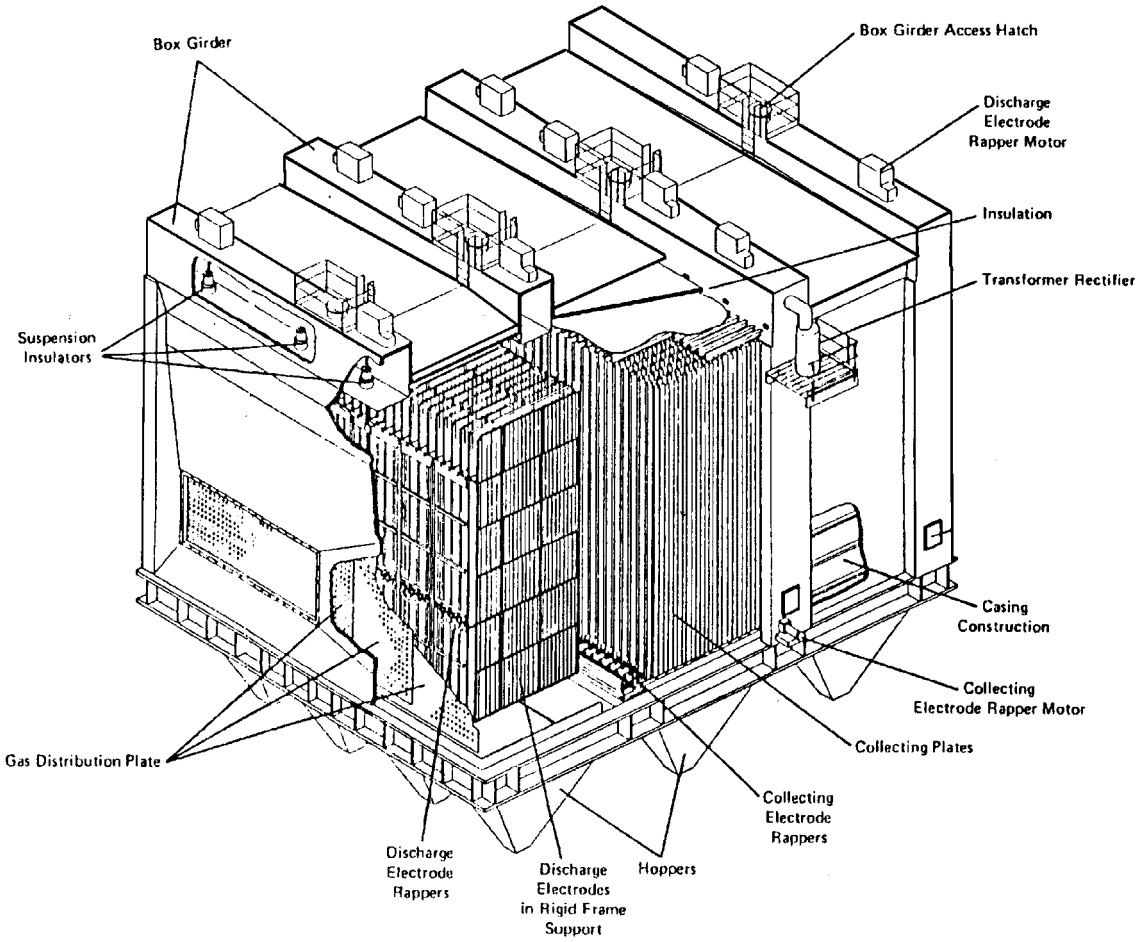
3. Utilities
   Supply lines as shown on the (above) sketch

4. Particulate hoppers
   Outlet flanges of all hoppers

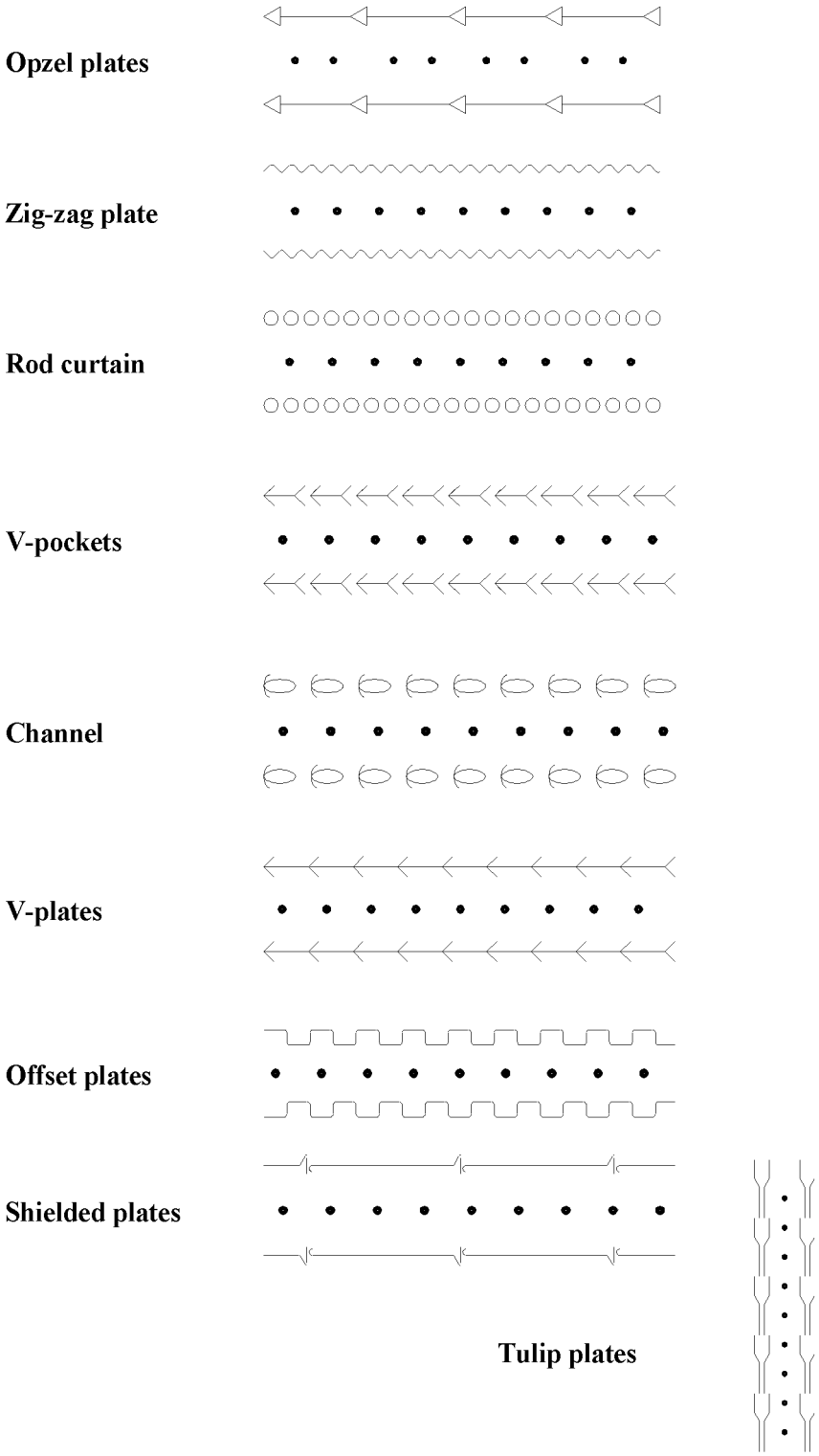
5. Dust disposal system
   Airlock, conveyors, silo/bunker

6. Electrical power
   Supply to T-R units (excluding connection of supply cable)
   Supply to motor terminals (excluding connection of supply cable)

APPENDIX 2 TYPICAL RIGID FRAME ESP



APPENDIX 3 TYPICAL COLLECTING ELECTRODE DESIGN



APPENDIX 4 AIR LOAD TEST PROCEDURE

Air load tests should be performed after insulators have been given sufficient time to dry. Following procedure shall be followed.

1. Perform the following prerequisite tasks four hours (minimum) before the air load test:
   - lock up precipitator to prevent personnel entry but do not seal. (Re-entry may be required if internal problems are uncovered);
   - turn on air purge system;
   - turn on hopper heaters.
2. Energise the rapping system.
3. Clear inlet and outlet ducting of personnel.
4. Open the outlet damper only enough to create and maintain a slight draft.
5. Perform air load tests of each field, one at a time, as follows:
   - set auto/man control switch to manual;
   - set manual control potentiometer fully counter-clockwise;
   - record date, time, precipitator temperature, and T-R name plate rating;
   - turn precipitator power on;
   - advance manual control potentiometer in approximately equal increments. Record all meter readings at each setting on the Precipitator Load Test form.

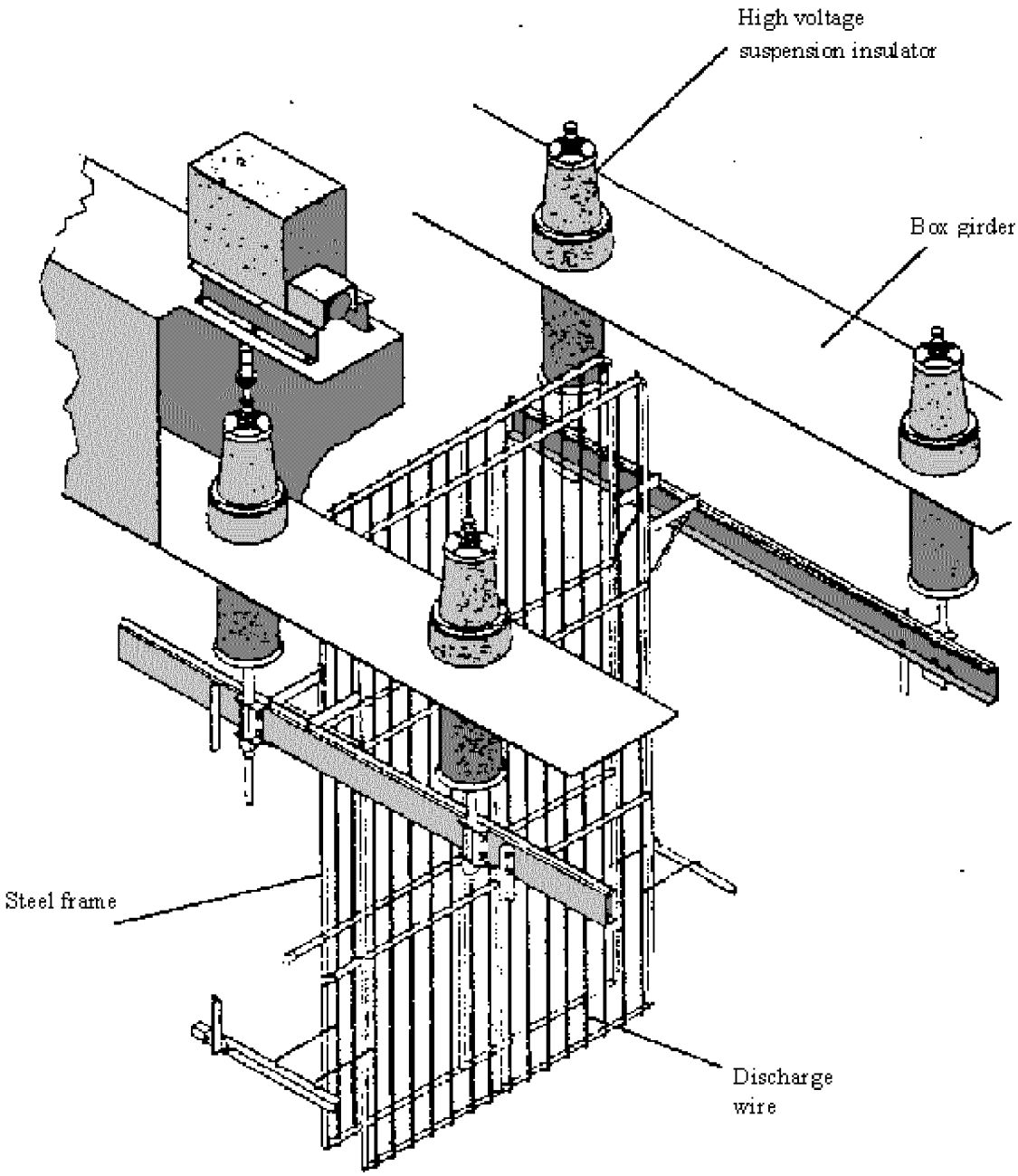
NOTE: If serious sparking occurs at low power input during this operational test, shut off power, ground all high voltage components, and make an internal inspection. Control circuits should be checked first, as possible cause of electrical instability. The inspection should consist of checks for (1) close electrical clearances, (2) foreign objects left inside the precipitator, (3) moisture or dirt on insulators, including anti-sway insulators, and (4) protuberances on high voltage components.

*WARNING: Do **not** enter the precipitator without implementing the appropriate safety measures*.

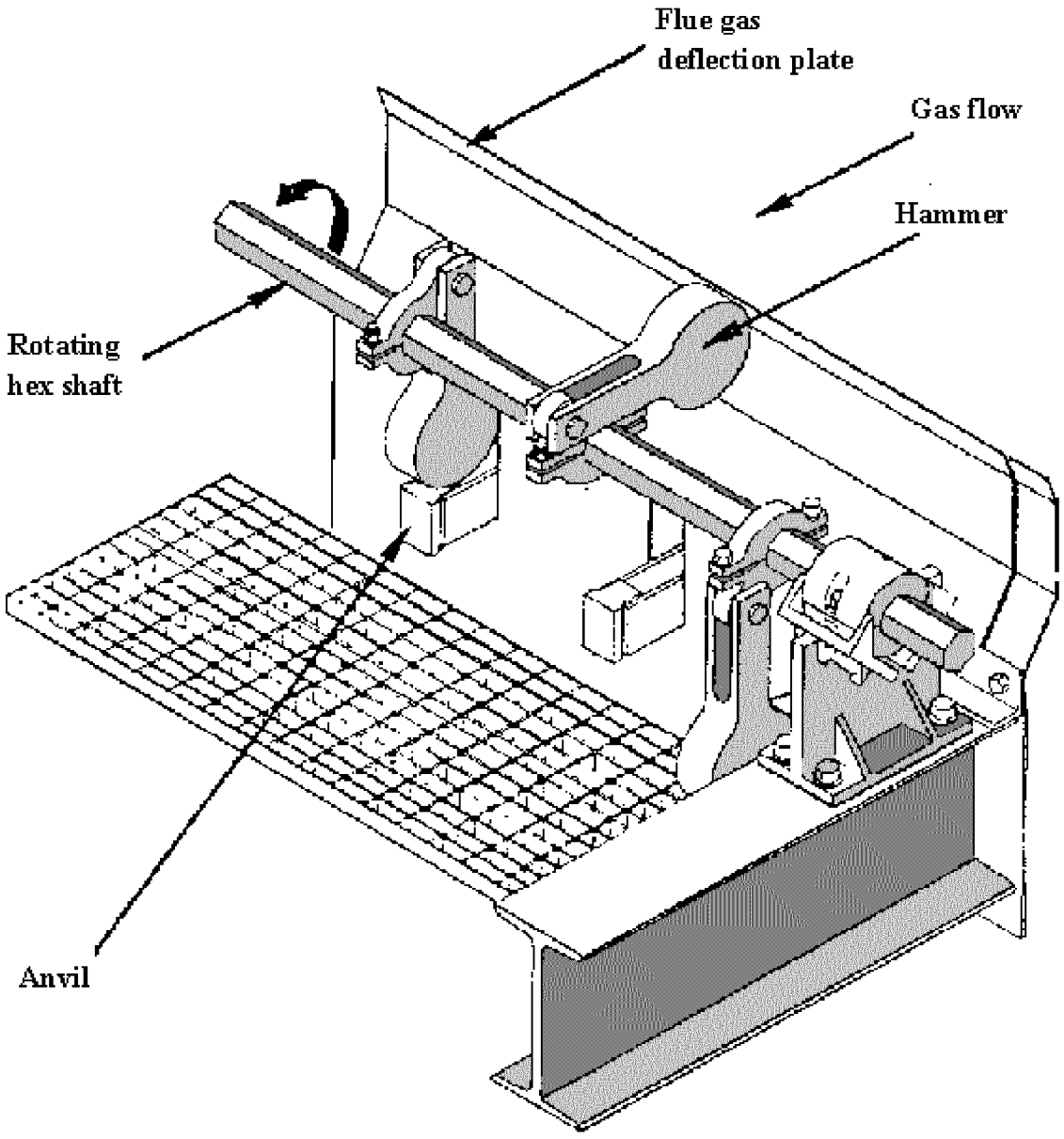
6. Turn power off at conclusion of test.
7. Return control potentiometer to a fully counter-clockwise position.
8. Set the auto/man control switch to automatic.
9. Check and record readings in the automatic mode. Voltage and current should ramp up to approximately the same limits as in the manual mode.
10. Check the operation of the:
    - overload trips and alarms;
    - under-voltage trips and alarms.
11. Adjust current and/or voltage limit settings.
12. Turn off power and proceed to the next controller.

Repeat steps 1 - 12 for each panel.

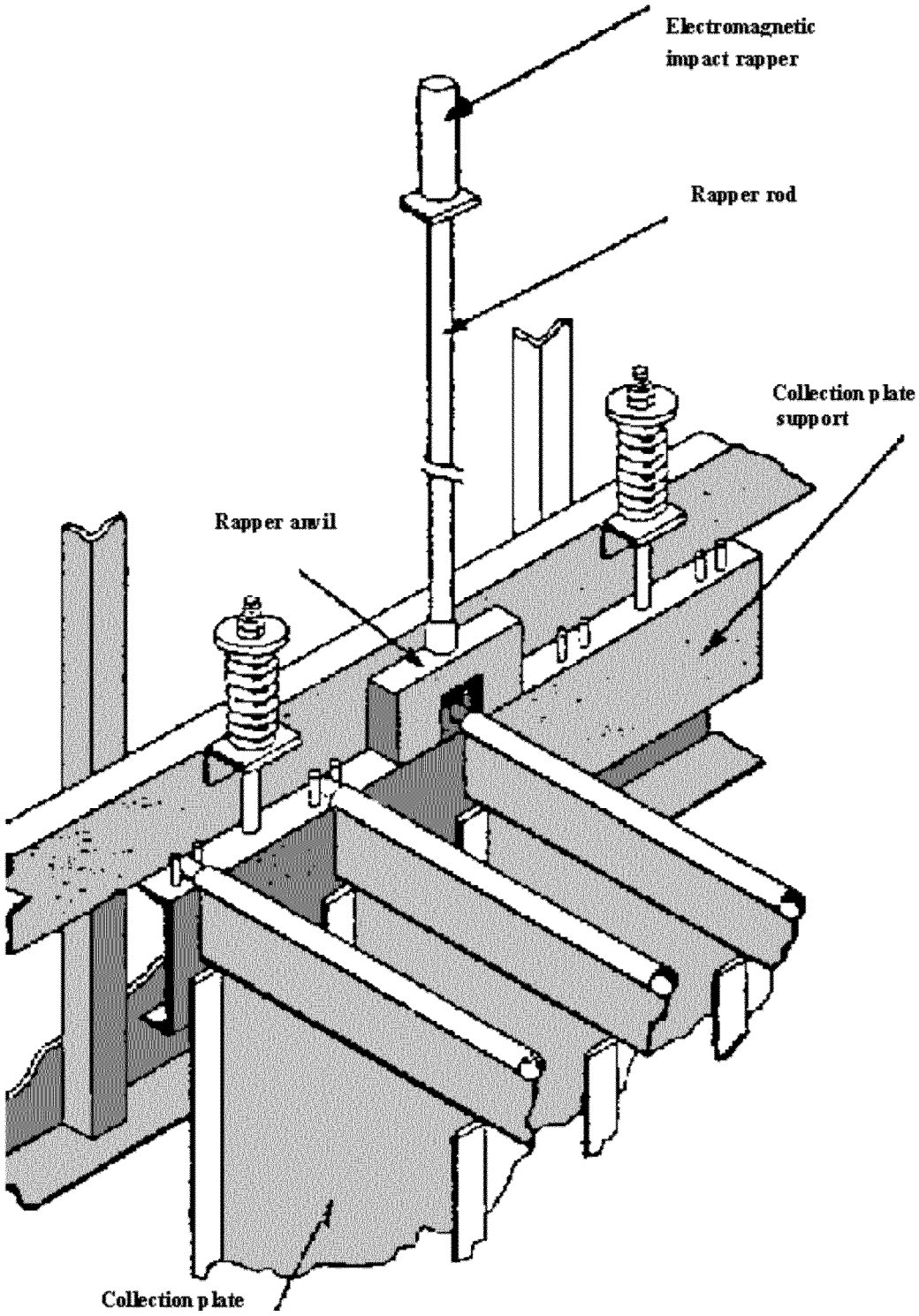
APPENDIX 5 TYPICAL DISCHARGE ELECTRODE SUPPORT



APPENDIX 6 TYPICAL HAMMER RAPPER SYSTEM



APPENDIX 7 TYPICAL ELECTROMAGNETIC IMPACT RAPPER SYSTEM



APPENDIX 8 DANGER NOTICE