



GS 158-1

INTERNAL FLOATING DECKS FOR STORAGE TANKS

March 1998

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INTERNAL FLOATING DECKS FOR STORAGE TANKS (Replaces BP Engineering Std 154)			
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This Guidance for Specification specifies BP requirements for the materials, design, construction and testing of internal floating decks for fixed roof storage tanks. It also specifies the design of related tank fittings. It is applicable to decks fitted as part of new tank construction and to decks retrospectively fitted to existing tanks. The following types of deck are covered:- (a) Lightweight All Metal Deck (b) Metal/Foam Sandwich Deck (c) Pan Deck			
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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Guidance for Specification

This specification specifies BP requirements for the materials, design, construction and testing of internal floating decks for fixed roof storage tanks. It also specifies the design of related tank fittings. It is applicable to decks fitted as part of new tank construction and to decks retrospectively fitted to existing tanks.

Application

This Guidance for Specification is intended to guide the purchaser in the use or creation of a fit-for-purpose specification for enquiry or purchasing activity.

Text in *italics* is Commentary. Commentary provides background information which supports the requirements of the Specification, and may discuss alternative options. It also gives guidance on the implementation of any 'Specification' or 'Approval' actions; specific actions are indicated by an (*) preceding a paragraph number.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Principal Changes from Previous Edition

This document is an update of BP Engineering Std 154. No technical changes have been made, the update comprises only re-formatting into the Guidance for Specification (GS) style. Users should be aware that this document retains the prescriptive requirements of BP Std 154.



Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application BP RPSEs, to assist in the process of their continuous improvement.

For feedback and further information, please contact Engineering Practices Group, BP International or the Custodian. See Quarterly Status List for contacts.



INTRODUCTION

1.1 Scope

This Specification specifies BP requirements for the materials, design, construction and testing of internal floating decks for fixed roof storage tanks. It also specifies the design of related tank fittings. It is applicable to decks fitted as part of new tank construction and to decks retrospectively fitted to existing tanks.

The following types of deck (see Figure 1) are covered in this Specification:-

(a) Lightweight All Metal Deck

This deck comprises thin metal sheet, usually aluminium alloy, which is fixed on a grid framework of the same material. It is supported by tubular aluminium buoyancy chambers and there is a vapour space between the liquid and the deck sheets.

(b) Metal/Foam Sandwich Deck

This is made of panels of polyurethane or similar material as a core with thin metal sheet bonded to the top and bottom. It floats in contact with the product. Separate buoyancy chambers are not required and there is no vapour space. Some degree of product absorption into the panel can occur.

(c) Pan Deck

This comprises a shallow pan which floats on the liquid. It may be made from either steel or aluminium. These decks are more prone to sinking than those in (a) and (b) above. They should be designed so that in the event of sinking they are capable of returning to full buoyancy.

1.2 Quality Assurance

Verification of the vendor's quality system is normally part of the pre-qualification procedure, and is therefore not specified in the core text of this specification. If this is not the case, clauses should be inserted to require the vendor to operate and be prepared to demonstrate the quality system to the purchaser. The quality system should ensure that the technical and QA requirements specified in the enquiry and purchase documents are applied to all materials, equipment and services provided by sub-contractors and to any free issue materials.

Further suggestions may be found in the BP Group RPSEs Introductory Volume.



2. GENERAL REQUIREMENTS

2.1 Floating decks, also known as floating covers or internal floating roofs, may be installed in fixed roof tanks for any of the following reasons:-

- (a) To reduce losses due to breathing and filling.
- (b) To reduce air pollution.
- (c) To provide thermal insulation in crude and heavy oil storage as an alternative to roof lagging. This is subject to special design considerations which are not covered in this Specification.
- (d) To reduce contamination of the stored product.

2.2 The vendor shall confirm that the proposed deck is compatible with the tank and the required duty.

Proposed operating procedures shall be reviewed jointly by the purchaser and the vendor. The operating procedures shall state that for reasons of both safety and reliability, the deck should be landed as infrequently as possible.

Where slugs of liquid or gas from long pipelines could be delivered to the tank or where there could be irregular flows as a result of pigging operations, precautions shall be included in the operating procedures to avoid damage to either the deck or the tank.

* 2.3 Each installation, i.e. deck, tank and fittings, shall meet the minimum requirements of either [BS 2654](#) Appendix E or [API 650](#) Appendix H. The code to be used will be specified by BP, together with any local codes or practices of the country of installation which are also to be applied.

2.4 Decks which have been proven on gasoline duties may also be used for naphtha, kerosene or aviation gasoline.

2.5 Floating decks shall not normally be fitted to tanks smaller than 6m diameter because of the difficulty of fitting seals to tight curvatures.

There are no upper limits on tank diameter for the installation of a floating deck.

2.6 Where a floating deck is to be installed in an existing tank an internal and external inspection of the tank shall be made by the vendor. As a minimum, the inspections listed below are required. The latest times at which they shall be carried out are also stated.



External inspection at time of quotation:-

- (a) The verticality of the tank shell.
- (b) The out-of-roundness of the shell (as much of the tank as accessible to be checked).
- (c) The size of the tank manway.

Internal inspection prior to deck installation:-

- (d) Tank out-of-roundness, and shell verticality (complete check).
- (e) Elevation of the lowest part of the roof structure in order to determine the permissible height of travel for the deck.
- (f) The minimum clearances between the deck and any internal fittings over the complete range of operation of the deck.
- (g) Size, position and verticality of any roof support columns.
- (h) Access available for insertion of deck components.
- (i) Any areas of unacceptable roughness in the shell welds or plate surface.

If any significant points are found in either survey BP shall be immediately notified.

2.7 Where the floating deck is being installed as part of a new tank construction, the following details shall be agreed between the tank manufacturer and the vendor:-

- (a) provision for adequate clearance between the deck high position and the roof structure.
- (b) position of shell manways and nozzles.
- (c) fitting of any floating suction (see 6.10).

After the tank has been erected, the vendor shall carry out an internal inspection of the tank, prior to installation of the deck, covering points (d) to (i) of para 2.6.

* 2.8 During the internal examination of an existing tank, the floor and shell shall be inspected for corrosion. If significant corrosion has occurred with pitting up to 2mm deep, BP may specify blast cleaning and



painting of the floor and first 2m of the shell. BP may specify the same treatment to new tanks being installed on duties which have a history of corrosion.

- 2.9 Tank recalibration will be necessary as a result of fitting a floating deck and this work may be included in the scope of the vendor's work (see 10.1.4). The displacement of the deck and all attachments, e.g., floating suction channel, shall be taken into account when preparing the recalibration chart for the tank.
- 2.10 The vendor shall be responsible for ensuring that all deck components can enter the tank.

3. OVERALL DESIGN REQUIREMENTS

3.1 Clearances

- 3.1.1 The deck shall be designed, constructed and installed so that it may rise to and descend from its design maximum height, without requiring attention and without damage to itself, the tank or any fittings.
- 3.1.2 The deck shall not impede or strike any tank fittings, mixers, pipework, gauges or nozzles at any position over its design range.

*** 3.2 Vapour Retention**

A method for determining the rate of change of vapour concentration above a deck is given in Appendix C. The deck performance parameter, static efficiency, is described and a method given for calculating it from the rate of change of vapour concentration.

For gasoline duties, static efficiency shall not be less than 95% as measured by the method given in Appendix C. A statement on this level of performance shall be provided in the vendor's quotation.

The static efficiency, the method of testing and the instruments to be used for measurement of vapour concentration shall be subject to agreement between the vendor and BP.

*** 3.3 Electrical Resistance**

The electrical resistance between the tank and the deck shall not be greater than 100 mega-ohms as measured by the method given in Appendix D. The equipment used for testing shall be subject to agreement between the vendor and BP.



* **3.4 Active Fire Protection**

Where active fire protection is specified by BP, the principles of [NFPA 11](#) shall be met.

* 3.4.1 For lightweight all metal decks and metal/foam sandwich decks, BP may specify a subsurface foam injection system. This type of system is appropriate to tanks 18m diameter and larger, and would be designed to produce foam at a rate of 4.1 l/min/m² over the tank liquid surface.

* 3.4.2 For pan type decks, BP may specify the fitting of fixed foam pourers at the top of the tank shell.

4. DECKS - MATERIALS, DESIGN AND FABRICATION

4.1 General

4.1.1 The deck shall be designed and constructed to float flat and horizontal. Designs should ensure that in normal operation stored product cannot get on to the deck top.

4.1.2 The deck shall be designed to support without permanent deformation at least 3 men (300kg over 3m²) anywhere over the surface, either when floating on water or when grounded and resting on its support feet.

The maximum load that the deck can take shall be stated as a safety factor on the 3 man load.

4.1.3 The materials used in the deck shall be selected to give adequate resistance against the following:-

- (a) Iron oxide corrosion - caused by flakes of tank scale or rust falling on to the deck surface.
- (b) Electrolytic corrosion - caused by surface moisture.
- (c) Salt water corrosion - caused by salt water entrained in the product.
- (d) Microbiological attack - caused by micro-organisms carried by the product.

Where necessary, special precautions to avoid the Thermite reaction (i.e. exothermic reaction between Iron Oxide and Aluminium) shall be applied.



- 4.1.4 Materials of all components, including adhesives if used, shall be suitable for the product specified. All materials shall be listed in the vendor's quotation.

Any non-metallic components shall offer the maximum resistance to penetration by the product liquid or vapour. Data on this resistance shall be provided in the vendor's quotation. Data on the effect of absorption on deck buoyancy shall be given.

4.2 Lightweight All Metal Decks

- 4.2.1 A minimum of 100% excess buoyancy shall be provided, i.e. there shall be sufficient buoyancy to support on the product, double the installed weight of the deck.
- 4.2.2 The deck shall be capable of floating in a liquid of specific gravity 0.7 when two buoyancy tubes plus the decking have been punctured.
- 4.2.3 Buoyancy tubes shall not be foam filled.
- 4.2.4 A skirt dipping into the product by at least 100mm (see Figure 1) shall be provided around the rim of the deck and around any opening in the deck with the exception of pressure/vacuum vents.
- 4.2.5 Sheeting thickness shall be stated in the vendor's quotation. Where aluminium sheeting is used it shall be corrosion resistant clad on both surfaces.
- 4.2.6 Aluminium and its alloys shall not be used where there is a risk of alkalinity, i.e. the pH could exceed 8.
- 4.2.7 Buoyancy tubes shall be pressure tested after fabrication to a minimum of 1 bar gauge using either air and soapy water or air under water. They shall be sealed with non-removable plugs.

4.3 Metal/Foam Sandwich Decks

- 4.3.1 The deck shall retain buoyancy when any two of the panels are punctured.
- 4.3.2 Any non-metal components shall offer the maximum resistance to vapour/liquid penetration. Edge surfaces should be sealed.
- 4.3.3 Any adhesive used in the deck shall be fully resistant to vapour/liquid penetration. Lack of adhesion or delamination of any part of a panel shall be cause for rejection of the complete panel.



- 4.3.4 Where oxygenates are present in the product, the resistance to the product of the polyurethane and any adhesives shall be determined by the vendor and stated in his quotation for consideration by BP.

4.4 Pan Decks

- 4.4.1 A minimum of 100% excess buoyancy as defined in 4.2.1, shall be provided.
- 4.4.2 The decks shall be designed to be self-righting, so that in the event of incipient sinking, liquid is automatically drained from the top of the deck and buoyancy is restored.
- 4.4.3 Fabrication and erection of mild steel pan decks shall be in accordance with [BS 2654](#) Clauses 13 and 14.
- 4.4.4 Fabrication of aluminium pan decks shall be in accordance with [API 650](#).

5. RIM SEALS - MATERIALS, DESIGN AND FABRICATION

- 5.1 The rim seal shall be one of the following types:-

(a) Wiper seal.

This is made from sheet polyurethane or similar plastic which is riveted or bolted to the deck. The seal reverses direction as the deck rises and falls.

For extra performance, either a wiper seal may be used on top of another seal, or double wiper seals may be used.

(b) Buffer seal.

This consists of polyester foam or equivalent surrounded by a sheet of polyurethane or polyurethane-covered fabric. The shape may be square or pentagonal. The seal provides a large area of contact which can take up substantial variations in the shape of the tank.

(c) Tubular seal.

This is made from polyurethane or nylon sheet which is formed into a circular shape and bolted to the deck. It is not usually filled internally.

- 5.2 For special applications, other seal materials may be used e.g. PTFE or carbon impregnated plastics.



- 5.3 The seal shall be constructed of material that is non-absorbent and compatible with the product to be stored.
- 5.4 The seal material (or outer sheathing) shall have a demonstrable abrasion resistance and durability under operating conditions. Data on expected seal life shall be provided by the vendor when quoting.
- * 5.5 Unless specified otherwise by the purchaser, the peripheral seal shall be designed for a radial movement of + and - 100mm on tanks up to 25m diameter, and + and - 125mm on tanks over 25m diameter.
- 5.6 At installation, the width of the gap between the deck and the tank shall be checked to ensure that during operation positive contact is always made between the seal and the tank wall.
- 5.7 The seal mounting shall be firm to ensure good seal contact. Positive wiping action by the seal is required at all points on the tank inner wall for the complete vertical movement of the deck up and down. The position of the seal mounting shall be kept as low as possible above the deck surface.
- 5.8 Circumferential joints on tubular and buffer seals shall be liquid tight. When the joints are made at site, there shall be an overlap of at least 75mm.
- 5.9 The deck vendor shall ensure that seal design and initial fit-up ensure free movement of the deck over its design range (see 7.1.1).

6. DECK FITTINGS

6.1 Penetrations

- 6.1.1 Where columns or other fittings penetrate the deck, wiper seals shall be fitted to ensure minimum leakage during all horizontal and vertical movements of the deck. They shall be designed to accommodate a local deviation of + and - 125 mm. Wiper seals are not required on roof drain or vent valves.
- 6.1.2 Penetrations for sampling and gauging shall be belled (tapered) to provide a guide for the sampling tube or gauge.
- 6.1.3 Penetrations through a metal/foam sandwich deck shall be sealed so that product cannot wet the foam.



6.1.4 With the exception of deck pressure/vacuum vents, penetrations through lightweight all-metal decks shall be fitted with skirts in accordance with 4.2.4.

6.1.5 Dip points shall be covered with a suitable seal through which dipping can take place.

6.2 Deck Manways

6.2.1 At least one manway is required in tanks up to 15m diameter; two manways at least are required in tanks above 15m diameter. They shall be designed to be opened from the underside.

6.2.2 Circular manways shall be not less than 600mm i.d. Rectangular or square manways may be fitted but no side shall be shorter than 600mm.

6.3 Vents

6.3.1 Vents shall be provided to release the air from under the deck during initial filling and to allow air and gas to pass through the deck when draining liquid with the deck resting on its support legs (see Figure 1). The legs on the vents shall be longer than the deck support legs to ensure that venting occurs when the deck is landed.

6.3.2 Calculations shall be provided by the vendor to show that the vent area is adequate and that during venting overstress cannot occur in either the deck or the seal.

6.4 Drains

6.4.1 On lightweight all metal decks, sufficient drains shall be fitted to enable product on the top of the deck to be quickly returned to the bulk product (see Figure 1). The design of the drains shall not affect the vapour sealing efficiency of the deck.

6.5 Support Legs

6.5.1 During deck installation, the support legs shall be adjusted to accommodate any unevenness of the tank floor so that the deck is installed horizontal. The height of the deck shall be fixed. A facility for altering the height at a later stage is not required.

* 6.5.2 The height of the deck shall be specified by the vendor in his quotation for approval by the purchaser. There shall be no obstruction of the shell manways by the deck. Sufficient access for working (1.5m minimum) under the deck shall be provided. Adequate clearance shall be provided so that fittings such as side entry mixers, internal piping, inlet and outlet



nozzles are clear of the deck when the deck is standing on the tank base.

6.5.3 The base of the legs shall be designed so that no undue wear can occur on the tank base. Design shall ensure adequate drainage of the legs.

6.5.4 Leg supports fixed to the deck are preferred to those fitted to the tank bottom. The supports, attachments and tank bottom shall be designed to withstand the weight of the deck plus a uniformly distributed load of 0.4 kN/m².

6.6 Anti-static Cables

Flexible cables shall be fitted between the deck and the tank shell. There shall be a minimum of 2 cables on tanks up to 20 m diameter and a minimum of 4 on larger tanks. There shall be no obstruction above the deck surface which could interfere with an anti-static cable during coiling. Alternatively, cable reels may be used to keep the cables taut at all times.

6.7 Anti-rotation Devices

To prevent rotation of the deck in the horizontal plane, at least two flexible multistrand anti-rotation cables shall be fitted. Alternatively non-central roof columns may be used if available. The cables shall be spring loaded to maintain tension and avoid damage to the tank. Guide tubes of suitable design and material will be required through the deck.

*** 6.8 Gauging and Sampling Devices**

Unless otherwise specified by the purchaser, the deck design shall ensure compatibility with the existing tank gauges. The deck shall be provided with suitable sampling devices as specified in the enquiry.

*** 6.9 Level Alarms**

Unless otherwise specified by the purchaser, a high level alarm shall be fitted to warn of tank overflow or the deck rising to an unacceptable height.

A low level alarm may be required to assist in the operation of the tank. One shall be fitted where the tank has a side entry mixer (see 7.5).

6.10 Floating Suctions

A guide channel shall be provided on the underside of the deck if a floating suction is fitted.



The fitting of a floating suction alters the buoyancy of the deck and could affect its stability. The vendor shall thus ensure that when a floating suction is fitted, buoyancy is not reduced below the levels stated in Section 4 of this Specification and that deck stability is not impaired.

7. TANK FITTINGS

7.1 Open Vents

7.1.1 Open vents, one at the centre of the tank roof and others at the periphery of the roof, shall be fitted in all cases except the following:-

- (a) Where the ullage is purged.
- (b) Where there are high winds which could cause significant vapour losses with conventional open vents.
- (c) Where open vents are prohibited by legislation.

In cases where open vents are not fitted, pressure vacuum vents shall be fitted.

7.1.2 The centre roof vent shall be provided as near as possible to the highest point of the tank roof. It shall have a minimum open area (see 7.1.5) of 0.03m².

- * 7.1.3 The peripheral roof vents shall be of the scoop type (see Figure 2) and shall be positioned as close to the edge of the tank as practicable. There should be at least one vent for every 10m of tank circumference but in no case shall there be less than four equally spaced vents. The effective total open area (see 7.1.5) of these vents shall not be less than 0.06m² per metre of tank diameter. Depending on the product, a larger area than this may be specified by BP.

Ideally at least one vent should be positioned in line with the prevailing wind to take maximum advantage of the wind's purging effect.

- * 7.1.4 Unless specified otherwise by the purchaser, all vents shall be provided with a coarse mesh (minimum openings 6mm square) to prevent the ingress of birds, animals or debris. Covers shall be provided to prevent water ingress.

7.1.5 The areas stated in 7.1.2 and 7.1.3 are minima. If severe icing is possible, these areas shall be increased accordingly.



- * 7.2 **Overflow**
- The purchaser shall specify when overflows are to be fitted together with their size and location.
- 7.3 **Internal Ladders**
- On existing tanks, internal ladders if fitted shall be removed.
- 7.4 **Inlet Diffuser**
- A diffuser shall be fitted to limit the product inlet velocity to 1m/sec and to break up incoming high pressure slugs of air or vapour. The diffuser shall be positioned to move the inlet point closer to the tank centre and away from the rim seal.
- 7.5 **Side Entry Mixer**
- The vendor shall specify the minimum liquid level at which side entry mixers may be allowed to operate. A low level alarm shall be fitted to the tank, together with a trip shutdown for the mixer, so that operation of the mixer cannot occur when the roof is below the specified minimum liquid level.

8. **INSTALLATION**

- 8.1 A check of the delivered components shall be made at site by the installer to ensure there has been neither damage during transport nor deterioration during storage.
- 8.2 A competent and experienced team shall be used for installation.
- 8.3 The deck shall be installed flat and horizontal (see 6.5.1).
- 8.4 The sheeting of lightweight all metal decks shall be laid without excessive rippling.
- 8.5 Soft soled safety shoes shall be worn when walking on the deck surface during installation.
- 8.6 The covers shall be capable of being maintained and repaired using existing tank access.
- 8.7 No 'hot work' shall be undertaken on the tanks after deck installation without complete removal of combustible materials.



9. INSPECTION AND TESTING

- 9.1 A flotation test over the full travel of the deck shall be carried out after deck installation. The tank shall be filled with water or product to check that the deck and seals travel freely over the design range of the deck and that the deck is free from leaks.
- * 9.2 Repair procedures to repair any leaks shall be subject to approval by the purchaser.
- 9.3 For decks with aluminium materials, the test water shall have less than 500 ppm chlorides. For stainless steel tanks or covers, chloride content shall be 30 ppm maximum.
- 9.4 If the deck is to be left for an appreciable period after the water test before filling with product, the shell mandrels shall be removed to ventilate the space below and above the deck.
- * 9.5 A performance test shall be carried out in accordance with Appendix C unless waived by the purchaser. This test shall be carried out only when the deck has been lifted and lowered on product, and the seals bedded in.
- If out-of-roundness has been found in the tank, the performance test shall be carried out at the level where it is at its most extreme.
- * 9.6 A measurement of the electrical resistance between the tank and the deck shall be made in accordance with Appendix D, unless waived by the purchaser.

10. INFORMATION AND DOCUMENTATION

- * 10.1 The information shown below shall be specified by the purchaser in the enquiry.
- 10.1.1 Product Data
- Chemical composition
Maximum and minimum operating temperatures
Density
True vapour pressure over the operating temperature range
Viscosity over the operating temperature range
Expected maximum salt water content.
- 10.1.2 Tank Data



Diameter
Height
Design Code
Type of roof construction
If column roof support, no. of columns and position
Condition
Age
Internal fittings, pipes, ladders etc.
Inlet size and arrangement
No. of sample points and type
No. of dip points
Area required for open roof vents and their position
Coating if any
Size of roof openings
Size of shell openings
Slope and direction of slope of tank base

10.1.3 Deck Design and Required Operation

Design Code to be applied to deck
Maximum rates of product filling and emptying
Design range for the deck including the maximum height to which the deck shall be designed to rise
Requirement for low and high level alarms
Minimum level during normal operation
Any features of deck design unacceptable for the application under consideration
Special features of operation e.g. water pump-over at start-up

10.1.4 Extent of Supply

The extent of supply will be specified by the purchaser.
The Vendor may be required to:-

- (a) supply/install deck
- (b) supply/install deck fittings
- (c) supply/install tank fittings
- (d) supply/install active fire protection system
- (e) carry out flotation test
- (f) carry out performance test
- (g) carry out electrical resistance test



(h) carry out tank recalibration

10.2

In the vendor's quotation, the following information shall be provided in addition to that required as above.

- (a) A statement of compliance to this Specification, or list of deviations.
- (b) A list of all materials, with specifications.
- (c) Sheet thickness for lightweight all metal decks.
- (d) Rim seal type and details.
- (e) An indication of man-hours for assembly.
- (f) Costs and completion times for each item in the extent of supply.
- (g) A statement on the expected service life of the deck and the spare part requirements.
- (h) Any precautions to be taken during storage prior to installation.

10.3

Within a specified period of order placement, the vendor shall forward to the purchaser:

- (a) Arrangement drawings showing deck construction and orientation relative to existing tank fittings. The design and orientation of the vents and any other fittings in his supply shall be shown.
- (b) Installation instructions, with components cross-referred to drawings, for information.

10.4

On completion, four sets of all drawings shall be forwarded to the purchaser as a final record.



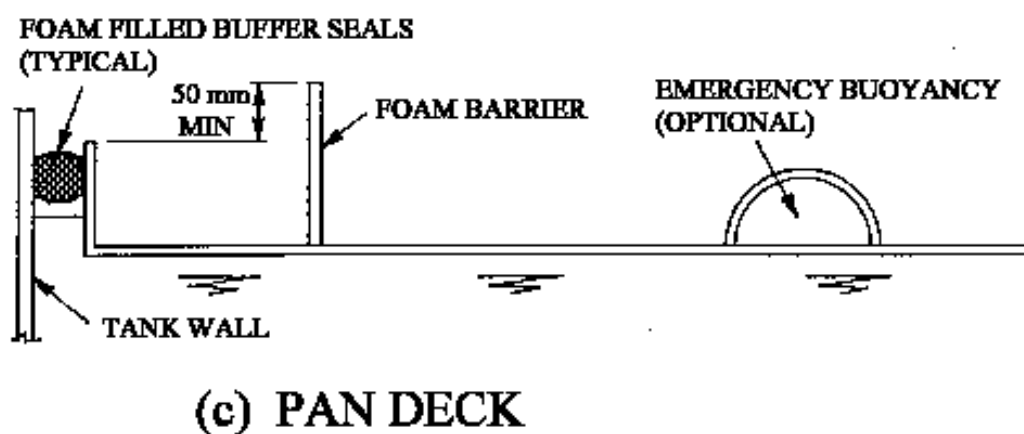
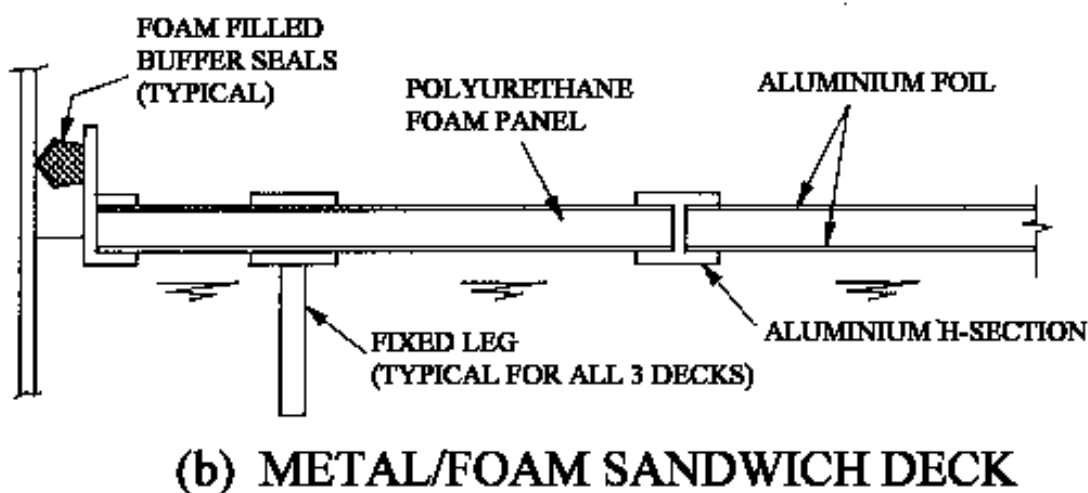
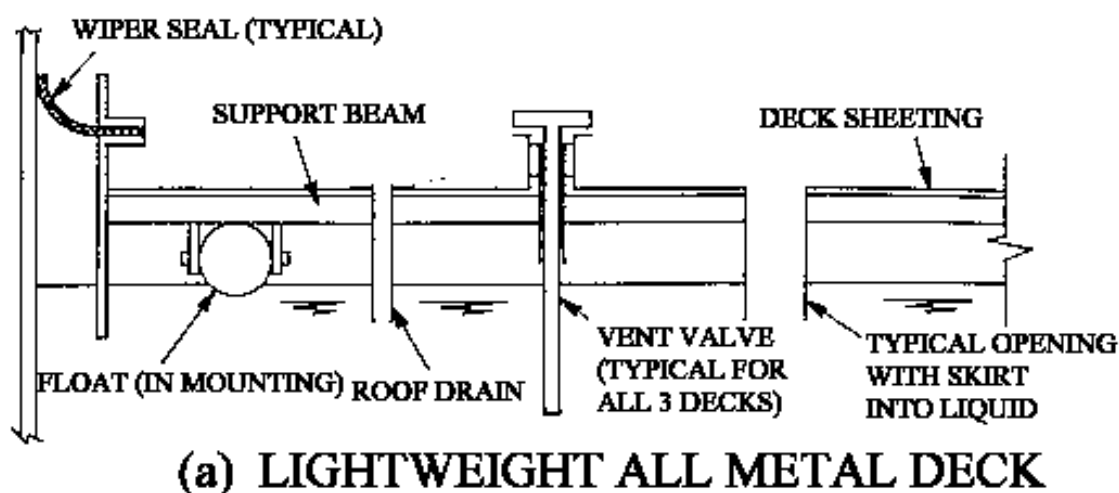


FIGURE 1
DECK TYPES

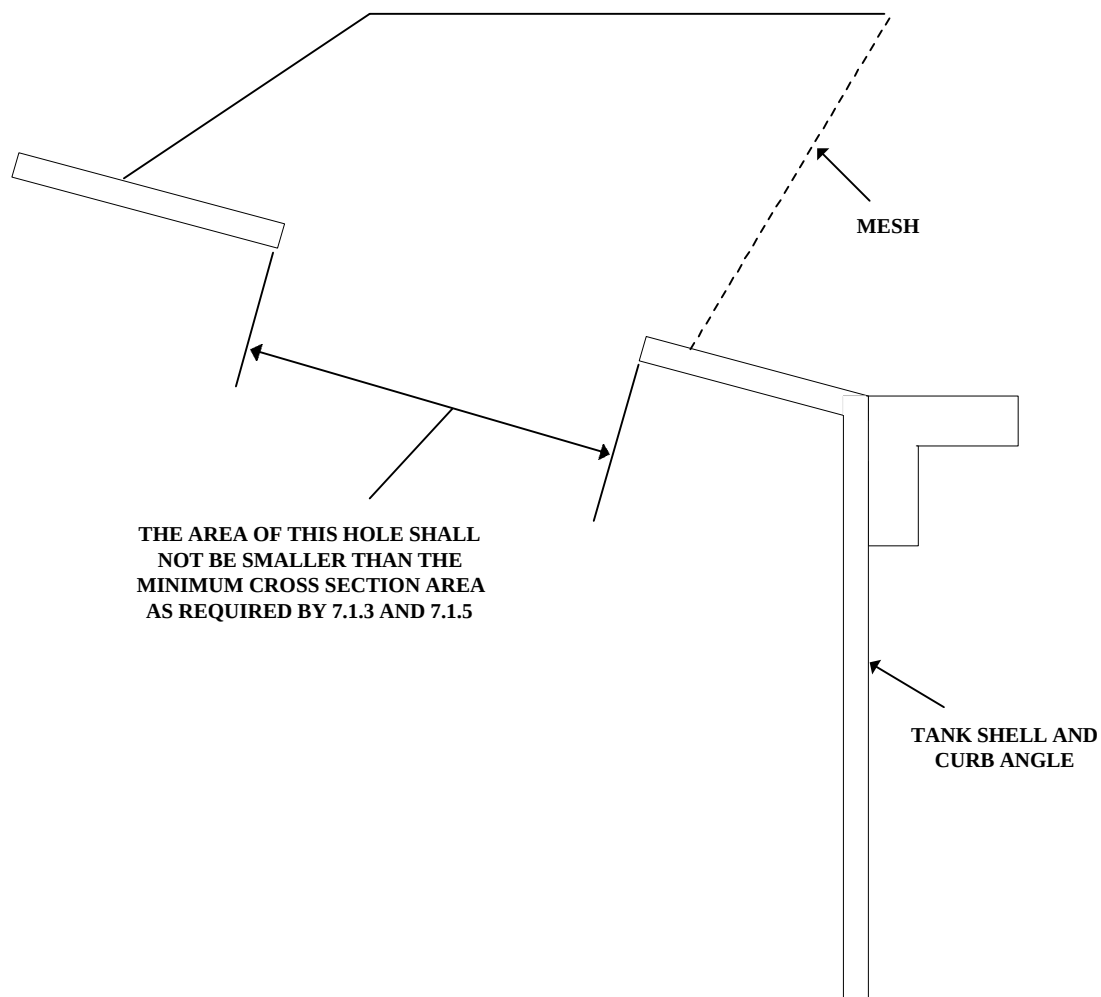


FIGURE 2
SECTION THROUGH A TYPICAL SCOOP TYPE AIR VENT

DEFINITIONS AND ABBREVIATIONS

Definitions

Standardised definitions may be found in the BP Group RPSE's Introductory volume

Abbreviations

API	American Petroleum Institute
BS	British Standard
LEL	Lower Explosive Limit
NFPA	National Fire Protection Association
PTFE	Polytetrafluoroethylene



LIST OF REFERENCE DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards

British Standards

[BS 2654](#) Manufacture of vertical steel welded storage tanks with butt-welded shells for the petroleum industry

American Standards

[API 650](#) Welded steel tanks for oil storage

[NFPA 11](#) Standard for low expansion foam and combined agent systems



MEASUREMENT OF THE STATIC EFFICIENCY

C.1 INTRODUCTION

A method for measuring the performance of internal floating decks has been developed by BP and is given in this Appendix. Static efficiency is used as the parameter of deck performance. A brief explanation is given of the theory and calculation of static efficiency followed by detailed instructions on the method and equipment required for measuring it.

At present, static efficiencies can only be determined for decks on gasoline duties. Data should soon be available so that they can also be determined for Avgas duties.

Advice on this test procedure may be obtained through the purchaser, from Project 140, BP Research Centre Sunbury.

C.2 THEORY

Static efficiency is a measure of the sealing performance of the deck. It is a parameter which compares the rate of increase in vapour concentration in a tank where a deck is fitted against that to be found in a tank where there is no deck.

The rate of evaporation from any liquid surface depends upon a number of factors. Among these are: the temperature of the liquid and gas, the concentration of the gas i.e. its vapour pressure, the amount of agitation in the liquid and the amount of movement in the gas especially close to the liquid surface.

In a tank, with or without a deck, the rate of evaporation is directly proportional to the difference between the saturated concentration at the operating temperature and the actual concentration. It is also directly proportional to the tank cross-section area and inversely proportional to the ullage volume (i.e. vapour space available in the tank).

The theory used to develop the formula for static efficiency is shown in Figure C(1).

C.3 EQUIPMENT

The following equipment is required for the test method:-

- (a) Combustible gas monitor

The instruments used shall be intrinsically safe. It is recommended that a dual range instrument is used, with the following ranges: 0-100% lower explosive limit, LEL (approximately 0-1.6% vol/vol hydrocarbon concentration for gasoline vapour) and 0-100% vol/vol gas.



Due to the non-linearity of response of some combustible gas monitors, calibration charts should be produced prior to use.

The instrument should be calibrated with 0.7% pentane in air (50% LEL) in flow mode and 100% butane in static mode for the two ranges. Flow mode is with calibration gas flowing through the instrument whereas static mode is with the calibration gas flow stopped when the reading is taken. Calibration gas flow should be similar to that obtained during normal use.

To give greater accuracy in the range up to 20% gas, an additional combustible gas monitor, calibrated for this range, can be used in series with the main gas monitor. If used, it should be fitted nearest the sample line and will need to be calibrated separately.

Advice on suitable gas monitors, and their calibration, may be obtained through the purchaser from Project 140, BP Research Centre Sunbury.

(b) Sample pump

The sample should be drawn through the gas monitor at about 1 litre per minute. This can be achieved either by using a hand operated aspirating bulb, or an intrinsically safe sampling pump.

(c) Sample line

The sample line must have low absorption properties for hydrocarbons and a low electrical resistivity. The line should be fitted with an earthing cable at the monitor end. Marking of the line at 0.5m intervals is suggested to assist in sampling at set heights in the tank ullage space. It is suggested that the end of the sample line be weighted to ensure that it hangs vertically. If metallic, the weight should be in electrical contact with the sample line, and covered.

(d) Sample can

(e) Thermometer

(f) Dip tape

(g) 0.5 litre can, or gas washing bottle

C.4 INITIAL TEST REQUIREMENTS

C.4.1 Floating Deck Position



The deck shall remain in the same position for the duration of the tests (approx. 3-3 ½ days). It is essential therefore that no product transfer to or from the tank occurs.

It is recommended that, for gasoline, the product level is adjusted until the floating cover is about 2.5m below the top of the tank wall. For less volatile products, a smaller ullage volume would be needed to get a measurable gas concentration increase over the test period.

C.4.2 Initial Hydrocarbon Concentration

It is essential that the initial hydrocarbon concentration, particularly close to the deck, is as low as possible (i.e. less than 5% vol/vol).

For tanks with open (API type) vents this should occur with natural ventilation.

For tanks fitted with pressure and vacuum (P and V) valves, it is suggested that immediately prior to the test, the product level in the tank is raised to the maximum and then lowered to the test level. This ensures dilution of the ullage by the air drawn in through the P and V valves.

C.5 PRE-TEST CHECKS

C.5.1 Cover and Seal Condition

The conditions of the cover and seal should be noted, if possible, by visual inspection through the hatches, particularly for:-

- (a) presence of product lying on top of the deck. If this exists the test should be postponed until the liquid has been removed.
- (b) damage to the deck or seals (e.g. due to impact with roof members, etc).

C.5.2 Hatch to Be Used

The hatch through which the sampling line is to be lowered into the tank shall not be above a dip funnel. It is preferable to use as small a hatch as possible so that dilution of the vapours during testing is kept to a minimum.

C.5.3 Tank Dimensions

The tank dimensions are required to calculate the ullage volume. Figure C(2) may be used to record the dimensions.

Tank wall height and diameter are normally available from storage volume calibration tables. The roof cone dimensions will probably have to be measured on the tank. The cone



height can be derived from the tank radius and from a measurement of the distance from the apex of the cone to the roof edge.

Using a dip tape the distance from the hatch lip to the deck can be measured. From this distance the sampling height can be decided. Normally it is recommended that sampling is done at 0.5m intervals from the hatch lip.

The main ullage volume can be determined either by determining the height of the hatch lip from the tank wall top, or by noting the tank gauge reading.

C.5.4 Gas Monitor Calibration

The gas monitors should be calibrated prior to, and after the test.

C.6 SATURATED CONCENTRATION OF PRODUCT VAPOUR

The saturated concentration of the product is required for the calculation of static efficiency. It may be calculated theoretically from a knowledge of the Reid Vapour Pressure (RVP) of the product, the temperature of the product and the atmospheric pressure. If possible, it should also be measured.

It can be measured using a sample from the tank and the combustible gas monitor.

This can be done in two ways, but for either, a sample of the product has to be obtained, the sample temperature taken, and the combustible gas monitor calibrated previously on the per cent gas range.

- (a) *The sample is put into a container about twice the sample volume in size and the container sealed. It is then agitated to ensure that the vapour space is saturated. The cap is then carefully removed and the vapour immediately above the liquid surface analysed using the combustible gas monitor. Very short sample lines are needed for this measurement, and great care should be taken to ensure that no liquid enters the combustible gas monitor as this will cause it to be inoperative.*
- (b) *Alternatively a gas washing bottle can be almost filled with the product. Air is drawn through the sample into the combustible gas monitor. Again, very short sample lines should be used and care taken to ensure that no liquid is carried over from the wash bottle into the combustible gas monitor.*

Care must be taken when samples are drawn from the tank that no product is spilled on to the deck. The sample should not be tipped back into the tank but disposed of in some other way.

C.7 VAPOUR RETENTION

The test method involves the measurement of the increase in hydrocarbon concentration in the ullage space during the test period. It is thus essential that open vents are covered to prevent ventilation causing dilution of the vapours. However, as tanks with open vents generally no longer have P and V valves fitted, it is also essential that the tank can breathe. Hence it is recommended that any covering over the open vents should be effective against ventilation, but allow any excess pressure, or vacuum,



in the tank to be dissipated. This can be done, for example, by introducing a length of pipe through one of the vent seals with the open pipe end facing downwards.

For tanks with only P and V valves fitted, no additional sealing is required.

For tanks with open vents where the P and V valve housings have been retained, check if the valve mechanisms have been retained. If the valves have been removed, cover the housing vents securely.

C.8 ULLAGE VAPOUR CONCENTRATION MEASUREMENTS

Immediately after sealing the open vents, the initial vapour concentration in the ullage space should be measured using the following procedure. This should then be repeated twice a day, preferably with a 6 to 8 hour interval between the tests, until five or six sets of readings have been obtained.

- (a) The combustible gas monitors should be placed upwind of the hatch to be used, switched on and allowed to stabilise for at least ten minutes.
- (b) The gas monitors should be zeroed. If there is a marked smell of vapours on the tank top, another sampling line leading to an area of fresh air will be required. The monitor range should be zeroed for the 0-100% LEL range in flow mode, with the sample pump switched on and should be zeroed for the 0-100% gas range in static mode with the pump switched off.
- (c) Securely earth the sample line to the tank structure, and attach the line to gas monitor.
- (d) Lower the sample line into the tank through the hatch. Ensure the hatch is not opened too wide, especially in high wind conditions.
- (e) Record gas monitor readings with the sample line at 0.5m below the hatch lip and at 0.5m intervals thereafter down to the deck surface.

A reading should also be taken with the end of the sample line on the deck surface, but this reading should not be used in the calculation of the average ullage vapour concentration.

Readings at the same positions should be taken as the sample line is withdrawn from the tank.

Ensure that sufficient air has been pumped at each sampling position to purge the line and monitor.

Take LEL readings on the gas monitor in flow mode. Take per cent gas readings in static mode.



- (f) Re-zero gas monitors at least after every fifth reading.
- (g) After removing sample line, the line and monitors shall be purged thoroughly before the monitors are switched off.
- (h) Ensure hatch is closed after test.
- (i) If a temperature indicator is fitted to the tank, record product temperature.

C.9 RESULTS

- (a) The readings from the gas monitor should be corrected using the average of the calibration factors obtained at the beginning and end of tests. Obtain true concentration values from calibration charts.
- (b) Calculate the average vapour concentration for each test. Do not use the reading taken on the deck surface.
- (c) Calculate average saturated concentration value from the readings obtained at the beginning and end of the tests.
- (d) Record the time in days taken for the test.
- (e) Calculate ullage volume from Figure C(2).
- (f) Calculate $\log_e [(C_s - C_o) / (C_s - C_n)]$ and $A t/V$ for each test and plot with $A t/V$ on the x axis on linear graph paper. An example of typical results is given in Figure C(3).
- (g) Determine best fit straight line through points, and measure slope i.e. the constant of proportionality.
- (h) Calculate static efficiency from the equations of Figure C(1).

C.10 SUMMARY OF TEST PROCEDURE

- (a) Deck to be positioned, if possible, about 2.5m from top of tank walls.
- (b) Ensure ullage space is adequately vented prior to test if P and V valves fitted to tank.
- (c) Ensure tank is out of service.
- (d) Obtain tank dimensions, including roof cone.
- (e) Calibrate gas monitors.



- (f) Take product sample and measure saturated vapour concentration and temperature. Ensure no product is spilled on to deck.
- (g) Check for hatches without dip funnel beneath. Choose smallest as hatch to be used during tests.
- (h) Seal open vents against ventilation.
- (i) Take ullage vapour measurements twice a day for three days.
- (j) Record product temperature, if gauge is fitted, at time of vapour concentration measurements.
- (k) At end of tests remove vent sealing covers.
- (l) Recalibrate gas monitors.
- (m) Take another product sample and remeasure saturated vapour concentration and temperature.
- (n) Correct readings from monitors using calibration factors and graph.
- (o) Calculate the static efficiency of deck.



$$\text{RATE OF EVAPORATION} = \frac{dC}{dt} = \hat{1} \frac{A}{V} (C_s - C)$$

WHERE C = CONCENTRATION m³/m³
 C_s = SATURATED CONCENTRATION m³/m³
 A = TANK CROSS SECTIONAL AREA m²
 V = ULLAGE VOLUME m³
 t = TIME DAYS
 $\hat{1}$ = CONSTANT OF PROPORTIONALITY m/DAY

WHERE A DECK IS FITTED THIS CONSTANT IS KNOWN AS THE FLOATING DECK CONSTANT AND IS DESIGNATED $\hat{1}$. WHERE THERE IS NO DECK IT IS KNOWN AS THE EVAPORATION CONSTANT FOR THE LIQUID AND IS DESIGNATED $\hat{1}_0$.

INTEGRATING GIVES

$$\text{LOG}_e \left[\frac{C_s - C_0}{(C_s - C_n)} \right] = \hat{1} \frac{At}{V}$$

WHERE:- C₀ = CONCENTRATION AT TIME t = 0
 C_n = CONCENTRATION AT TIME t = n

$\hat{1}$ IS FOUND BY PLOTTING LOG_e [(C_s - C₀)/(C_s - C_n)] AGAINST At/V AND DRAWING A STRAIGHT LINE THROUGH THE POINTS FROM THE ORIGIN. THE SLOPE IS $\hat{1}$ IF A DECK IS FITTED AND $\hat{1}_0$ IF NOT. PREVIOUS TESTING ON GASOLINE TANKS WITHOUT DECKS HAS GIVEN $\hat{1}_0 = 5\text{m/DAY}$.

$$\text{STATIC EFFICIENCY OF DECK} = 1 - \frac{e}{e_0} \times 100\%$$

$$= \frac{(5 - e)}{5} \times 100\%$$

FIGURE C(1)

THEORY OF STATIC EFFICIENCY



TERMINAL

DATE

TANK NO

PRODUCT

Tank Dimensions in Metres

Height of vertical shell (h) =

Diameter of tank (d) =

Angle distance from roof apex to shell wall (w) =

Vertical distance from deck to hatch lip (a) =

Vertical distance from top of shell wall to hatch lip (b) =

Distance of deck from roof (a-b) = (z) =

Height of roof cone (y) = $\frac{(w^2 - (0.5d)^2)^{0.5}}{(0.5d)}$ =

Ullage volume (v) = $0.785(d)^2 z + 0.262(d)^2 y$ =

Saturation Concentration Readings

Start of test % at degree C

Gas monitor calibration 100% butane = % gas reading

End of test % at degree C

Gas monitor calibration 100% butane = % gas reading

FIGURE C(2)

TABULATION OF TANK DIMENSIONS



Time (t) days	Product Temp degree C	Average Ullage Vapour Conc. (C) %	$\frac{C}{C_s}$	$\text{Loge } \frac{(C_s - C_o)}{(C_s - C_n)}$	$\frac{A t}{V}$
0	9.1	2.52	0.066	0.000	0.000
0.59	-	4.23	0.111	0.049	0.125
0.85	-	4.50	0.118	0.057	0.180
1.67	-	5.69	0.150	0.094	0.354
2.64	-	7.35	0.193	0.146	0.560
2.93	9.2	7.76	0.204	0.160	0.621

where

C_s = Average saturated vapour concentration = 38% at 9.2 C
 C_o = Initial average vapour concentration
 C_n = Average vapour concentration after time n days
 A = Area of floating deck
 V = Ullage volume

Plotting $\text{Loge } \frac{(C_s - C_o)}{(C_s - C_n)}$ against $\frac{A t}{V}$ gives the constant of proportionality as 0.258

$$\text{Hence Static Efficiency} = \frac{(5.0 - 0.258)}{(5.0)} \times 100$$

$$= 94.8\%$$

FIGURE C(3)

EXAMPLE OF TYPICAL TEST RESULTS



**MEASUREMENT OF ELECTRICAL RESISTANCE BETWEEN THE FLOATING
DECK AND THE TANK SHELL**

D.1 INTRODUCTION

Floating decks should be sufficiently conducting to ensure the dissipation of any static charge. The resistance from the centre of the deck to the tank shell (with the anti-static cables disconnected) shall be less than 100mega-ohms.

The test procedure that has been adopted requires the use of non-certified equipment. It is thus important that the test is conducted when the tank is empty and has been declared gas free.

In order to measure the resistance of the seal, it is important that the legs are insulated from the tank floor plates.

Advice on this test procedure may be obtained through the purchaser from Project 140, BP Research Centre, Sunbury.

D.2 EQUIPMENT

- (a) An instrument to measure resistance up to and in excess of 100mega-ohms.
- (b) A brass weight attached to the centre core of a screened electrical lead of sufficient length to reach from the centre of the floating cover to the instrument located in the safe area. The electrical resistance between the signal lead and the screen should be in excess of 100 000mega-ohms.

D.3 TEST PROCEDURE

- (a) Ensure tank is empty and gas-free.
- (b) Ensure that the deck legs are insulated from the tank floor plates.
- (c) Locate instrument in convenient safe area. Place brass weight on the approximate centre of the deck and connect the signal lead to one input of the instrument (instrument inputs vary in design - consult instruction book for instrument used). Connect the other input to the tank shell. If access to the top of the deck is difficult, the brass weight can be lowered onto the deck through a roof hatch.
- (d) Ensure that the anti-static cables have been disconnected.
- (e) Measure resistance between centre of the deck and tank shell. If the design of the deck is such that significant variations in resistance across the deck could exist, the



resistance between different parts of the deck and the tank shell should also be measured.

- (f) At conclusion of test, ensure anti-static cables are reconnected.

If the legs are not insulated from the tank floor plates, this test could be conducted when the deck is floating on product. However, due to the use of non-certified equipment and the likelihood of a flammable atmosphere existing in the tank ullage space, this test method is not recommended for general use. In these circumstances guidance should be obtained through the purchaser from BP Research Centre Sunbury, before the test is undertaken and approval obtained from BP.

