TECHNICAL SPECIFICATION

ELECTRICAL HEATING SYSTEM FOR FROST HEAVE PREVENTION OF REFRIGERATED HYDROCARBON STORAGE TANKS

DEP 33.68.30.31-Gen.

May 1994
(DEP Circular 51/99 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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.

The right to use DEPs is granted by SIOP, SIEP or SIC, in most cases under Service Agreements primarily with companies of the Royal Dutch/Shell Group and other companies receiving technical advice and services from SIOP, SIEP or SIC. Consequently, three categories of users of DEPs can be distinguished:

1) Operating companies having a Service Agreement with SIOP, SIEP, SIC or other Service Company. The use of DEPs by these Operating companies is subject in all respects to the terms and conditions of the relevant Service Agreement.

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.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, SIOP, SIEP and SIC disclaim any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof. The benefit of this disclaimer shall inure in all respects to SIOP, SIEP, SIC and/or any company affiliated to these companies that may issue DEPs or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of SIOP and SIEP, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of SIOP and SIEP. The copyright of DEPs vests in SIOP and SIEP. Users shall arrange for DEPs to be held in safe custody and SIOP or SIEP may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

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.

TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP is a revision of the DEP with the same number and title dated May 1985. It gives minimum requirements for the electrical heating system used for preventing frost heave in refrigerated storage tanks. It covers design, material selection, installation and testing.

Revision was necessary in view of the changes in design of these types of tank and to become aligned with DEP 33.68.30.32-Gen. "Electrical Trace Heating".

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, 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 and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, supply/marketing facilities and production installations.

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 document as closely as possible.

1.3 DEFINITIONS

1.3.1 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 electrical heat trace equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project work 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, authorized to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Technical definitions

- **Certificate**

  Document issued by a recognized authority certifying that it has examined a certain type of apparatus and, if necessary, has tested it and concluded that the apparatus complies with the relevant standard for such apparatus.

- **Certificate of conformity**

  Certificate stating that the electrical apparatus complies with the relevant standards for apparatus for potentially explosive atmospheres.

- **Declaration of compliance**

  Document issued by the Manufacturer declaring that the electrical apparatus complies with the requirements of IEC 79-15.

- **Power output**

  The power (thermal) output of self-regulating heating cable is the electrical consumption measured in watts per metre of cable.

  Procedures for determining the power output of heating cable for frost heave prevention systems are given in BS 6351: Part 1.

- **Rated value**, 05-41-010, IEC 50

  Qualifying term, applied to a quantity which is used in the specification of a machine or an apparatus.

- **Self-regulating/self-limiting heating cable**

  A parallel heating cable with a semi-conductive element, which responds to temperature variation by adjusting its thermal output so as finally to reach an equilibrium.

- **Self-regulating index**

  The self-regulating index is a measure of the ability of a self-regulating heating cable to respond to changes in temperature.

  Procedures for determining the self-regulating index are given in Appendix 2.

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets.

All publications referred to in this DEP are listed in (9).

2. GENERAL DESIGN REQUIREMENTS

2.1 CONTRACTOR RESPONSIBILITIES

The overall responsibility for the heating system shall rest with the Contractor.

The manufacturer of the heating cable should be involved in the basic design of, and calculations for, the heating system or at least confirm that the basic design is sound (which shall be based on the data supplied by the Contractor). This shall allow for the typical characteristics of the heating system and the effect on heat output due to the installation of the heating cable in conduits.

2.2 SAFETY

For safe and reliable application of electrical heating systems, the climatic, environmental and operating conditions shall be taken into consideration.

As far as practical, the electrical equipment should be located in non-hazardous areas or in the least hazardous areas. It shall not be located in Zone 0 areas.

2.2.1 Hazardous Areas

When installed in a hazardous area, the construction of electrical equipment shall comply with the requirements of the relevant parts of IEC 79 or EN 50 014 to 50 020 inclusive, 50 028 and 50 039. Equipment complying with standards different from the above may only be used with the specific approval of the Principal.

For installations in Zone 1 and Zone 2 areas, the following types of protection shall be used:

- Junction boxes : Ex "e" enclosure
- Temperature control systems : Ex "i" for e.g. PT 100 connections.

For the above-mentioned electrical apparatus, a Certificate of Conformity shall be obtained from the Manufacturer.

The heating cable shall be suitable for Zone 1 and Temperature Class T3.

2.2.2 Non-Hazardous Areas

In non-hazardous areas, industrial type equipment may be used subject to approval by the Principal.

NOTE: For standardization, material as specified for Zone 1 and 2 areas may also be used in non-hazardous areas.

2.3 SITE CONDITIONS

The parts of a heating system installed outdoors shall be suitable for outdoor use in a relative humidity of 100%, exposed to direct sunlight, and without protective shelter. The atmosphere shall be considered saliferous, sulphurous and dusty as commonly encountered in petrochemical installations located close to open water. The possibility of condensation, as experienced during large temperature fluctuations in a humid atmosphere, shall be taken into account.

2.4 DEGREE OF PROTECTION

As a minimum, the enclosures shall have a degree of protection IP 55 in accordance with IEC 529. The IP rating of the main and sub-distribution boards shall be in accordance with DEP 33.67.01.31-Gen.

2.5 ELECTRICAL SUPPLY SYSTEM

The AC supply to the heating system shall be symmetrical three phase + neutral, sub-divided into single phase with a nominal voltage and frequency as indicated in the requisition. The supply variations at the distribution board, under steady-state conditions, shall be limited to:

- nominal system voltage : plus and minus 10%
- nominal system frequency : plus and minus 2%

In addition to the above, input voltage variations may be subject to temporary voltage variations of +10% and -20% of the nominal voltage, caused by, for example, motor starts.

Transient high-frequency voltages of 2 kV peak may also be superimposed on the input voltage as a consequence of system switching operations, etc.

2.6 OPERATION AND MAINTENANCE

All electrical equipment subject to operating and maintenance activities shall be easily accessible and shall allow for safe and convenient performance of such activities.

System components shall be standardized as much as possible.

2.7 TEMPERATURE CONTROL SYSTEM

Amended per Circular 51/99

The design and installation of the temperature control system shall be in accordance with DEP 32.31.00.32-Gen.

3. PERFORMANCE REQUIREMENTS

3.1 GENERAL

The system (materials, components and assembly methods) shall have a design life of at least 20 years.

3.2 HEAT DISTRIBUTION

The heating system shall be designed and positioned to provide a uniform and constant temperature in the protected areas and shall not result in uneconomic boil-off of refrigerated hydrocarbon as result of an unbalanced design. The system shall be capable of preventing ice formation in the ground under the tank foundation.

3.3 TEMPERATURE LIMITS

The concrete base slab under the tank foundation shall be kept at between 5 °C and 10 °C. This shall be achieved by switching the whole system on and off via one selected temperature-measuring point.

Heat density, heater conduit layout and the electrical distribution system shall be such that failure of one heating cable or tripping of one circuit-breaker or loss of supply to one sub-distribution panel will not result in a concrete base slab temperature below + 2 °C in any protected region.

3.4 TEMPERATURE MEASUREMENTS

The temperatures of the various protected sections shall be automatically monitored and recorded. An alarm in a manned control room shall show when the high and low operating temperature limits are exceeded. A temperature-measuring point showing the coldest area at the bottom shall be automatically selected to control the heating system.

4. MATERIALS REQUIREMENTS

4.1 HEATERS

Self-regulating/self-limiting cables shall be utilized. Heating cable shall consist of two parallel copper conductors, both being in contact with a self-regulating/self-limiting semi-conductive material. This basic element shall be insulated by one or more non-hygroscopic jackets, and shall be covered with a braided metal screen covering at least 70% of the surface and a fluoropolymer outer jacket. The braided metal screen shall have an electrical conductivity not less than the conductivity of one of the conductors.

The heaters shall vary the power output in response to the sensed temperature at every point of the surface. As the temperature increases, the heater output shall decrease automatically, and vice versa. The natural reduction in heat output by increasing temperatures shall be at least so much that the heater cable will not be damaged due to overheating as result of e.g. overlapping.

The minimum self-regulating index of the heating cable between 5 and 40 °C shall be 0.3 W/m/°C. See Appendix 2 for the test procedure.

The outer jacket shall be capable of protecting the inner part of the cable against damage during installation as well as against the environmental conditions. The heating cable shall have sufficient strength to withstand a pulling force of at least 500 N without affecting its mechanical integrity or electrical properties.

4.2 CONDUIT SYSTEM

A conduit system shall be embedded in the concrete tank foundation to protect the heating cable inside the concrete and to allow easy installation and replacement.

The conduit shall be of stainless steel (AISI 316), and have an inside diameter of 25 mm, unless otherwise specified.

Conduit ends shall be threaded for interconnection by means of conduit couplings. The couplings shall be made waterproof by applying a heat shrinkable tubing over them.

4.3 PULLING WIRES

To facilitate installation and replacement of heating cable a continuous pulling wire shall be drawn into the conduits. The pulling wires shall be flexible, stainless steel (AISI 316) and suitable for a pulling force of at least 1000 N. A rope of stranded stainless steel wires with a fluoropolymer jacket shall be used for this purpose, unless otherwise specified; see also (6.4).

4.4 JUNCTION BOXES

A junction box shall be used at both ends of each heating cable. The junction boxes, including glands and terminals, shall be type Ex"e" and constructed of non-corrosive polymeric material.

Junction boxes at the feeding end of the cables shall be supplied with four main terminals (3 phase + neutral) and an earth terminal. These boxes shall have three glands in the bottom plate, two for the throughgoing power supply cabling and one in the middle for the heating cable, or alternatively one gland in each side plate for the throughgoing supply cabling and one gland in the bottom plate for the heating cable. Junction boxes at the end of the heating cables shall have one gland in the bottom plate for the heating cable.

Special requirements for the heating cable glands shall be specified by the heating cable manufacturer.

5. POWER SUPPLY AND DISTRIBUTION

5.1 DISTRIBUTION PANEL

The distribution panel shall be of the indoor, industrial type in accordance with DEP 33.67.01.31-Gen.
Appendix 1 shows the typical arrangement of the supply and control of the tank heating installation. The total heating system of a tank shall be divided into a number of circuits, each of which shall not exceed a maximum continuous heating load of 50 kW. Each circuit shall consist of a 125 A fused contactor panel supplying four 3-phase + neutral or twelve single-phase subcircuits provided with padlockable miniature circuit-breakers.

The main circuits shall be energized in steps with a time delay between the steps to avoid high inrush currents. The required timing relays shall be adjustable up to 2 minutes and shall be included in the distribution panel.

It may be economically attractive to install the distribution panel or a sub-distribution panel nearer to the heater installation. For this, the Principal's approval is required.

These panels shall be suitable for outside installation as defined in DEP 33.67.01.31-Gen. The incoming feeders of such panels shall be protected by short circuit limiting devices installed in the main switchboard having a maximum nominal current of 355 A. These (sub-)distribution panels shall be installed in a non-hazardous area.

5.2 CIRCUIT PROTECTION

Miniature circuit breakers in the circuits shall be four pole for three-phase circuits, and shall have trip characteristics corresponding thermally and electromagnetically to IEC 947-2, Category B or C.

The maximum rating of the circuit breakers for heater cables shall be 25 A, and the minimum short circuit breaking capacity shall be 10 kA with current limiting capabilities.

The circuit breakers shall be equipped with a residual current protection device. The maximum rated trip current shall be 30 mA. Auxiliary contacts shall be provided, wired up together for one common trip signal combined with a loss of supply voltage alarm measured upstream of the main circuit contactor to a manned control room.

It shall be ensured that the protective devices will operate effectively regardless of the location of a possible fault in the heating cable. The breaker shall be suitable for the inrush current of the heating elements. The type and rating of the circuit breakers shall be approved by the manufacturer of the heating cable.

5.3 FIELD DISTRIBUTION

The supply cabling between the distribution board and the heaters shall have a cross section adequately rated for the maximum load and restricting the voltage drop over the cable under full load conditions to maximum 5% of the nominal voltage. The cables shall be XLPE insulated with copper conductors and a steel wire armouring or braiding and, if required, lead sheathing.

6. ENGINEERING AND INSTALLATION

6.1 GENERAL

The engineering and the installation shall be in accordance with DEP 33.64.10.10-Gen.

6.2 CABLING

The supply cabling shall be installed underground. The heating cable shall be divided equally over the three phases. Each subcircuit phase shall be connected to a maximum of three heating cables, with a combined total length not exceeding 120 m. Two adjacent heating cables shall not be connected to the same subcircuit. Adjacent cables shall be fed from opposite sides of the tank to compensate for the heat output reduction due to voltage drop in the heating cable and shall also be connected to different (sub-)distribution panels in such a way that loss of supply to a panel shall affect only half of the heating cables.

6.3 CONDUIT SYSTEM

Both during and after the construction of the conduit system, care shall be taken to keep the system internally clean. The conduits shall be ordered and supplied with caps sealing the conduit ends in order to avoid internal corrosion and prevent concrete, dirt, water, etc. from entering the conduit system. The conduit ends shall be sealed with heat shrink caps after the installation of the heating cable.

6.4 HEATING CABLE AND PULL WIRES

Extreme care shall be taken to prevent heater cables absorbing water during transport, and during and after installation. During transportation from the supplier to the site, the ends of the cables or the connection leads shall be suitably sealed by heat shrinkable adhesive end-seals, which shall remain fitted until the final connection is made in the junction boxes.

During the construction of the conduit system, a stainless steel pull wire shall be inserted in each conduit. A second pull wire shall be drawn in at the time the heater cable is installed, so that finally each conduit will be filled with a heating cable and a pull wire. Pull wires shall protrude approximately 1 m from each conduit end.

7. TESTING AND COMMISSIONING

7.1 FACTORY TESTING

The testing of the distribution board shall be done in accordance with the requirements of DEP 33.67.01.31-Gen.

On request, the Manufacturer shall supply type test certificates of the heaters quoted, based on the requirements in accordance with DEP 33.68.30.32-Gen.

If Manufacturer testing is based on other codes, this shall be stated in the quotation. Before leaving the Manufacturer's works, each length of heating cable shall be inspected and tested for performance.

Results shall be recorded in test reports, which shall be distributed as specified in the purchasing documents.

7.2 COMMISSIONING

The commissioning schedule for the heating system shall be prepared in accordance with DEP 63.10.08.11-Gen.

8. DOCUMENTS

8.1 GENERAL

Documents, including drawings, required for the installation shall form an integral part of the design. The documents shall be distributed as specified in the purchasing documents. The documents shall show the relevant order and item numbers and the Manufacturer's reference number. Documents shall be updated when alterations are made to the design.

8.2 DOCUMENTS TO BE SUBMITTED

As well as any additional instructions in the requisition/purchase order, the following documents shall be submitted.

- General arrangement drawings showing the configuration of the heating system.
- Bill of material for the total installation.
- Technical data of heaters, electrical equipment and other materials used.
- Heat balance calculations used for design.
- Schematic and connection diagrams covering the complete heating installation.
- Manufacturer's installation manual.
- Manufacturer's test reports, certificates of conformity, declarations of compliance.

8.3 DATA BASE

As part of the detailed design a data base, in the format specified by the Principal, shall be submitted to the Principal for inclusion in a (computerized) management system.

This data base shall contain as a minimum the following information for each individual heater circuit:

- type of heating system
- length of the heating cable(s) and number of circuits
- type of the heating cable
- maximum, minimum and maintaining temperature
- power demand per circuit at maintaining temperature
- list of switches and junction boxes, cross-referenced with the marking of the installation at site
- data on thermostat(s) and or temperature control system.

9. 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 51/99

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-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.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Low-voltage AC switchgear and controlgear assemblies	DEP 33.67.01.31-Gen.
Electrical trace heating	DEP 33.68.30.32-Gen.
Field commissioning and maintenance of electrical installations and equipment	DEP 63.10.08.11-Gen.

BRITISH STANDARDS

Specification for electric surface heating devices	BS 6351: Part 1

Issued by:
British Standards Institution
2 Park Street
London W1A 2BS, England
United Kingdom.

EUROPEAN STANDARDS (CENELEC)

Electrical apparatus for potentially explosive atmospheres	EN 50 014 through EN 50 020 EN 50 028 and EN 50 039

Issued by:
European Committee for Electrotechnical Standardization
Brederodestraat 2
P.O. Box 5
B-1000 Brussels
Belgium.

INTERNATIONAL STANDARDS

International electrotechnical vocabulary	IEC 50
Electrical apparatus for explosive gas atmospheres	IEC 79
Classification of degrees of protection provided by enclosures	IEC 529

Low voltage switchgear and control gear, Part 2: Circuit breakers — IEC 947-2

Issued by:
Central Office of the IEC
(Sales Department)
3, Rue de Varembé
2111 Geneva 20
Switzerland.

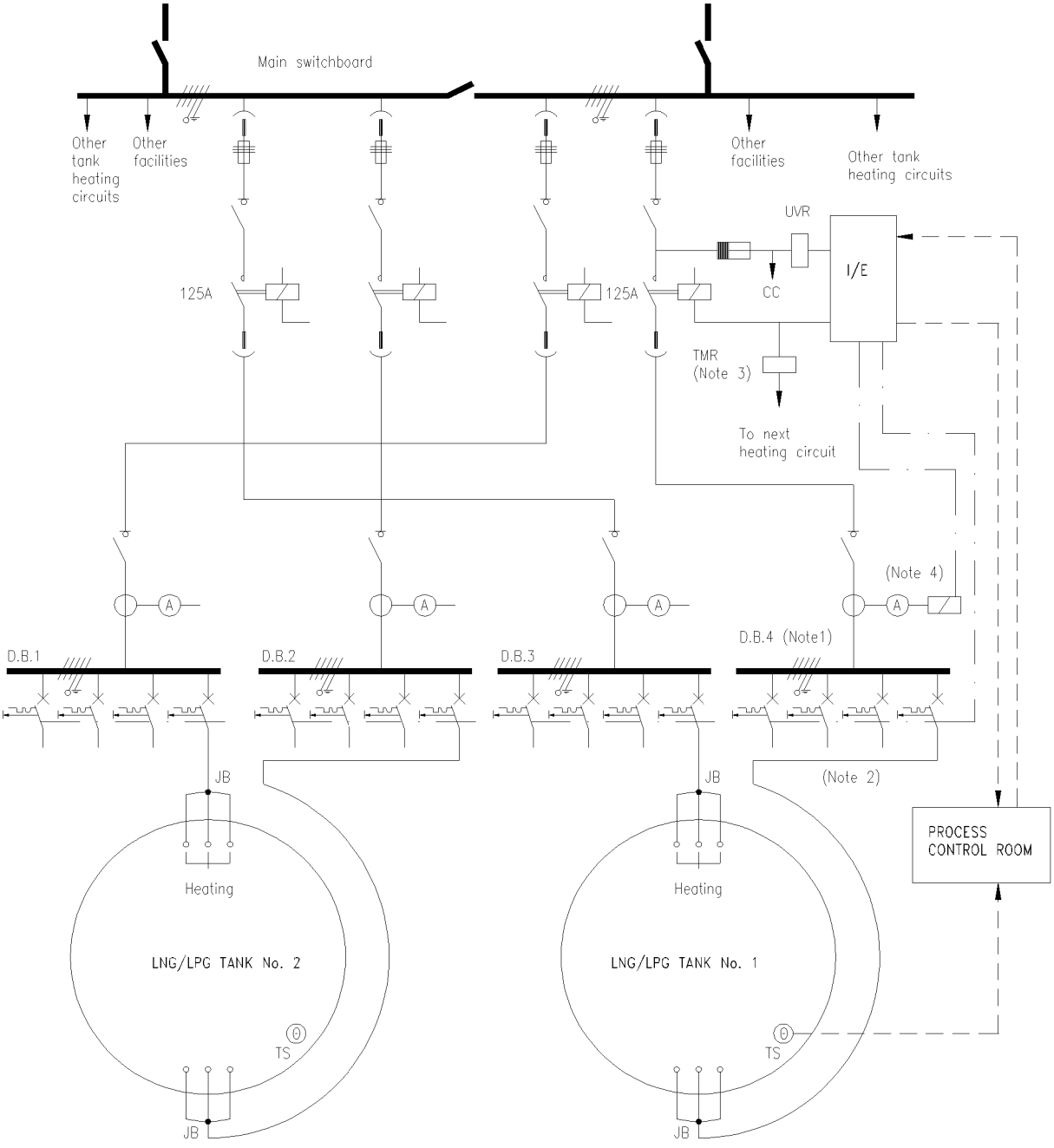
10. APPENDICES

Appendix

1. Typical arrangement for supply and control of tank base heating

2. Test procedure for self-regulating index

APPENDIX 1 TYPICAL ARRANGEMENT FOR SUPPLY AND CONTROL OF TANK BASE HEATING



LEGEND:
- CC = Control circuit
- I/E = Interface relay box
- JB = Junction box
- MCB = Miniature circuit breaker
- TMR = Timing relay
- TS = Temperature sensors
- UVR = Under-voltage relay
- — · — · — Electrical-cabling
- — — — — Instrument-cabling

NOTES:
1. Controls and alarms for distribution panels D.B.1, D.B.2, D.B.3 identical to D.B.4.
2. MCB with overload (25A), and earth leakage (30mA) protection and common trip signal to I/E.
3. Timing relay: 0-2 minutes.
4. Transducer 4-20 mA.

APPENDIX 2 TEST PROCEDURE FOR SELF-REGULATING INDEX

The self-regulating index is a measure of the ability of a self-regulating heat tracing cable to respond to changes in temperature, i.e. to exhibit the self-regulating characteristic. This is related to the steepness of the power-temperature curve.

1. EQUIPMENT

The self-regulating index is based on the power output at +5 and +40 °C. The power output at these two temperatures shall be determined as described in BS 6351: Part 1.

2. CALCULATION

From the power outputs obtained at the two different temperatures, the self-regulating index shall be determined by the equation:

$$\text{Self-regulating index} = \frac{P_1 - P_2}{t_2 - t_1} \frac{W/m}{°C}$$

where: P_1 = W/m at the lower temperature t_1 = 5 °C

P_2 = W/m at the lower temperature t_2 = 40 °C

The output of the heating cable shall not vary more than plus 25% or minus 5% from the design figures.