

DEP SPECIFICATION

DRY ELECTROSTATIC PRECIPITATORS

DEP 31.27.21.30-Gen.

February 2017

DESIGN AND ENGINEERING PRACTICE



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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 is a revision of the DEP of the same number dated February 2013. This revision has been extensive. A summary of the main changes is given in (1.5).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing and gasification. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could 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 with regards to the 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, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that 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 that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. 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.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
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
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. For further information, refer to DEP 32.80.10.10-Gen. Now known as SIF (Safety Instrumented Function)
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. Now known as SIS (Safety Instrumented System)
T-R set	Transformer and rectifier unit
velocity, face or gas	Average velocity of the gas across the ESP
Hot ESP	Typically operating in flue gas temperature range of 300-450 degree C
Cold ESP	Typically operating in flue gas temperature range of 130-200 degree C

1.3.3 Abbreviations

Term	Definition
CFD	Contract for difference
ESP	Dry electrostatic precipitator
FCCU	Fluidised catalytic cracking unit
HV	High voltage
IOM	Instruction and operation manual
RMS	Root Mean Square
SOR	Start of Run
EOR	End of Run
PFS	Process Flow Scheme
FCC	Fluidized Catalyst Cracker
TDL	Tunable Diode Laser

1.4 CROSS-REFERENCES

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

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2013. The changes followed a requirements quality review and were not a full technical update. The following are the main, non-editorial changes.

Section/Clause	Change
2.1	Restructured requirements, removed redundant text
2.2	Removed redundant text
3.1	Restructured requirements, removed redundant text
3.2	Clarified type of steel as Carbon steel and removed words sufficiently and convenient
3.3	Restructured requirements, removed redundant text
3.4.1	Restructured requirements, removed redundant text
3.4.2	Restructured requirements, removed redundant text
3.6.1	Restructured requirements, removed redundant text
3.6.3	Restructured requirements, removed redundant text
3.6.5	Restructured requirements, removed redundant text
3.7	Restructured requirements, removed redundant text
3.8	Restructured requirements, removed redundant text

Section/Clause	Change
3.9	Restructured requirements, removed redundant text
3.10.1	Restructured requirements, removed redundant text
3.12	Restructured requirements, removed redundant text
3.13	Restructured requirements, removed redundant text
3.14	Restructured requirements, removed redundant text
4.0	Restructured requirements, removed redundant text
5.0	Removed redundant text
6.1	Removed redundant text
6.4	Restructured requirements, removed redundant text
6.5	Removed redundant text
6.6.	Removed redundant text
6.7	Removed redundant text
6.8	Restructured requirements, removed redundant text
6.9	Removed redundant text
7.1	Removed redundant text
7.3	Removed redundant text
7.4	Restructured requirements, removed redundant text
8.1	Restructured requirements
9.1	Restructured requirements
9.2	Removed redundant text
9.3	Restructured requirements, removed redundant text
10.1	Restructured requirements, removed redundant text
12	Restructured requirements, removed redundant text
13.0	Restructured requirements, removed redundant text
14.0	Restructured requirements, removed redundant text
15	Whole section moved to Informative

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

1.9 DECISIONS

A bullet (•) is shown in the margin of this DEP where further decisions or information are to be provided by the Principal or Contractor. Refer to Standard Form DEP 30.75.10.80-Gen. for recording decisions on the bulleted items indicated in this DEP.

1.10 DATA SHEET

Refer to Requisition/data sheet DEP 31.27.21.94-Gen.

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 the 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.

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.

1. The run length of an ESP without any forced shutdown shall be 3 years minimum, or as specified by Principal.

3. DESIGN AND ENGINEERING

3.1 GENERAL

1. A "Scope of Supply" document shall be provided to the Principal.
2. The installation shall comprise the equipment listed on the "Scope of Supply".
3. 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).

4. To facilitate exchange and assessment of information by the Principal and the Manufacturer/Supplier, data/requisition sheets shall be used based on DEP 31.27.21.94-Gen. The purpose of these sheets is described in (14).

Specific standards or codes may be specified by the Principal if local conditions so dictate.

5. The ESP shall be of the dry plate type, suitable for continuous outdoor operation.
6. The ESP shall be designed for the maximum specified throughput, i.e., for the combined peak flow rate and dust load specified by the Principal.
7. When determining the maximum specified throughput, the following scenarios shall be included:
 - a. soot blowing of upstream equipment;
 - b. start-of-run (SOR) and end-of-run (EOR) conditions of the process.
8. The equipment configuration (i.e. the upstream fired equipment and the ESP) shall be able to adhere to the applicable dust emission requirements under the conditions of:
 - a. a fluctuating dust and soot load;
 - b. start-up and shut-down and upset process conditions.
9. The aspect ratio of the ESP shall be at least 1.0.
10. The applicable local and national regulations shall be stated by the Manufacturer/Supplier on the data/requisition sheets.

11. All metal surfaces in contact with flue gases shall be at a higher temperature than the highest dew point (acid or water, as applicable) with any of the flue gas compositions specified in the data/requisition sheets.
12. Before the contract is awarded, the Manufacturer/Supplier shall satisfy to the Principal that, at all loads, an even distribution of flue gas across 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.

13. The Manufacturer/Supplier shall state in the tender whether the dust is or can be pyrophoric.
14. The Manufacturer/Supplier shall describe in the tender all special features and precautions taken to avoid exposure to air when dealing with pyrophoric dust.
15. The ESP shall be sized on the maximum flue gas flow rate - consistent with the maximum continuous ratings (MCR), established for the sizing of upstream equipment, e.g., the water-tube boiler, waste heat boiler, CO-boiler.

This means that the maximum flue gas flow rate will be at about 1.10 x the 100% PFS flue gas rate established for the upstream system as the guaranteed condition.

16. For design, it should be assumed that solid particulates production between start-of-run (SOR) and end-of-run (EOR) conditions to be a factor 2 or more.

This will take into account damaged burner(s), higher soot blowing frequency, more cat fines (in case of FCC units), etc.

3.2 ESP CASING, INCLUDING INLET AND OUTLET TRANSITIONS

1. The casing shall be designed for a combination of gas design pressure and temperature, and wind/snow/seismic loads, in accordance with DEP 34.00.01.30-Gen.
2. The design pressure shall be based on the maximum operating pressure and/or vacuum in the casing.
3. The casing shall be all-welded and gas-tight, minimum 6 mm (0.24 in) thick carbon steel sheeting material, stiffened by carbon steel sections.
4. A corrosion allowance of 2 mm (0.08 in) shall be included in the design.
5. There shall be no restriction to the free expansion of internals or insulation/sheeting.
6. All elements and panels shall be stiffened against damage during transport, erection, and (flow induced) mechanical vibration.
7. Stiffening shall not interfere with the free expansion of the casing.
8. The casing design and construction shall facilitate the removal and/or installation, at site, of internals.
9. The design shall further allow access for removal and installation of discharge electrodes.
10. Thermal insulation of the casing shall be external, see (5).

3.3 GAS DISTRIBUTION DEVICES

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

Inlet and outlet plenums (transition sections) contain perforated plates and/or flow distribution devices, to guarantee even gas velocities throughout the treatment zone.

1. Deviation from the average gas velocity at any point in a gas passage shall be within 20%.
2. The Manufacturer/Supplier shall provide a flow model study (showing details of average gas velocity).
3. The flow model study shall be subject to approval by the Principal.
4. The inlet plenum shall be designed so that collected particles will be discharged into the first ESP hopper.
5. Dedicated rappers shall be installed on the inlet gas distributors.

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, strip or mast (rigid) electrodes and the collecting plate electrodes at ground potential. A high voltage pulsating direct current produces a unidirectional, 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.

1. ESPs shall have two or more fields with segregated electrodes.
2. Manufacturer/Supplier shall provide to the Principal:
 - a. redundancy figure to cope with electrode outages;
 - b. the degree of sectionalisation of the ESP high-tension sections.
3. For collecting electrode spacing, the following shall apply:
 - a. minimum 300 mm (12 in);
 - b. maximum 500 mm (20 in);
 - c. maximum tolerance for the electrode spacing 12 mm (0.5 in).

3.4.2 Electrodes

1. Discharge electrodes shall be made from stainless steel.
2. Collecting electrodes shall be made from cold or hot rolled sheet metal with stiffeners.
3. The collecting electrodes shall have a 0.6 mm (0.025 in) corrosion allowance, i.e., 0.3 mm (0.0125 in) on either side.

The discharge electrodes do not require a corrosion allowance.

4. Collecting electrodes shall be suspended from the roof.
5. Discharge electrodes shall be supported from insulators.
6. 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.
7. All internals shall be supported to prevent distortion of electrodes.
8. Internals shall not rest on cladding or any internal insulation.
9. The distance between collecting electrode edges and the inner walls of the casing shall be minimal to minimise flue gas by-passing.
10. Gas passages and the collecting electrode surface shall be so designed that re-entrainment of particulates will be avoided and will not be a source of vortex shedding.
11. Arrangements and written procedures for the removal of emitting electrodes and rapping gear shall be provided by the Manufacturer/Supplier.

3.5 ELECTRODE CLEANING MECHANISM

1. Zonal control of rapping shall be provided, as precipitation near the inlet zone will be much higher than that near the outlet zone.
2. The rapping frequency shall be adjustable and impact rappers shall also be provided with adjustable rapping intensity.
3. Rapping equipment, for cleaning the collecting and discharge electrodes, may be executed as:
 - a. acoustic horns;
 - b. mechanical rappers;
 - c. electromagnetic impulse rapper.
4. For both the collecting and discharge electrodes, the electrode supplier shall indicate the following:
 - a. number, arrangement, type, and size of rapping devices required;
 - b. power requirements per rapping device and the installed power;
 - c. frequency control (timer or pressure drop);
 - d. range of frequency and intensity settings;
 - e. typical filtration cycle with respect to the frequency of cleaning;
 - f. time required for cleaning (downtime/year).

3.6 ESP DUST HOPPERS

3.6.1 General

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

1. Hoppers shall be equipped with baffles to prevent gas by-passing and dust re-entrainment.
2. Hopper insides shall be smooth (e.g., no weld beads).
3. Hopper insides shall be clear from obstructions (e.g., no internal rungs).
- 4. The Principal will specify the hopper storage capacity to allow for maintenance and disturbances in the ESP operation.
5. Hopper sizes of ESPs fitted with continuous dust removal equipment may provide for shorter storage capacities; however this shall be subject to agreement by the Principal.
6. The free space beneath the hopper flanges shall be minimum 3 m (10 ft.), in order to create sufficient access for dust removal.

3.6.2 Troubleshooting assembly for dust hopper

Depending on the particulate properties, bridging may occur in the dust hopper.

1. The Manufacturer/Supplier shall review the need for any of the following systems and state his recommendation or design standard in the tender:
 - a. ring flushing system to fluidize particulates;
 - b. air-shock system to break bridges;
 - c. rappers;
 - d. mechanically driven vibrators;
 - e. acoustic horns;
 - f. poke / rodding holes;
 - g. blast and aeration air connections;
 - h. anvils.
2. For troubleshooting purposes as a minimum, each dust hopper shall be provided with the following connections for future usage and / or installation:
 - a. nozzle connections on dust hopper for (future) installation of ring flushing system;
 - b. mounting bracket(s) for (future) rapper installation;
 - c. anvils on the bottom cone of the dust hopper;
 - d. a minimum of four (4) poke / rodding holes (i.e., one each side of the dust hopper at bottom cone);
 - e. a minimum of four (4) blast and aeration air connections (i.e., one each side of the dust hopper at bottom cone);
 - f. one 150 mm or 200 mm (6 in or 8 in). connection at bottom cone for removal of accumulated dust by vacuum truck.

3.6.3 Heating for dust hopper

1. Dust hopper bottoms shall be fitted with electrical heat tracing to prevent dew point issues.

Condensation of liquids will lead to bridging and clogging of dust inside the dust hopper.

2. Heating by other means shall be subject to approval 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

1. Each dust hopper outlet shall be equipped with a manually operated slide valve and rotary star valve.
2. Rotary star valves shall not be applied if condensation cannot be prevented.
3. Valves shall be suitable for troubleshooting or repair of downstream equipment (i.e., the dust transportation system), without the need of stopping ESP operation or reducing throughput of the ESP.
4. For all rotary star valves, data/requisition sheet DEP 31.25.40.93-Gen. shall be completed by the Manufacturer/Supplier.

3.6.5 Dust hopper level measurement

ESP dust hoppers may be operated with some dust level inside the hoppers, to prevent flue gas break-through.

1. Each ESP dust hopper shall be executed with a minimum of two (2) level instruments.
2. Setpoint for each of the level instruments shall be different, at H (High) and HH (High High) dust level.
3. Level measurements should be Gamma ray type.