MANUAL

INSTALLATION, TESTING AND BALANCING, AND COMMISSIONING OF HVAC SYSTEMS

DEP 31.76.10.11-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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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.

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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.

TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP gives minimum requirements for installation, testing and balancing, and commissioning of HVAC systems for both plant buildings (e.g. control rooms) and office buildings. While this DEP is primarily applicable to new buildings, it should also be followed, as far as practical, for revamps of existing installations.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this document is confined to companies forming part of or managed by the Royal Dutch/Shell Group, 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 intended for use in oil refineries, gas plants, chemical plants and exploration and production facilities**.**

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, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document 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 document as closely as possible.

1.3 DEFINITIONS

For the purpose of this DEP, the following definitions shall hold:

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 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 (5).

2. INSTALLATION

The Contractor shall install the equipment and materials in compliance with the relevant sections of ASHRAE/NFPA90A and SMACNA.

The requirements for climatic conditioning of plant buildings shall be in accordance with DEP 31.76.10.10-Gen. For office buildings refer DEP 34.17.00.32-Gen.

The requirements for electrical facilities for installations shall be in accordance with DEP 33.64.10.10-Gen.

NOTE: Where suitable alternative refrigerants exists which are less harmfull to the environment than chlorofluorohydrocarbons (CFCs), HVAC equipment shall be capable of satisfactory operation, and shall be supplied, with such refrigerant.

3. TESTING AND BALANCING

3.1 GENERAL

After installation of mechanical equipment, piping, ducting and control systems, the Contractor shall perform all tests as specified and shall demonstrate the proper operation and performance of all systems.

In general, factory tests shall not be repeated unless required by the particular equipment/system tests.

Before the commencement of tests/commissioning, the updated drawings, manuals, certificates and factory test data shall be made available.

Test procedures in accordance with ASHRAE, complete with schedules indicating the extent and sequence of the tests, shall be submitted to the Principal for review and approval at least 30 days prior to the start of the tests.

The Contractor shall proceed with testing after obtaining approval from the Principal. The Principal may witness the testing.

The Contractor shall supply all materials and items of equipment necessary for him to carry out the tests adequately, efficiently and safely.

The Contractor shall provide a list of acceptable test equipment.

Prior to final testing and balancing, new filters shall be installed, bearings lubricated as specified by the Manufacturer, belts tightened to proper tension, etc.

After completion of the mechanical system tests, the control systems involved shall be tested with full operating and performance tests. Prior to 'live' testing, all circuits shall be checked for protective items such as relays, fuses and shutdown systems. Electrical circuits shall be insulation tested.

Electrical installations and equipment shall be tested and commissioned in accordance with DEP 33.64.10.10-Gen. and DEP 63.10.08.11-Gen.

Defective equipment, materials and/or workmanship shall be replaced, repaired or corrected, retested and redemonstrated for proper operation to the satisfaction of the Principal.

Upon completion of the site tests, the Contractor shall submit the test results to the Principal. Upon acceptance of the test results, the Contractor shall remove all the necessary test equipment and dispose of the test media where necessary.

Disposal of test media shall comply with local regulations and shall be done in close cooperation with the Principal.

3.2 DUCT SYSTEMS PRESSURE TESTING

Each air ducting system shall be pressure tested in accordance with SMACNA, HVAC Air Duct Leakage Test Manual.

3.3 PIPE SYSTEMS PRESSURE TESTING

Unless otherwise specified, all piping shall be pressure tested in accordance with ASME B31.3.

Chilled water and central heating pipes shall be hydrostatically tested for 24 hours at a pressure of not less than 1.5 times the design pressure, and not less than 1000 kPa (ga).

Compressed air pipelines shall be hydrostatically tested for 24 hours at a pressure of not less than 1.5 times the design pressure, and not less than 600 kPa (ga).

Pressure testing shall be performed prior to painting, installation of insulation or concealment. Isolated portions of piping may be tested separately to facilitate general progress of the installation. Any revisions made in piping systems will subsequently necessitate retesting of the system.

Expansion joints included in the test shall be provided with temporary restraints, if required.

Piping containing check valves shall have the source of test pressure located on the upstream side of the check valve.

Unless otherwise specified, instruments shall be excluded from the hydrotest. The diaphragm connections on pressure balance control valves shall be removed during the test.

Relief valves shall be blinded off or gagged during pressure tests; the spring setting on the valve shall not be adjusted.

3.4 AIR CENTRAL HEATING AND CHILLED WATER SYSTEM TESTING AND BALANCING

Testing, adjusting and balancing shall be based on ASHRAE or SMACNA, and shall be carried out as specified hereafter.

To achieve the design air quantities during final air balancing, an allowance shall be made for one pulley change on fixed blade fans or for fan blade adjustment on axial flow fans.

3.4.1 Preparation

Preparation for testing and balancing work shall include the following:

- prepare report forms for all systems in each building;
- produce report sheets for all air inlets and outlets; also indicate associated equipment numbers.

3.4.2 Test procedure

The testing and balancing of the system shall be performed in accordance with Test and Balancing Procedures, Phase I, II and III, as given in Appendices 1, 2 and 3.

3.5 CONTROL SYSTEMS

Testing shall be based on the relevant sections of ASHRAE and NFPA 90A.

Checking and/or testing and recording shall include the following:

- satisfactory operation of any automatic or manually operated sequence to be used in the event of fire;
- safety in the event of failure and of sudden resumption of electricity supply;
- satisfactory operation of safety interlocks designed for the protection of personnel, such as those associated with remote electrically operated plant;
- desired set value of all control devices;
- satisfactory operation of equipment protection devices;
- satisfactory operation of all sequencing operations and alternate working selections and automatic or manual change-over of duplicate plant.

3.6 NOISE

Airborne noise measurements shall be taken under normal equipment and HVAC system operating conditions.

Measurements shall be in accordance with ISO 2204 and the following requirements:

- Measurements shall be taken:
  - in at least 3 locations relevant to occupants;
  - at least 1 m away from any reflecting plane or opening of the ventilation system, and at least 1.5 m away from any window
- Measurements of the A-weighted sound pressure level shall be in accordance with the "survey method" of ISO 2204, and last for at least 10 seconds.
- If one of the sound pressure levels measured in a room exceeds the required noise limit, all measurements inside the room shall be carried out according to the "engineering method" of ISO 2204 (involving the determination of octave band spectra).

3.7 REPORTS AND RECORDS

Test and balance data report forms (Appendix 4) shall be submitted prior to final inspection. The report shall include records of flow measurements made during testing and balancing. A complete set of marked-up balancing plans shall be furnished with the report. The plans shall indicate the reference location numbers for air openings and these shall correspond with the numbering system in the balancing logs.

4. COMMISSIONING

4.1 GENERAL

After a system has been installed, checked for layout and compliance with the specifications, cleaned and tested, it shall be prepared for commissioning. A detailed start-up and commissioning schedule shall be prepared by the Contractor and submitted to the Principal for approval.

In the schedule the following items shall be listed:

- list of all control panels and substations;
- list of all installations connected to these panels and substations;
- cause and effect checklist for each installation;
- list of all programs used with all control settings of the installation;
- checklist for all programs used;
- checklist for all control settings;
- checklist for all hardware components, including performance (duty) data;
- list of all control components, their function and settings;
- "As built" drawings, including general assembly drawings, flow diagrams with design flow rates, resistances, etc.

During start-up, simulation and commissioning, the system shall be continually monitored and the data recorded. These data shall be compiled and incorporated in the performance test record.

The Contractor shall notify the Principal of commissioning tests in accordance with the agreed schedule. Where required, the Contractor shall have qualified Manufacturer's technicians and specialists present at the facility during commissioning.

Upon successful completion of the commissioning, i.e. after rectifying of defects and deficiencies reported by the Principal, an authenticated test certificate signed by the Principal shall be provided to the Contractor.

4.2 CLEANING

All plant and distribution systems shall be kept clean during construction. Just prior to commissioning a cleanliness check shall be made and any necessary cleaning performed.

Ducts, plenum and casings shall be thoroughly cleaned of all debris and blown free of all small particles of rubbish and dust before installing outlet faces (grilles, diffusers, etc.).

Temporary filters shall be replaced for all systems which are to be operated during construction. Before final testing and balancing and commissioning, new filters shall be installed.

When a system has been running for 300 hours after successful completion of the commisioning, the Contractor shall replace the filters for all systems.

Bearings shall be properly lubricated with oil or grease as recommended by the Manufacturer. Belts shall be tightened to proper tension. All control valves and other miscellaneous equipment requiring adjustment shall be adjusted to the correct setting.

Equipment, pipes, valves, fittings and fixtures shall be cleaned of oil, dust, dirt and sludge that may have accumulated from operation of the system during the test and blown free of all small particles before installing outlet faces.

Any damage (e.g. to the building or furnishing, including discolouration) due to the Contractor's failure to properly clean the piping system, shall be repaired.

Electrical equipment shall be protected from damp during cleaning, testing and balancing. Particularly sensitive or fragile items shall be protected from the activities of other trades during construction and from dirt and maloperation during testing and balancing.

Distribution systems shall be cleaned during commissioning.

4.3 PERFORMANCE TESTING

In the presence of the Principal, all operating systems shall be started up in a progressive manner in accordance with the Manufacturer's instructions and a detailed start-up and commissioning schedule.

All necessary preparations for the start-up shall be made by the Contractor. Any defects which occur during start-up, and which affect the validity of the performance tests, shall be rectified immediately.

4.4 FINAL INSPECTION AND ADJUSTMENTS

All systems shall be kept in operation for a period of five days, during which time the final inspection shall be carried out.

During this inspection the operating/maintenance manuals shall be checked against the actual (as built) installation.

During these five days, when the systems are in operation for final test, portable thermohygrograph recorders shall be used to continuously record the temperature and relative humidity within the controlled space.

After completion, the adjusted position of each balancing valve and damper shall be clearly marked for permanent reference.

5. 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.

SHELL STANDARDS:

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Heating, ventilation and air conditioning for plant buildings	DEP 31.76.10.10-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Minimum requirements for design and engineering of buildings	DEP 34.17.00.32-Gen.
Field inspection of electrical installations and equipment	DEP 63.10.08.11-Gen.

AMERICAN STANDARDS:

ASHRAE HANDBOOK — ASHRAE
HVAC Systems and Applications - Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems

Issued by:
American Society of Heating, Refrigeration and Air-Conditioning Engineers Incorporated
1971 Tullie Circle NE
Atlanta GA 30329
USA.

Installation of Air Conditioning and Ventilation Systems — NFPA 90A

Issued by:
National Fire Protection Association
470 Atlantic Avenue
Boston
Massachusetts 02210
USA.

SMACNA publications: — SMACNA
HVAC Systems - Testing, Adjusting and Balancing

HVAC Air Duct Leakage Test Manual

Issued by:
Sheet Metal and Air Conditioning Contractor's National Association
P.O.Box 70
Merrifield VA 22116
USA.

Chemical Plant and Refinery Piping — ANSI/ASME B31.3

Issued by:
American National Standards Institute
Sales Department
1430 Broadway

New York NY 10018,
USA.

INTERNATIONAL STANDARDS:

Acoustics - Guide to International Standards on the measurement of airborne acoustical noise and evaluating of its effect on human beings	ISO 2204

Issued by:
Central Secretariat of ISO
1, rue de Varembé
1211 Geneva 20
Switzerland.

APPENDICES

Appendix	
1	Test and balancing procedures - Phase I
2	Test and balancing procedures - Phase II
3	Test and balancing procedures - Phase III
4	Test and balancing data report forms

APPENDIX 1 TEST AND BALANCING PROCEDURES - PHASE I

a. Air systems (supply, exhaust and recirculation)

- Test and adjust the fan speed to meet the design requirements.
- Test and record the consumed motor load in Amps for clean and 50% dirty filter.
- Make pitot tube traversal tests of main supply ducts. Obtain design air flow at 50% dirty filter conditions in m^3/h.
- Test and adjust the system to achieve the outside and recirculated air design requirements in m^3/h.
- Test and record the entering air temperatures (DB for heating and DB and WB for cooling).
- Test and record the leaving air temperatures (DB for heating and DB and WB for cooling).
- Adjust all main supply and return air control dampers to meet the design air flow.
- Adjust all manual dampers in supply and return branches to meet the design air flow.
- Test and adjust each diffuser, grille and register to within 5% of the design requirements.
- Reference each grille, diffuser and register by location and area.
- Reference and list the size, type and manufacture of diffusers, grilles, registers and all tested equipment.
- Test diffusers and grilles. Test readings shall include:
  - required velocity (m/s)
  - actual velocity (m/s)
  - required flow (m^3/h)
  - actual flow (m^3/h)
- Set and adjust the automatically operated dampers to meet the design data.
- All diffusers, grilles and registers shall be adjusted to minimize draughts.
- Test the filter pressure differential switches and set the alarm at maximum allowable pressure drop.
- Complete air balance before starting water balance.
- Test and record the room noise level.

b. Water systems

- Open all 'Normally Open' manual valves to the fully open position.
- Clean and replace all strainers.
- Examine the water quality in the system.
- Check pump rotation.
- Check to ensure that the system is completely filled with water.
- Check that all air vents are installed and function correctly. Bleed all air from the manual vents.
- Set the temperature controls.
- Check and set the water return and flow design temperatures at the unit.

APPENDIX 2 TEST AND BALANCING PROCEDURES - PHASE II

After completion of Phase I, proceed with Phase II as follows:

- Set the water system to the correct flow in litres per second.
- Adjust water flow throughout the system.
- Check water inlet and outlet temperatures and adjust to design temperatures.
- Check the water temperatures at the inlet side of the AHU coils. Note the temperature difference between unit outlet and coil inlet.
- Balance flow through each AHU coil.
- Upon completion of flow readings and adjustments at coils, all settings shall be recorded.

APPENDIX 3 TEST AND BALANCING PROCEDURES - PHASE III

Upon completion of Phase II, proceed with Phase III as follows:

- After adjustments to the coils, re-check the settings at the pumps and the heat exchanger and re-adjust as necessary.
- Install pressure gauges on the coil and read the pressure drop across the coil at the set flow rate for full load.
- Repeat air temperature tests carried out in Phase I of the balancing procedure and record results.

APPENDIX 4 TEST AND BALANCING DATA REPORT FORMS

1. GENERAL

Report forms shall contain as a minimum the following tabulated data. Listings shall include design and actual conditions for each item mentioned. Reports shall be required for each air handling system (supply, exhaust and recirculation), central heating and chilled water system.

2. SUPPLY SYSTEMS

- Date
- System number and location
- Rooms or area served
- Fan speed (rpm)
- Initial pressure drop across the filter
- Fan suction static pressure
- Fan discharge static pressure
- Rated motor output (kW), full load current in Amps
- Recirculated air flow (m^3/h)
- Incoming air flow (m^3/h)
- Ambient air conditions (dry bulb (DB) and wet bulb (WB))
- Entering air condition to cooling coil, humidifier (DB and WB) and heating coil (DB)
- Leaving air condition from cooling coil, humidifier (DB and WB) and heating coil (DB)
- Main supply duct conditions (DB and WB)
- Main supply duct air flow (m^3/h)
- Final adjustment, percentage of design air flow (m^3/h)
- Zone air flow (m^3/h)
- Identify all air dampers left in the fully open position.

3. EXHAUST AND RECIRCULATING SYSTEMS

- Date
- System number and location
- Rooms or area served
- Fan speed (rpm)
- Rated motor output (kW), full load current in Amps
- Total air flow (m^3/h)
- Fan inlet static pressure
- Fan outlet static pressure
- Final adjustment, percentage of design air flow (m^3/h).

4. ROOM DATA

- Room number
- Supply and exhaust system number
- Supply air flow at each diffuser (m^3/h)
- Exhaust air flow (m^3/h) per item
- Sizes of grilles and diffusers and free area factors
- Final adjustment, percentage of design air flow of each outlet

5. WATER SYSTEMS

- Date
- System number and location
- Rooms or area served
- Ambient conditions at time of test
- Pump name and number
- Pump speed (rpm)
- Rated motor output (kW), full load current in Amps
- Pump inlet pressure
- Pump outlet pressure
- Pump flow (m^3/h)
- Unit flow temperature
- Unit return temperature
- Air flow (m^3/h) at each coil bank
- Inlet and outlet temperature at air handling unit coils (coil water conditions shall be recorded at the same time as air temperatures)
- Inlet and outlet pressures at air handling unit and terminal unit coils
- Final adjustment, percentage of design water flow (m^3/min) through the balancing valves

6. NOISE LEVELS

The reports shall contain the following:

- Acoustical environment: dimensions of the room (area) tested, description of the physical treatment of the room (area), sketch showing the locations of the microphone(s) and room contents
- Instrumentation: equipment, calibration method, analysis method and filter characteristics
- Equipment noise levels under operating conditions
- Noise levels measured versus acceptance criteria
- Date and time of measurements