LEVEL

DEPARTMENT OF TRANSPORTATION

COAST GUARD

ADA086973

COMMANDANT'S INTERNATIONAL TECHNICAL SERIES

DTIC ELECTE JUL 22 1980

VOLUME VII

Regulations and Guidelines

For Inert Gas Systems

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DDC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

This document is available to the public through the

National Technical Information Service,

Springfield, Virginia 22151

USCG CITS-8Ø-1-1

FILE COPY

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
USCG-CITS-80-1-1	AD-A086 973	

4. Title and Subtitle	5. Report Date
Commandant's International Technical Series-- Volume VII Regulations and Guidelines For Inert Gas Systems	April 1980
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Department of Transportation U.S. Coast Guard Washington, D.C. 20593	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Same as 9.	Final report
	14. Sponsoring Agency Code

15. Supplementary Notes

Regulations and Guidelines developed by the Subcommittee on Fire Protection of the Intergovernmental Maritime Consultative Organization (IMCO) as well as material aspects developed by the National Materials Advisory Board.

16. Abstract

~~The documents attached concern~~ This report is concerned with a new international regulation on inert gas systems for tank vessels, adopted in November 1979 by the Assembly of the Intergovernmental Maritime Consultative Organization (IMCO). This regulation is the result of several years of study internationally by the IMCO Subcommittee on Fire Protection, in which some 20 countries participated.

In addition, Guidelines which are recommended to governments when fitting inert gas systems in tank vessels in accordance with Regulation 62 of Chapter II-2 of SOLAS 1974 are attached.

A third attachment represents the findings by the National Materials Advisory Board concerning material aspects of inert gas systems.

17. Key Words	18. Distribution Statement
Inert Gas Systems Tank Vessels SOLAS, 1974	Releasable to the public. Available from: National Technical Information Service Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of this form is authorized

THE COMMANDANT OF THE UNITED STATES COAST GUARD
WASHINGTON, D.C. 20593

TO UNITED STATES MARITIME INTERESTS:

INERT GAS SYSTEMS FOR TANK VESSELS

The documents attached concern a new regulation on inert gas systems, adopted in November 1979 by the Assembly of the Intergovernmental Maritime Consultative Organization (IMCO). This new regulation is supplemented with Guidelines for Inert Gas Systems.

This new regulation and Guidelines are the result of several years of study internationally by the IMCO Subcommittee on Fire Protection, in which some 20 countries participated.

In addition, the findings of a National Materials Advisory Board study on materials aspects of inert gas systems are included.

The text attached and the supplementary information I commend to your attention in the interest of Maritime Safety.

Toward our common goal of safety at sea,

J. B. Hayes

J. B. HAYES
Admiral, U. S. Coast Guard

Accession For
NTIS GRA&I
DDC TAB
Unannounced
Justification
By
Dist
A 23

INTER-GOVERNMENTAL MARITIME
CONSULTATIVE ORGANIZATION

ASSEMBLY - 11th session
Agenda item 10(b)

Distr.
GENERAL

A XI/Res.416
6 March 1980

Original: ENGLISH

RECEIVED
U.S. C...
APR 1 8 1980
Washington, D.C.
G...

IMCO

REVISED REGULATION 62 OF CHAPTER II-2 OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974

THE ASSEMBLY,

RECALLING Article 16(i) of the Convention on the Inter-Governmental Maritime Consultative Organization concerning the functions of the Assembly,

RECALLING ALSO resolution 5 of the International Conference on Tanker Safety and Pollution Prevention, 1978 which recommends IMCO to re-examine the requirements relating to inert gas systems in Regulation 62 of Chapter II-2 of the International Convention for the Safety of Life at Sea, 1974, and to develop guidelines to supplement the requirements of that regulation,

NOTING WITH SATISFACTION that the 1974 SOLAS Convention will come into force on 25 May 1980,

NOTING ALSO that the Maritime Safety Committee at its forty-first session approved a revised text of Regulation 62 for inclusion in the amendments to the 1974 SOLAS Convention and that supporting guidelines are under development,

1. URGES Governments, under the provisions of Regulation 5 of Chapter I of the International Convention for the Safety of Life at Sea, 1974, to apply the revised Regulation 62 set out in the Annex to the present resolution in place of the existing requirements;

2. REQUESTS the Maritime Safety Committee to continue with all possible speed the development of the guidelines for inert gas systems;

3. AUTHORIZES the Maritime Safety Committee to circulate the completed guidelines to all Governments concerned.

ANNEX

REVISED REGULATION 62 OF CHAPTER II-2 OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974

Inert Gas Systems

(a) The inert gas system referred to in Regulation 60 of this Chapter, as amended by the 1978 SOLAS Protocol, shall be designed, constructed and tested to the satisfaction of the Administration. It shall be designed and operated so as to render and maintain the atmosphere of the cargo tanks* non-flammable at all times, except when such tanks are required to be gas free

* Throughout this Regulation the term "cargo tank" includes also "slop tanks"

For reasons of economy, this document is printed in a limited number. Delegates are kindly asked to bring their copies to meetings and not to request additional copies.

In the event that the inert gas system is unable to meet the operational requirement set out above and it has been assessed that it is impractical to effect a repair, then cargo discharge, deballasting and necessary tank cleaning shall only be resumed when the "emergency conditions" laid down in the guidelines on inert gas systems are complied with.

(b) The system shall be capable of:

(i) inerting empty cargo tanks by reducing the oxygen content of the atmosphere in each tank to a level at which combustion cannot be supported;

(ii) maintaining the atmosphere in any part of any cargo tank with an oxygen content not exceeding 8 per cent by volume and at a positive pressure at all times in port and at sea except when it is necessary for such a tank to be gas free;

(iii) eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas free;

(iv) purging empty cargo tanks of hydrocarbon gas, so that subsequent gas freeing operations will at no time create a flammable atmosphere within the tank.

(c) (i) The system shall be capable of delivering inert gas to the cargo tanks at a rate of at least 125 per cent of the maximum rate of discharge capacity of the ship expressed as a volume.

(ii) The system shall be capable of delivering inert gas with an oxygen content of not more than 5 per cent by volume in the inert gas supply main to the cargo tanks at any required rate of flow.

(d) The inert gas supply may be treated flue gas from the main or auxiliary boiler(s), from one or more separate gas generators or other sources or from any combination thereof. The Administration may accept systems using inert gases other than flue gas, provided that an equivalent standard of safety is achieved. Systems using stored carbon dioxide shall not be permitted unless the Administration is satisfied that the risk of ignition from generation of static electricity by the system itself is minimized.

(e) Flue gas isolating valve(s) shall be fitted in the inert gas supply main(s) between the boiler uptake(s) and the flue gas scrubber. These valves shall be provided with indicators to show whether they are open or shut, and precautions shall be taken to maintain them gas-tight and keep the seatings clear of soot. Arrangements shall be made so that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

(f) (i) A flue gas scrubber shall be fitted which will effectively cool the volume of gas specified in paragraph (c) of this Regulation and remove solids and sulphur combustion products. The cooling water arrangements shall be such that an adequate supply of water will always be available without interfering with any essential services on the ship. Provision shall also be made for an alternative supply of cooling water.

(ii) Filters or equivalent devices shall be fitted to minimize the amount of water carried over to the inert gas blowers.

(iii) The scrubber shall be located aft of all cargo tanks, cargo pump rooms and cofferdams separating these spaces from machinery spaces of Category A.

(g) (i) At least two blowers shall be fitted which together shall be capable of delivering to the cargo tanks at least the volume of gas required by paragraph (c) of this Regulation.

(ii) The inert gas system shall be designed so that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank. Suitable shut-off arrangements shall be provided on the suction and discharge connexions of each blower. Arrangements shall be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge. If the blowers are to be used for gas freeing, their air inlets shall be provided with blanking arrangements.

(iii) The blowers shall be located aft of all cargo tanks, cargo pump rooms and cofferdams separating these spaces from machinery spaces of Category A.

(h) (i) Special consideration shall be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.

(ii) To permit safe maintenance, an additional water seal or other effective means of preventing flue gas leakage should be fitted between the flue gas isolating valves and scrubber or incorporated in the gas entry to the scrubber.

(i) (i) A gas regulating valve shall be fitted in the inert gas supply main. This valve shall be automatically controlled to close as required in sub-paragraphs (s)(ii) and (s)(iii) of this Regulation. It shall also be capable of automatically regulating the flow of inert gas to the cargo tanks unless means are provided to automatically control the speed of the inert gas blowers required in paragraph (g) of this Regulation.

(ii) The valve referred to in sub-paragraph (i) of this paragraph shall be located at the forward bulkhead of the most forward gas safe space* through which the inert gas supply main passes.

(j) (i) At least two non-return devices, one of which shall be a water seal, shall be fitted in the inert gas supply main, in order to prevent the return of hydrocarbon vapour to the machinery spaces uptakes or to any gas safe spaces under all normal conditions of trim, list and motion of the ship. They shall be located between the automatic valve required by paragraph (i) of this Regulation and the aftermost connexion to any cargo tank or cargo pipeline.

(ii) The devices referred to in sub-paragraph (i) of this paragraph shall be located in the cargo tank area on deck.

(iii) The water seal referred to in sub-paragraph (i) of this pargraph shall be capable of being supplied by two separate pumps, each of which shall be capable of maintaining an adequate supply at all times.

(iv) The arrangement of the seal and its associated provisions shall be such that it will prevent backflow of hydrocarbon vapours and will ensure the proper functioning of the seal under operating conditions.

(v) Provision shall be made to ensure that the water seal is protected against freezing, in such a way that the integrity of seal is not impaired by overheating.

(vi) A water loop or other approved arrangement shall also be fitted to all associated water supply and drain piping and all venting or pressure sensing piping leading to gas safe spaces. Means shall be provided to prevent such loops from being emptied by vacuum

(vii) The deck water seal and all loop arrangements shall be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the cargo tanks.

(viii) The second device shall be a non-return valve or equivalent capable of preventing the return of vapours and/or liquids and fitted forward of the deck water seal required in sub-paragraph (i) of this paragraph. It shall be provided with positive means of closure As an alternative to positive means of closure, an additional valve having such means of closure may be provided forward of non-return valve to isolate the deck water seal from the inert gas main to the cargo tanks.

(ix) As an additional safeguard against the possible leakage of hydrocarbon liquids or vapours back from the deck main, means shall be provided to permit this section

---

* Gas safe space is a space into which the entry of hydrocarbon gases would produce hazards with regard to flammability or toxicity.

of the line between the valve having positive means of closure referred to in sub-paragraph (viii) of this paragraph and the valve referred to in paragraph (i) of this Regulation to be vented in a safe manner when the first of these valves is closed.

(k) (i) The inert gas main may be divided into two or more branches forward of the non-return devices required by paragraph (j) of this Regulation.

(ii) (1) The inert gas supply main(s) shall be fitted with branch piping leading to each cargo tank. Branch piping for inert gas shall be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they shall be provided with locking arrangements, which shall be under the control of a responsible ship's officer.

(2) In combination carriers, the arrangement to isolate the slop tanks containing oil or oil residues from other tanks shall consist of blank flanges which will remain in position at all times when cargoes other than oil are being carried except as provided for in the relevant section of the guidelines on inert gas systems.

(iii) Means shall be provided to protect cargo tanks against the effect of over-pressure or vacuum caused by thermal variations when the cargo tanks are isolated from inert gas main(s).

(iv) Piping systems shall be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

(v) Suitable arrangements shall be provided to enable the inert gas main to be connected to an external supply of inert gas.

(l) The arrangements for the venting of all vapours displaced from the cargo tanks during loading and ballasting shall comply with paragraph (a) of Regulation 58 of this Chapter and shall consist either of one or more mast risers, or of a number of high velocity vents. The inert gas supply main(s) may be used for such venting.

(m) The arrangements for inerting, purging or gas freeing of empty tanks as required in paragraph (b) of this Regulation shall be to the satisfaction of the Administration and shall be such that the accumulation of hydrocarbon vapours in pockets formed by the internal structural members in a tank is minimized and that:

(i) on individual cargo tanks the gas outlet pipe, if fitted, shall be positioned as far as practicable from the inert gas/air inlet and in accordance with paragraph (a) of Regulation 58 of this Chapter. The inlet of such outlet pipes may be located either at deck level or at not more than 1 metre above the bottom of the tank;

(ii) the cross sectional area of such gas outlet pipe referred to in sub-paragraph (i) of this paragraph shall be such that an exit velocity of at least 20 m/sec can be maintained when any three tanks are being simultaneously supplied with inert gas. Their outlets shall extend not less than 2 metres above deck level;

(iii) each gas outlet referred to in sub-paragraph (ii) of this paragraph shall be fitted with suitable blanking arrangements;

(iv) (1) if a connexion is fitted between the inert gas supply main(s) and the cargo piping system, arrangements shall be made to ensure an effective isolation having regard to the high pressure difference which may exist between the systems. This shall consist of two shut-off valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks;

(2) the valve separating the inert gas supply main from the cargo main and which is on the cargo main side shall be a non-return valve with a positive means of closure.

(n) (i) One or more pressure-vacuum breaking devices shall be provided on the inert gas supply main to prevent the cargo tanks from being subject to:

(1) a positive pressure in excess of the test pressure of the cargo tank if the cargo were to be loaded at the maximum specified rate and all other outlets are left shut; or

(2) a negative pressure in excess of 700 millimetres water gauge if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blower(s) were to fail.

(ii) The location and design of the devices referred to in sub-paragraph (i) of this paragraph shall be in accordance with paragraph (a) of Regulation 58 of this Chapter.

(o) Means shall be provided for continuously indicating the temperature and pressure of the inert gas at the discharge side of the gas blowers, whenever the gas blowers are operating.

(p) (i) Instrumentation shall be fitted for continuously indicating and permanently recording when the inert gas is being supplied:

(1) the pressure of the inert gas supply main(s) forward of the non-return devices required by sub-paragraph (j)(i) of this Regulation; and

(2) the oxygen content of the inert gas in the inert gas supply main on the discharge side of the gas blower.

(ii) The devices referred to in sub-paragraph (i) of this paragraph shall be placed in the cargo control room where provided. But where no cargo control room is provided, they shall be placed in a position easily accessible to the officer in charge of cargo operations.

(iii) In addition, meters shall be fitted:

(1) in the navigating bridge to indicate at all times the pressure referred to in sub-paragraph (i)(1) of this paragraph and the pressure in the slop tanks of combination carriers, whenever those tanks are isolated from the inert gas supply main; and

(2) in the machinery control room or in the machinery space to indicate the oxygen content referred to in sub-paragraph (i)(2) of this paragraph.

(q) Portable instruments for measuring oxygen and flammable vapour concentration shall be provided. In addition, suitable arrangement shall be made on each cargo tank such that the condition of the tank atmosphere can be determined using these portable instruments.

(r) Suitable means shall be provided for the zero and span calibration of both fixed and portable gas concentration measurement instruments, referred to in paragraphs (p) and (q) of this Regulation.

(s) (i) Audible and visual alarms shall be provided to indicate

(1) low water pressure or low water flow rate to the flue gas scrubber as referred to in sub-paragraph (f)(i) of this Regulation;

(2) high water level in the flue gas scrubber as referred to in sub-paragraph (f)(i) of this Regulation;

(3) high gas temperature as referred to in paragraph (o) of this Regulation,

(4) failure of the inert gas blower(s) referred to in paragraph (g) of this Regulation,

(5) oxygen content in excess of 8 per cent by volume as referred to in sub-paragraph (p)(i)(2) of this Regulation,

(6) failure of the power supply to the automatic control system for the gas regulating valve and to the indicating devices as referred to in paragraph (i) and sub-paragraph (p)(i) of this Regulation,

(7) low water level in the water seal as referred to in sub-paragraph (j)(i) of this Regulation;

(8) gas pressure less than 100 millimetres water gauge as referred to in sub-paragraph (p)(i) of this Regulation. The alarm arrangement shall be such as to ensure that the pressure in slop tanks in combination carriers can be monitored at all times; and

(9) high gas pressure as referred to in sub-paragraph (p)(i)(1) of this Regulation.

(ii) Automatic shut down of the inert gas blowers and gas regulating valve shall be arranged on predetermined limits being reached in respect of sub-paragraphs (i)(1), (i)(2) and (i)(3) of this paragraph.

(iii) Automatic shut down of the gas regulating valve shall be arranged in respect of sub-paragraph (i)(4) of this paragraph.

(iv) In respect of sub-paragraph (i)(5) of this paragraph, when the oxygen content of the inert gas exceeds 8 per cent, immediate action shall be taken to improve the gas quality. Unless the quality of the gas improves, all cargo tank operations shall be suspended so as to avoid air being drawn into the tanks and the isolation valve referred to in sub-paragraph (j)(viii) of this Regulation shall be closed.

(v) The alarms required in sub-paragraphs (i)(5), (i)(6) and (i)(8) of this paragraph shall be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

(vi) In respect of sub-paragraph (i)(7) of this paragraph the Administration shall be satisfied as to the maintenance of an adequate reserve of water at all times and the integrity of the arrangements to permit the automatic formation of the water seal when the gas flow ceases. The audible and visual alarm on the low level of water in the water seal shall operate when the inert gas is not being supplied.

(vii) An audible alarm system independent of that required in sub-paragraph (i)(8) of this paragraph or automatic shut down of cargo pumps shall be provided to operate on predetermined limits of low pressure in the inert gas main(s) being reached.

(t) All existing tankers, as defined in sub-paragraph (a)(v) of Regulation 1 of Chapter II-2 of the 1978 SOLAS Protocol, which are required to have an inert gas system, shall at least comply with the original Regulation 62 of this Chapter as adopted by the International Conference on Safety of Life at Sea, 1974. In addition, they shall comply with the requirements of this Regulation, except that:

(i) Inert gas systems already fitted on board such tankers or which will be fitted before June 1981 need not comply with the following sub-paragraphs:

(c)(ii); (f)(iii); (g)(iii); (h); (i)(ii); (j)(ii); (j)(vii); (j)(ix); (k)(iii); (k)(iv); (m)(ii); (m)(iv)(2) and (s)(vii);

(ii) Inert gas systems which will be fitted on board such tankers on or after June 1981 need not comply with the following sub-paragraphs:

(c)(ii); (f)(iii); (g)(iii) and (m)(ii).

(u) Detailed instruction manual(s) shall be provided on board, covering the operational, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the cargo tank system*. The manual(s) shall include guidance on procedures to be followed in the event of a fault or failure of the inert gas system.

---

* Reference is made to the guidelines on inert gas systems, under development, to be circulated in due course

INTER-GOVERNMENTAL MARITIME
CONSULTATIVE ORGANIZATION
101-104 PICCADILLY,
LONDON, W1V OAE
Telegrams: INMARCOR-LONDON, W.1
Telephone: 01-499 9040

MSC/Circ.282
2 June 1980

IMCO

Ref. T4/4.03

GUIDELINES FOR INERT GAS SYSTEMS

1. In response to resolution 5 of the International Conference on Tanker Safety and Pollution Prevention, 1978 which requested the Organization to promote studies with a view to re-examining the requirements relating to inert gas systems in Regulation 62 of Chapter II-2 of the 1974 SOLAS Convention and to develop guidelines to supplement the requirements of that regulation, the Assembly adopted with resolution A.418(XI) a revised text for inclusion in the first set of amendments to that convention.

2. The Committee at its forty-second session approved the Guidelines for Inert Gas Systems which are attached at annex and are referred to in the revised Regulation 62 of Chapter II-2 of the 1974 SOLAS Convention.

3. The guidelines are based on the design and operation of current inert gas systems using flue gas from boiler uptakes. Consideration is being given to provisions for inert gas systems in chemical tankers.

4. Member governments are invited to give effect to these guidelines, to be used for the design, operation and maintenance of such systems.

5. Member governments are further invited to inform the Organization on steps taken in the implementation of draft revised Regulation 62 and the associated guidelines for inert gas systems.

***

ANNEX

GUIDELINES FOR INERT GAS SYSTEMS

Table of Contents

11 INSTRUCTION MANUAL(S)

12 SOME SAFETY CONSIDERATIONS WITH INERT GAS SYSTEMS

12.1 Backflow of cargo gases

12.2 Health hazards

12.3 Tank pressure

12.4 Electrostatic hazards

12.5 Repair of inert gas plant

1 INTRODUCTION

1.1 Purpose

The International Conference on Tanker Safety and Pollution Prevention held in February 1978 passed resolution 5 recommending that the Inter-Governmental Maritime Consultative Organization develop guidelines to supplement the requirements of amended Regulation 62 of Chapter II-2 of the 1974 SOLAS Convention* by taking into account the arduous operating conditions of inert gas systems and the need to maintain them to a satisfactory standard. In addition Regulation 62(a) requires that an inert gas system shall be designed, constructed and tested to the satisfaction of the Administration. These Guidelines have accordingly been developed to supplement and complement the Convention requirements for inert gas systems. They are offered to Administrations to assist them in determining appropriate design and constructional parameters and in formulating suitable operations procedures when inert gas systems are installed in ships flying the flag of their State.

1.2 Application

1.2.1 The status of these Guidelines is advisory. They are intended to cover the design and operation of:

.1 inert gas systems that are required on new tankers by Regulation 60 of Chapter II-2 of the 1978 SOLAS Protocol and in accordance with Regulation 62;

.2 inert gas systems that are required on existing tankers by Regulation 60 of Chapter II-2 of the 1978 SOLAS Protocol and in accordance with Regulation 62(t);

.3 inert gas systems which are fitted but not required to comply with the requirements of Regulation 60 of Chapter II-2 of the 1978 SOLAS Protocol.

1.2.2 However, for existing inert gas systems the Guidelines are directed primarily at operational procedures and are not intended to be interpreted as requiring modifications to existing equipment other than those which are required on ships to which Regulation 62(t) applies.

1.2.3 The content of these Guidelines is based on current general practice used in the design and operation of inert gas systems using flue gas from the uptake from the ship's main or auxiliary boilers, and installed on crude oil tankers and combination carriers. The Guidelines do not exclude other sources of inert gas, such as systems incorporating independent inert gas generators, other designs, materials or operational procedures. All such divergences should be carefully assessed to ensure that they achieve the objectives of these Guidelines.

---

* Wherever Regulation 62 is referred to in these "Guidelines" it means revised text of Regulation 62 of Chapter II-2 of the 1974 SOLAS Convention, as approved by the Maritime Safety Committee at its forty-first session in October 1979 and referred to in Resolution A.418(XI).

1.3 Definitions

1.3.1 Inert gas means a gas or a mixture of gases, such as flue gas, containing insufficient oxygen to support the combustion of hydrocarbons.

1.3.2 Inert condition means a condition in which the oxygen content throughout the atmosphere of a tank has been reduced to 8 per cent or less by volume by addition of inert gas.

1.3.3 Inert gas plant means all equipment specially fitted to supply, cool, clean, pressurize, monitor and control delivery of inert gas to cargo tank systems.

1.3.4 Inert gas distribution system means all piping, valves, and associated fittings to distribute inert gas from the inert gas plant to cargo tanks, to vent gases to atmosphere and to protect tanks against excessive pressure or vacuum.

1.3.5 Inert gas system means an inert gas plant and inert gas distribution system together with means for preventing backflow of cargo gases to the machinery spaces, fixed and portable measuring instruments and control devices.

1.3.6 Inerting means the introduction of inert gas into a tank with the object of attaining the inert condition defined in 1.3.2.

1.3.7 Gas-freeing means the introduction of fresh air into a tank with the object of removing toxic, flammable and inert gases and increasing the oxygen content to 21 per cent by volume.

1.3.8 Purging means the introduction of inert gas into a tank already in the inert condition with the object of:

.1 further reducing the existing oxygen content; and/or

.2 reducing the existing hydrocarbon gas content to a level below which combustion cannot be supported if air is subsequently introduced into the tank.

1.3.9 Topping-up means the introduction of inert gas into a tank which is already in the inert condition with the object of raising the tank pressure to prevent any ingress of air.

2 PRINCIPLES

2.1 General

With an inert gas system the protection against a tank explosion is achieved by introducing inert gas into the tank to keep the oxygen content low and reduce to safe proportions the hydrocarbon gas concentration of the tank atmosphere.

2.2 Flammable limits

2.2.1 A mixture of hydrocarbon gas and air cannot ignite unless its composition lies within a range of gas-in-air concentrations known as the "flammable range". The lower limit of this range, known as the "lower flammable limit" is any hydrocarbon concentration below which there is insufficient hydrocarbon gas to support combustion. The upper limit of the range, known as the "upper flammable limit" is any hydrocarbon concentration above which there is insufficient air to support combustion.

2.2.2 The flammable limits vary somewhat for different pure hydrocarbon gases and for the gas mixtures derived from different petroleum liquids. In practice, however, the lower and upper flammable limits of oil cargoes carried in tankers can be taken, for general purposes, to be 1 per cent and 10 per cent hydrocarbon by volume, respectively.

2.3 Effect of inert gas on flammability

2.3.1 When an inert gas is added to a hydrocarbon gas/air mixture the result is to increase the lower flammable limit concentration and to decrease the upper flammable limit concentration. These effects are illustrated in figure 1, which should be regarded only as a guide to the principles involved.

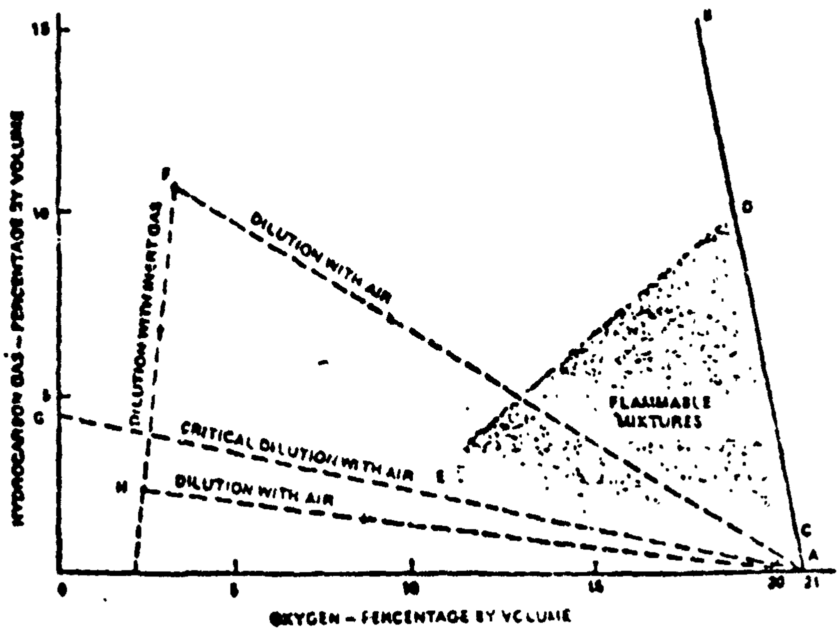


Figure 1

2.3.2 Any point on the diagram represents a hydrocarbon gas/air/inert gas mixture, specified in terms of its hydrocarbon and oxygen content. Hydrocarbon/air mixtures without inert gas lie on the line AB, the slope of which shows the reduction in oxygen content as the hydrocarbon content increases. Points to the left of AB represent mixtures with their oxygen content further reduced by the addition of inert gas. It is evident from figure 1 that as inert gas is added to hydrocarbon/air mixtures the flammable range progressively decreases until the oxygen content reaches a level generally taken to be about 11 per cent by volume, at which no mixture can burn. The figure of 8 per cent by volume specified in these Guidelines for a safely inerted gas mixture allows some margin beyond this value.

2.3.3 The lower and upper flammability limit mixtures for hydrocarbon gas in air are represented by the points C and D. As the inert gas content increases, the flammable limit mixtures change. This is indicated by the lines CE and DE, which finally converge at the point E. Only those mixtures represented by points in the shaded area within the loop CED are capable of burning. Changes of composition, due to the addition of either air or inert gas, are represented by movements along straight lines. These lines are directed either towards the point A (pure air), or towards a point on the oxygen content axis corresponding to the composition of the added inert gas. Such lines are shown for the gas mixture represented by the point F.

2.3.4 When an inert mixture, such as that represented by the point F, is diluted by air its composition moves along the line FA and therefore enters the shaded area of flammable mixtures. This means that all inert mixtures in the region above the line GA (critical dilution line) pass through a flammable condition as they are mixed with air (for example during a gas-freeing operation). Those below the line GA, such as that represented by point H, do not become flammable on dilution. It will be noted that it is possible to move from a mixture, such as that represented by F, to one such as that represented by H, by dilution with additional inert gas, i.e. purging.

2.4 Sources

Possible sources of inert gas on tankers including combination carriers are:

.1 the uptake from the ship's main or auxiliary boilers;

.2 an independent inert gas generator; or

.3 a gas turbine plant when equipped with an afterburner.

2.5 Quality

Good combustion control in ship's boilers is necessary to achieve an oxygen content of 5 per cent by volume. In order to obtain this quality, it may be necessary to use automatic combustion control.

2.6 Methods of gas replacement

2.6.1 There are three operations which involve replacement of gas in cargo tanks, namely:

.1 inerting,

.2 purging;

.3 gas-freeing.

2.6.2 In each of these replacement operations, one of two processes can predominate:

.1 dilution, which is a mixing process; (see 2.6.3)

.2 displacement, which is a layering process. (see 2.6.4)

These two processes have a marked effect on the method of monitoring the tank atmosphere and the interpretation of the results. Figures 3 and 5 show that an understanding of the nature of the gas replacement process actually taking place within the tank is necessary for the correct interpretation of the reading shown on the appropriate gas sampling instrument.

2.6.3. The dilution theory assumes that the incoming gas mixes with the original gases to form a homogeneous mixture throughout the tank. The result is that the concentration of the original gas decreases exponentially. In practice the actual rate of gas replacement depends upon the volume flow of the incoming gas, its entry velocity, and the dimensions of the tank. For complete gas replacement it is important that the entry velocity of the incoming gas is high enough for the jet to reach the bottom of the tank. It is therefore important to confirm the ability of every installation using this principle to achieve the required degree of gas replacement throughout the tank.

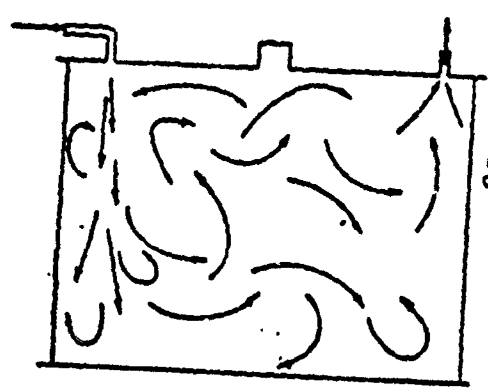


Figure 2.

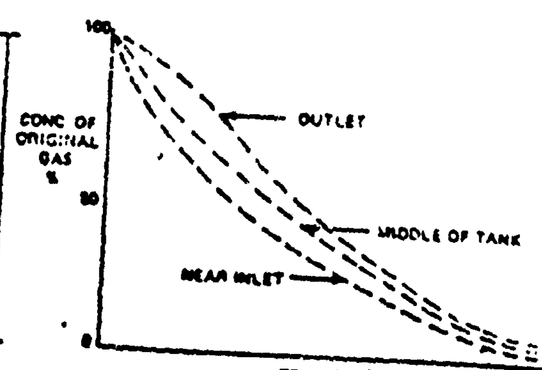


Figure 3.

Figure 2 shows an inlet and outlet configuration for the dilution process and illustrates the turbulent nature of the gas flow within the tank.

Figure 3 shows typical curves of gas concentration against time for three different sampling positions

2.6.4 Ideal replacement requires a stable horizontal interface between the lighter gas entering at the top of the tank and the heavier gas being displaced from the bottom of the tank through some suitable piping arrangement. This method requires a relatively low entry velocity of gas and in practice more than one volume change is necessary. It is therefore important to confirm the ability of every installation using this principle to achieve the required degree of gas replacement throughout the tank.

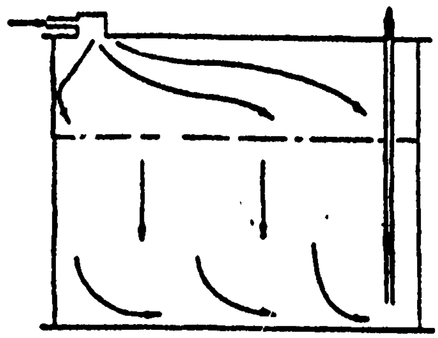


Figure 4.

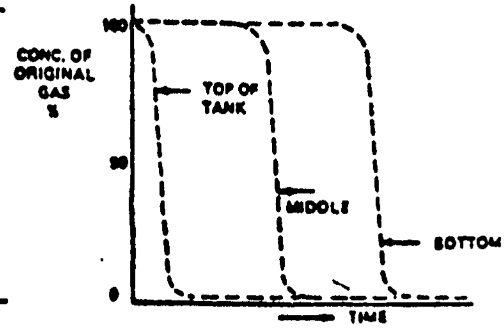


Figure 5.

Figure 4 shows an inlet and outlet configuration for the displacement process, and indicates the interface between the incoming and outgoing gases.

Figure 5 shows typical curves of gas concentration against time for three different sampling levels.

2.7 General policy of cargo tank atmosphere control

2.7.1 Tankers fitted with an inert gas system should have their cargo tanks kept in a non-flammable condition at all times (see figure 1). It follows that:

.1 tanks should be kept in the inert condition whenever they contain cargo residues or ballast. The oxygen content should be kept at 8 per cent or less by volume with a positive gas pressure in all the cargo tanks;

.2 the atmosphere within the tank should make the transition from the inert condition to the gas-free condition without passing through the flammable condition. In practice this means that before any tank is gas freed, it should be purged with inert gas until the hydrocarbon content of the tank atmosphere is below the critical dilution line (see figure 1);

.3 when a ship is in a gas-free condition before arrival at a loading port, tanks should be inerted prior to loading.

2.7.2 In order to maintain cargo tanks in a non-flammable condition the inert gas plant will be required to:

.1 inert empty cargo tanks (see 5.1);

.2 be operated during cargo discharge, deballasting and necessary in-tank operations (see 5.2, 5.5, 5.6, 5.8 and 5.9);

.3 purge tanks prior to gas-freeing (see 5.10);

.4 top-up pressure in the cargo tanks when necessary, during other stages of the voyage (see 5.4 and 5.8).

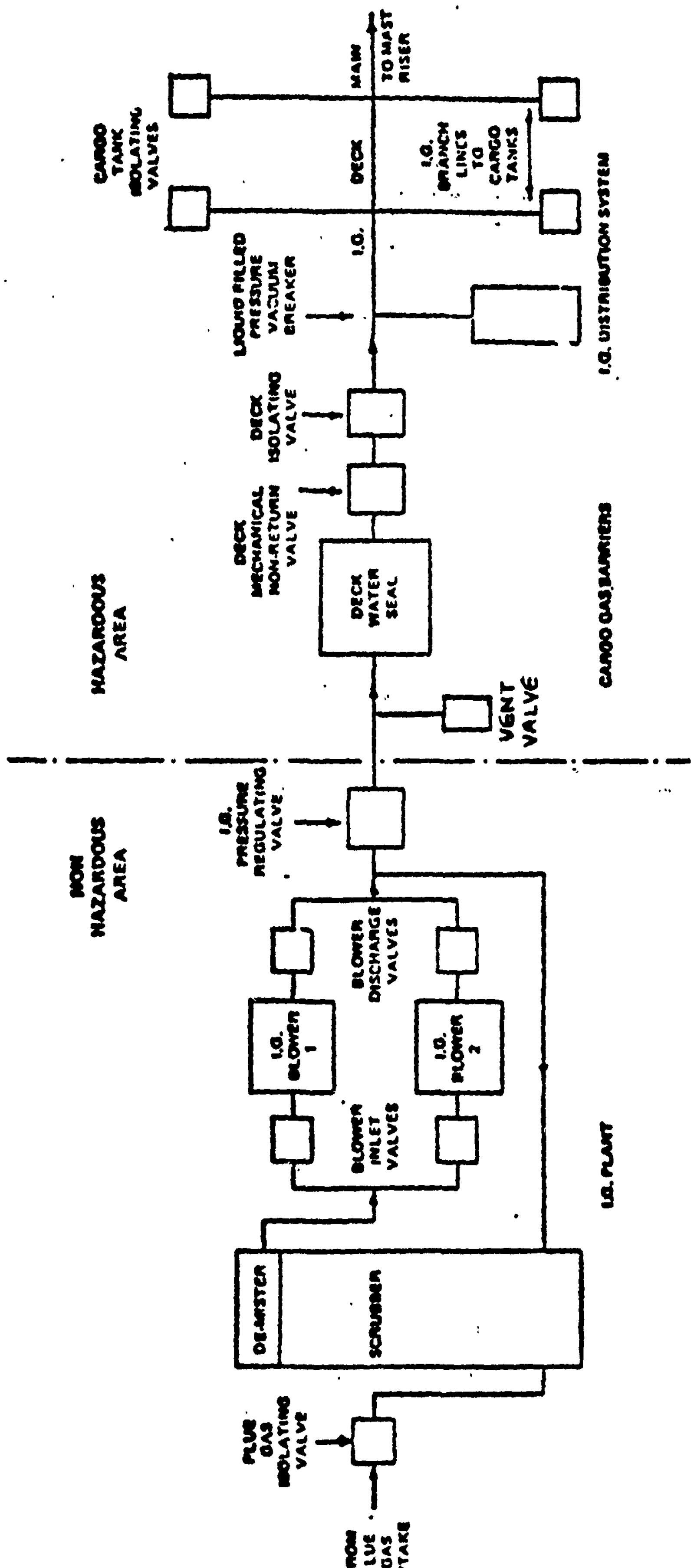


Figure 6 A typical arrangement for an inert gas system

3 FUNCTION AND DESIGN CONSIDERATIONS

This section addresses itself to inert flue gas systems. The design of systems other than inert flue gas systems should take into account, whenever applicable, the general principles outlined in this section.

3.1 Description of an inert flue gas system

3.1.1 A typical arrangement for an inert flue gas system is shown in figure 6. It consists of flue gas isolating valves located at the boiler uptake points through which passes hot, dirty gases to the scrubber and demister. Here the gas is cooled and cleaned before being piped to blowers which deliver the gas through the deck water seal, the non-return valve, and the deck isolating valve to the cargo tanks. A gas pressure regulating valve is fitted downstream of the blowers to regulate the flow of gases to the cargo tank. A liquid filled pressure vacuum breaker is fitted to prevent excessive pressure or vacuum from causing structural damage to cargo tanks. A vent is fitted between the deck isolating/non-return valve and the gas pressure regulating valve to vent any leakage when the plant is shut down.

3.1.2 For delivering inert gas to the cargo tanks during cargo discharge, de-ballasting, tank cleaning and for topping up the pressure of gas in the tank during other phases of the voyage, an inert gas deck main runs forward from the deck isolating valve for the length of the cargo deck. From this inert gas main, inert gas branch lines lead to the top of each cargo tank.

3.2 Function of inert gas scrubber

3.2.1 The purpose of the scrubber is to cool the flue gas and remove most of the sulphur dioxide and particulate soot. All three actions are achieved by direct contact between the flue gas and large quantities of sea water.

3.2.2 Before entering the bottom of the scrubbing tower the gas is cooled by being passed either through a water spray, or bubbled through a water seal. Such a seal may also serve as the additional safety device to prevent any leakage of gas from the boiler uptake when the scrubber is opened up for inspection or maintenance.

3.2.3 In the scrubbing tower itself the gas moves upwards through downward flowing water. For maximum contact between gas and water, several layers made up of one or more of the following arrangements may be fitted:

.1 spray nozzles;

.2 trays of "packed" stones or plastic chippings;

.3 perforated "impingement" plates;

.4 venturi nozzles and slots.

3.2.4 At the top of or downstream of the scrubbing tower, water droplets are removed by one or more demisters which may be polypropylene mattresses or cyclone dryers.

Designs of individual manufacturers vary considerably.

3.3 Design considerations for inert gas scrubber

3.3.1 The scrubber should be of a design related to the type of tanker, cargoes and combustion control equipment of the inert gas supply source and be capable of dealing with the quantity of inert gas required by Regulation 62 at the designed pressure differential of the system.

3.3.2 The performance of the scrubber at full gas flow should be such as to remove at least 90 per cent of sulphur dioxide and to remove solids effectively. In product carriers more stringent requirements may be needed for product quality.

3.3.3 The internal parts of the scrubber should be constructed in corrosion resistant materials in respect of the corrosive effect of the gas. Alternatively, the internal parts may be lined with rubber, glass fibre epoxy resin or other equivalent material, in which case the flue gases may require to be cooled before they are introduced into the lined sections of the scrubber.

3.3.4 Adequate openings and sight glasses should be provided in the shell for inspection, cleaning and observational purposes. The sight glasses should be reinforced to withstand impact and be of a heat resisting type. This may be achieved by the use of double glazing.

3.3.5 The design should be such that under normal conditions of trim and list the scrubber efficiency will not fall by more than 3 per cent, nor will the temperature rise at the gas outlet exceed the designed gas outlet temperature by more than 3°C.

3.3.6 The location of the scrubber above the load waterline should be such that the drainage of the effluent is not impaired when the ship is in the fully loaded condition.

3.4 Function of inert gas blowers

3.4.1 Blowers are used to deliver the scrubbed flue gas to the cargo tanks. Regulation 62(c)(i) requires that at least two blowers shall be provided which together shall be capable of delivering inert gas to the cargo tanks at a rate of at least 125 per cent of the maximum rate of discharge capacity of the ship expressed as a volume.

3.4.2 In practice, installations vary from those which have one large blower and one small blower, whose combined total capacity complies with Regulation 62, to those in which each blower can meet this requirement. The advantage claimed for the former is that it is convenient to use a small capacity blower when topping up the gas pressure in the cargo tanks at sea; the advantage claimed for the latter is that if either blower is defective the other one is capable of maintaining a positive gas pressure in the cargo tanks without extending the duration of the cargo discharge.

3.5 Design considerations for inert gas blowers

3.5.1 The blower casing should be constructed in corrosion resistant material or alternatively of mild steel but then its internal surfaces should be stove-coated, or lined with rubber or glass fibre epoxy resin or other equivalent material to protect it from the corrosive effect of the gas.

3.5.2 The impellers should be manufactured in a corrosion resistant material. Aluminium bronze impellers should be stress relieved after welding. All impellers should be tested by overspeeding to 20 per cent above the design running speed of the electric motor or 10 per cent above the speed at which the overspeed trip of the turbine would operate, whichever is applicable.

3.5.3 Substantial drains, fitted with adequate water seals, should be provided in the casing to prevent damage by an accumulation of water. The drains should be in accordance with the provisions of 3.15.4.

3.5.4 Means should be provided such as fresh water washing to remove the build up of deposits which would cause vibration during blower operation.

3.5.5 The casing should be adequately ribbed to prevent panting and should be so designed and arranged as to facilitate the removal of the rotor without disturbing major parts of the inlet and outlet gas connexions.

3.5.6 Sufficient openings in the casing should be provided to permit inspection.

3.5.7 Where separate shafts are provided for the prime mover and the blower, a flexible coupling between these shafts should be provided.

3.5.8 When roller or ball bearings are used, due regard should be paid to the problem of brinelling and the method of lubrication. The type of lubrication chosen, i.e. oil or grease, should have regard to the diameter and rotational speed of the shaft. If sleeve bearings are fitted then resilient mountings are not recommended.

3.5.9 The blower pressure/volume characteristics should be matched to the maximum system requirements. The characteristics should be such that in the event of the discharge of any combination of cargo tanks at the discharge rate indicated in 3.4, a minimum pressure of 200 millimetres water gauge is maintained in any cargo tank after allowing for pressure losses due to:

.1 the scrubber tower and demister;

.2 the piping conveying the hot gas to the scrubbing tower;

.3 the distribution piping downstream of the scrubber;

.4 the deck water seal;

.5 the length and diameter of the inert gas distribution system.

3.5.10 When both blowers are not of equal capacity the pressure/volume characteristics and inlet and outlet piping should be so matched that if both blowers can be run in parallel, they are able to develop their designed outputs. The arrangements should be such as to prevent the blower on load from motoring the blower that is stopped or has tripped out.

3.5.11 If the prime mover is an electric motor then it should be of sufficient power to ensure that it will not be overloaded under all possible operating conditions of the blower. The overload power requirement should be based on the blower inlet conditions of $-5^{\circ}C$ at -400 millimetres water gauge and outlet conditions of $0^{\circ}C$ and atmospheric pressure. Arrangements, should be provided, if necessary, to maintain the windings in a dry condition during the inoperative period.

3.6 Function of non-return devices

3.6.1 The deck water seal and mechanical non-return valve together form the means of automatically preventing the backflow of cargo gases from the cargo tanks to the machinery space or other safe area in which the inert gas plant is located.

3.6.2 Deck water seal (see Regulation 62(j))

This is the principal barrier. A water seal is fitted which permits inert gas to be delivered to the deck main but prevents any backflow of cargo gas even when the inert gas plant is shut down. It is vital that a supply of water is maintained to the seal at all times, particularly when the inert gas plant is shut down. In addition drains should be led directly overboard and should not pass through the machinery spaces. There are different designs but one of three principal types may be adopted.

.1 Wet type

This is the simplest type of water seal. When the inert gas plant is operating, the gas bubbles through the water from the submerged inert gas inlet pipe, but if the tank pressure exceeds the pressure in the inert gas inlet line the water is pressed up into this inlet pipe and thus prevents backflow. The drawback of this type of water seal is that water droplets may be carried over with the inert gas which, although it does not impair the quality of the inert gas, could increase corrosion. A demister should, therefore, be fitted in the gas outlet from the water seal to reduce any carry-over. Figure 7 shows an example of this type.

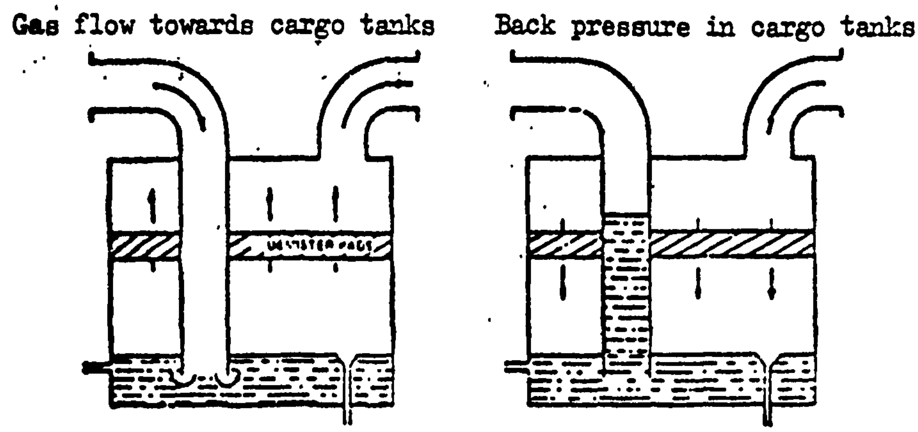


Figure 7. Deck water seal - wet type

.2 **Semi-dry type**

Instead of bubbling through the water trap the inert gas flow draws the sealing water into a separate holding chamber by venturi action thus avoiding or at least reducing the amount of water droplets being carried over. Otherwise it is functionally the same as wet type. **Figure** 8 **shows an example of this type.**

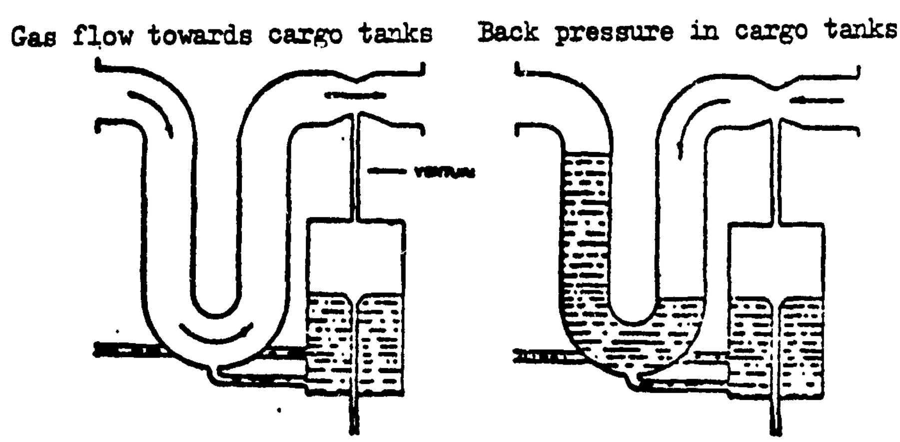


Figure 8. **Deck** water seal - semi dry type

.3 Dry type

In this type the water is drained when the inert gas plant is in operation (gas flowing to the tanks) and filled with water when the inert gas plant is either shut down or the tank pressure exceeds the inert gas blower discharge pressure. Filling and drainage are performed by automatically operated valves controlled by the levels in the water seal and drop tanks and by the operating state of the blowers. The advantage of this type is that water carry-over is prevented. The drawback could be the risk of failure of the automatically controlled valves which may render the water seal ineffective. Figure 9 shows an example of this type.

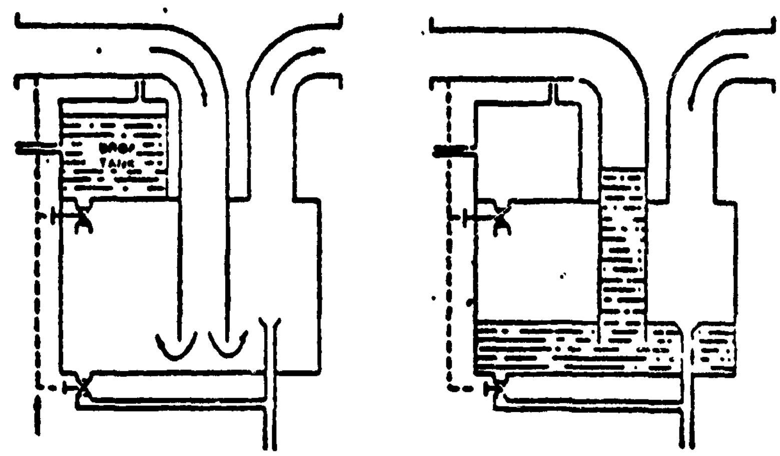


Figure 9. Deck water seal - dry type

3.6.3 Deck mechanical non-return valve and deck isolating valve.

As a further precaution to avoid any backflow of gas from the cargo tanks, and to prevent any backflow of liquid which may enter the inert gas main if the cargo tanks are overfilled, Regulation 62(j)(viii) requires a mechanical non-return valve, or equivalent, which should be fitted forward of the deck water seal and should operate automatically at all times.

This valve should be provided with a positive means of closure or, alternatively, a separate deck isolating valve fitted forward of the non-return valve, so that the inert gas deck main may be isolated from the non-return devices. The separate isolating valve has the advantage of enabling maintenance work to be carried out on the non-return valve.

3.6.4 Inert gas vent valve (see Regulation 62(j)(ix))

This valve should be opened when the inert gas plant is shut down to prevent leakage past the non-return devices from building up any pressure in the inert gas line between the gas pressure regulating valve and these non-return devices.

3.7 Design considerations for non-return devices

3.7.1 The material used in the construction of the non-return devices should be resistant to fire and to the corrosive attack from acids formed by the gas. Alternatively low carbon steel protected by a rubber lining or coated with glass fibre epoxy resin or equivalent material may be used. Particular attention should be paid to the gas inlet pipe to the water seal.

3.7.2 The deck water seal should present a resistance to backflow of not less than the pressure setting of the pressure/vacuum breaking device on the inert gas distribution system and should be so designed as to prevent the backflow of gases under any foreseeable operating conditions.

3.7.3 The water in the deck seal should be maintained by a regulating flow of clean water through the deck seal reservoir.

3.7.4 Sight glasses and inspection openings should be provided on the deck seal to permit satisfactory observation of the water level during its operation and to facilitate a thorough survey. The sight glasses should be reinforced to withstand impact.

3.7.5 Any drains from the non-return devices should incorporate a water seal in accordance with 3.15.4 and should comply generally with 3.16.

3.8 Inert gas distribution system

3.8.1 The inert gas distribution system, together with the cargo tank venting system, where applicable, has to provide:

.1 means of delivering inert gas to the cargo tanks during discharge, de-ballasting and tank cleaning operations, and for topping up the pressure of gas in the tank;

.2 means of venting tank gases to atmosphere during cargo loading and ballasting;

.3 additional inlet or outlet points for inerting, purging and gas-freeing;

.4 means of isolating individual tanks from the inert gas main for gas-freeing (see 3.12.4);

.5 means of protecting tanks from excessive pressure or vacuum.

3.8.2 A large variety of designs and operational procedures may be used to meet these interrelated requirements. In 3.9 are considered some of the major design options and their more important operational consequences: further advice on operational precautions is given in section 5.

3.9 Design considerations for valves and pipework in inert gas systems

3.9.1 The flue gas uptake point should be selected such that the gas is not too hot for the scrubber, or causes hard deposits on the flue gas isolating valves. It should not be so close to the uptake outlet that air can be drawn into the system. When boilers are fitted with rotary air heaters, the offtake point should be before the air heater inlet.

3.9.2 The materials used for flue gas isolating valves should take into account the temperature of gas at the offtake. Cast iron is acceptable for temperatures below 220°C. Valves exposed to a temperature exceeding 220°C should be made from a material not only compatible with the temperature but also resistant to the corrosive effect of stagnant flue gases.

3.9.3 Flue gas isolating valves should be provided with facilities to keep the seatings clear of soot unless the valve is designed to close with a seat cleaning action. Flue gas isolating valves should also be provided with air sealing arrangements.

3.9.4 If expansion bellows are considered necessary they should have a smooth internal sleeve and preferably be mounted so that the gas flow through them is vertical. They should be constructed of material resistant to stagnant damp acidic soot.

3.9.5 The pipework between the flue gas isolating valve and the scrubber should be made from heavy gauge steel resistant to corrosion and so arranged as to prevent the accumulation of damp acidic soot by the avoidance of unnecessary bends and branches.

3.9.6 The inlet piping to the scrubber should be so arranged as to permit positive isolation from the flue gases prior to gas-freeing the scrubber for entry for maintenance purposes. This may be accomplished by the removal of a suitable length of pipe section and blanking, by spectacle flanges or by a water seal which would prevent any leakage of gas from the boiler when the flue gas isolating valve is shut and the scrubber is opened up for inspection and maintenance. In the event that the drainage of the water seal is itself required for inspection purposes then isolation should be achieved either by removal of the suitable lengths of pipe sections and blanking, or by the use of spectacle flanges.

3.9.7 The gas outlet piping from the scrubber to the blowers and recirculating lines should be made from steel suitably coated internally.

3.9.8 Suitable isolating arrangements should be incorporated in the inlet and outlet of each blower to permit safe overhaul and maintenance of a blower while permitting the use of the inert gas system using the other blower

3.9.9 The regulating valve required by Regulation 62(i)(i) should be provided with means to indicate whether the valve is open or shut. Where the valve is used to regulate the flow of inert gas it should be controlled by the inert gas pressure sensed between the deck isolating valve and the cargo tanks.

3.9.10 Deck lines should be of steel and be so arranged as to be self draining and should be firmly attached to the ship's structure with suitable arrangements to take into account movement due to heavy weather, thermal expansion and flexing of the ship.

3.9.11 The diameter of the inert gas main, valves and branch pipes should take account of the system requirements detailed in 3.5.9. To avoid excessive pressure drop, the inert gas velocity should not exceed 40 m/s in any section of the distribution system when the inert gas system is operating at its maximum capacity. If the inert gas main is used for venting during loading, other factors may need to be taken into consideration as developed in Regulation 58 of Chapter II-2 of the 1974 SOLAS Convention for cargo tank venting systems.

3.9.12 All pressure and vacuum relief openings should be fitted with flame screens with easy access for cleaning and renewal. The flame screens should be at the inlets and the outlets of any relief device and be of robust construction sufficient to withstand the pressure of gas generated at maximum loading and during ballasting operations while presenting minimum resistance.

3.10 <u>Gas pressure regulating valves and recirculating arrangements</u>

3.10.1 Pressure control arrangements should be fitted to fulfil two functions:

.1 to prevent automatically any backflow of gas in the event of either a failure of the inert gas blower, scrubber pump, etc., or when the inert gas plant is operating correctly but the deck water seal and mechanical non-return valve have failed and the pressure of gas in the tank exceeds the blower discharge pressure, e.g. during simultaneous stripping and ballasting operations;

.2 to regulate the flow of inert gas to the inert gas deck main.

3.10.2 A typical arrangement by which 3.10.1.2 can be achieved is as follows:

Systems with automatic pressure control and a gas recirculating line. These installations permit control of inert gas pressure in the deck main without having to adjust the inert gas blower speed. Gas not required in the cargo tanks is recirculated to the scrubber or vented to atmosphere. Gas pressure regulating valves are fitted in both the main and recirculating lines; one is controlled by a gas pressure transmitter and regulator, while the other may be controlled either in a similar manner or by a weight operated valve. The pressure transmitter is sited downstream of the deck isolating valve; this enables a positive pressure to be maintained in the cargo tanks during discharge. However, it does not necessarily ensure that the scrubber is not overloaded during inerting and purging operations.

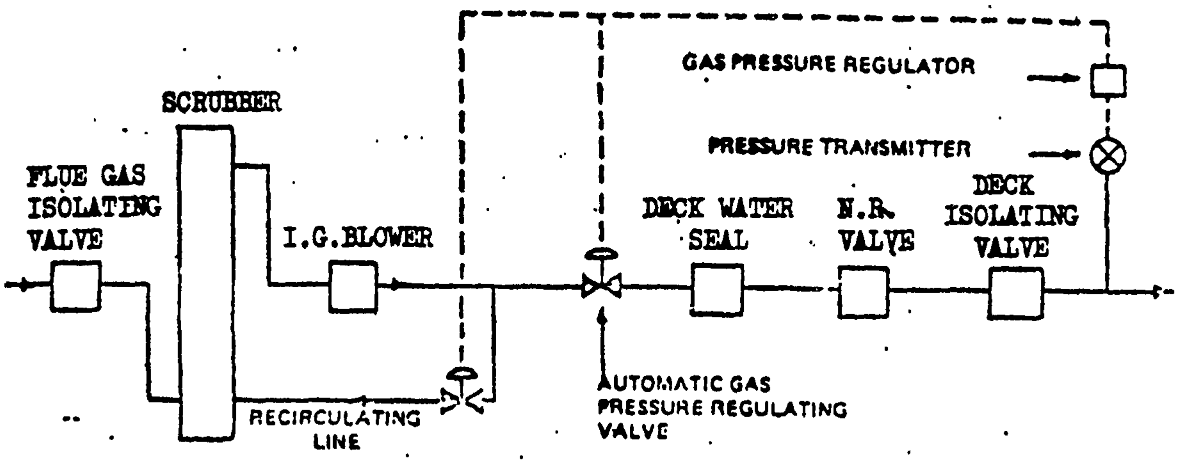


Figure 10. Typical automatic pressure control system

Alternative methods which comply with Regulation 62(i)(i) may be considered.

3.11 Arrangements for inerting, purging and gas-freeing (Regulation 62(m))

3.11.1 The principles of dilution and displacement have already been described in 2.6.3 and 2.6.4. Their application to specific installations depends on a variety of factors, including:

.1 the results of laboratory tests;

.2 whether or not purging of hydrocarbon gas is required in every tank on every voyage; and

.3 the method of venting cargo tank vapours.

3.11.2 Several arrangements are possible. One feature which should be common to all is that the inlet and outlet points should be so located that efficient gas replacement can take place throughout the tank.

There are three principal arrangements:

Arrangement	Inlet point	Outlet point	Principle
I	top	top	dilution
II	bottom	top	dilution
III	top	bottom	displacement or dilution

It will be noted that all three arrangements can be used for inerting, purging and gas freeing, and that a particular ship design may incorporate more than one arrangement.

3.11.3 **Arrangement I**

Gases are both introduced and vented from the top of the tank. This is the simplest arrangement. Gas replacement is by the dilution method. The incoming gas should always enter the tank in such a way as to achieve maximum penetration and thorough mixing throughout the tank. Gases can be vented through a vent stack on each tank or through a common vent main. (see figure 11)

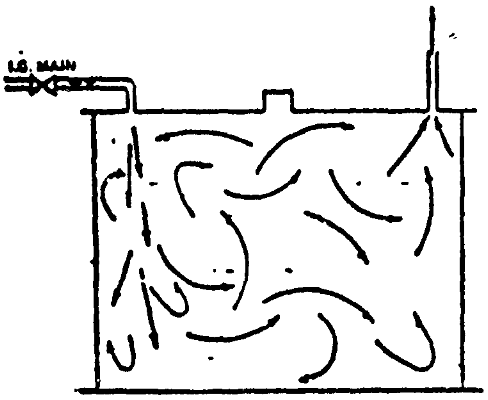


Figure 11. Dilution (I)

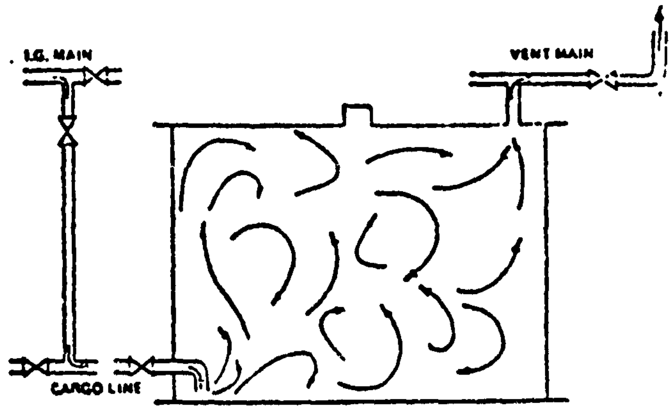


Figure 12. Dilution (II)

3.11.4 **Arrangement II**

Gas is introduced at the bottom of the tank and vented from the top. Gas replacement is by the dilution method. This arrangement introduces the gas through a connexion between the inert gas deck main (just forward of the mechanical non-return valve) and the bottom cargo lines (see figure 12). A special fixed gas-freeing fan may also be fitted. Exhaust gas may be vented through individual vent stacks or, if valves are fitted to isolate each cargo tank from the inert gas main, through this main to the mast riser or high velocity vent.

3.11.5 **Arrangement III**

Gas is introduced at the top of the tank and discharged from the bottom. This arrangement permits the displacement method (see figure 13), although the dilution method may predominate if the density difference between the incoming and existing gases is small or the gas inlet velocity is high (see figure 14). The inert gas inlet point is often led horizontally into a tank hatch in order to minimize turbulence at the interface. The outlet point is often a specially fitted purge pipe extending from within 1 metre of the bottom plating to 2 metres above deck level (to minimize the amount of vapour at deck level).

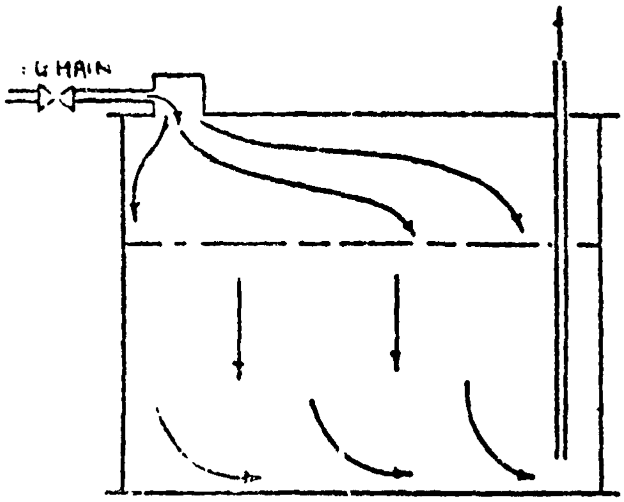


Figure 13. Displacement (III)

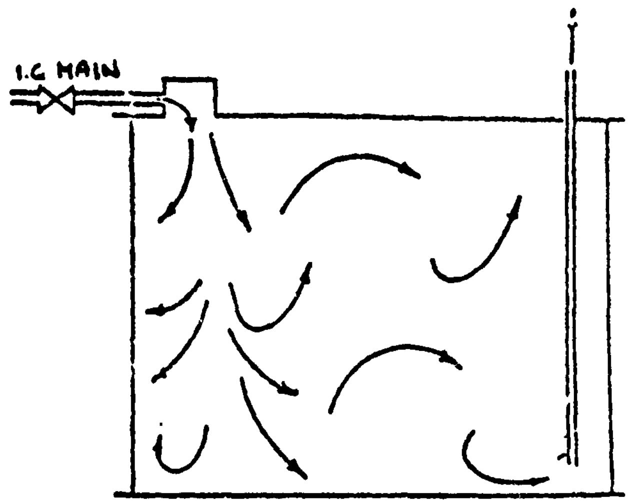


Figure 14. Dilution (III)

3.12 <u>Isolation of cargo tanks from the inert gas deck main</u> (Regulation 62(k))

3.12.1 For gas-freeing and tank entry some valve or blanking arrangement is always fitted to isolate individual cargo tanks from the inert gas deck main.

3.12.2 The following factors should be considered in choosing a suitable arrangement:

- .1 protection against gas leakage or incorrect operation during tank entry;
- .2 ease and safety of use;
- .3 facility to use the inert gas main for routine gas-freeing operations;
- .4 facility to isolate tanks for short periods for the regulation of tank pressures and manual ullaging;
- .5 protection against structural damage due to cargo pumping and ballasting operations when a cargo tank is inadvertently isolated from the inert gas main.

3.12.3 In no case should the arrangement prevent the proper venting of the tank.

3.12.4 Some examples of arrangements in use are shown in figure 15.

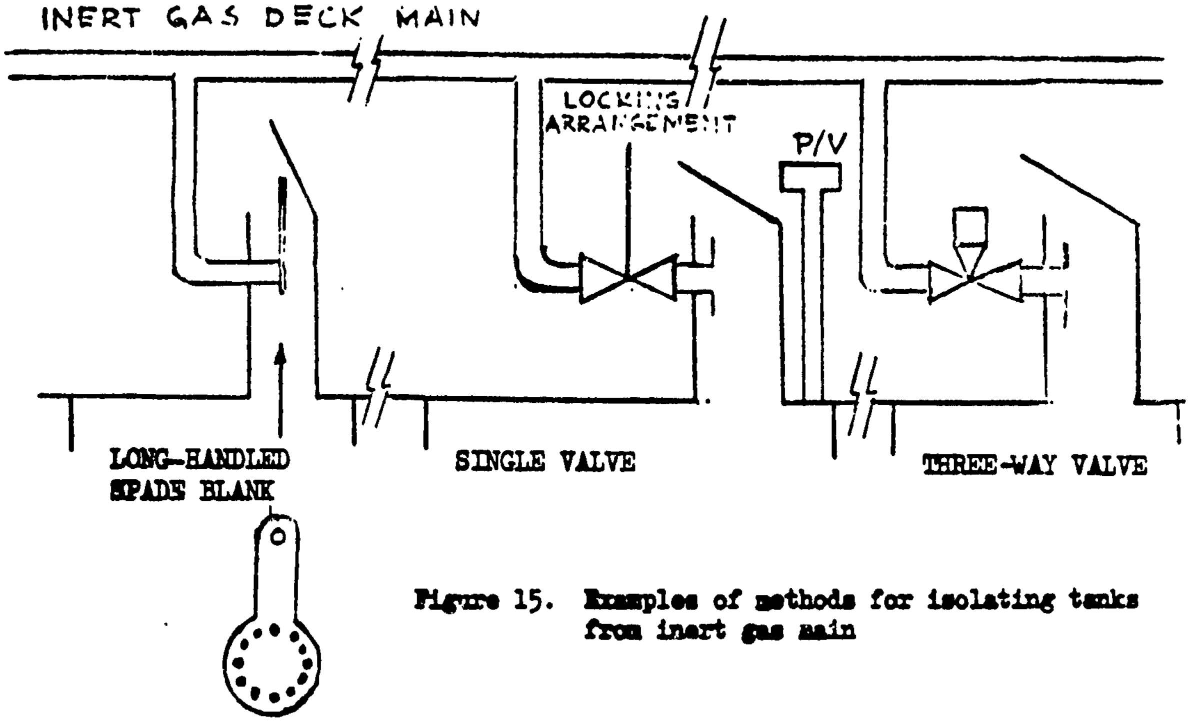


Figure 15. Examples of methods for isolating tanks from inert gas main

3.13 Liquid-filled pressure-vacuum breakers

3.13.1 One or more liquid-filled pressure-vacuum breakers should be fitted, unless pressure-vacuum valves having the capacity to prevent excessive pressure or vacuum in accordance with requirements of Regulation 62(n) are fitted.

3.13.2 These devices require little maintenance, but will only operate at the required pressure if they are filled to the correct level with liquid of the correct density. Either a suitable oil or a freshwater/glycol mixture should be used to prevent freezing in cold weather. Evaporation, ingress of seawater, condensation and corrosion should be taken into consideration and adequately compensated for. In heavy weather, the pressure surge caused by the motion of liquid in the cargo tanks may cause the liquid of the pressure-vacuum breaker to be blown out (see figure 16).

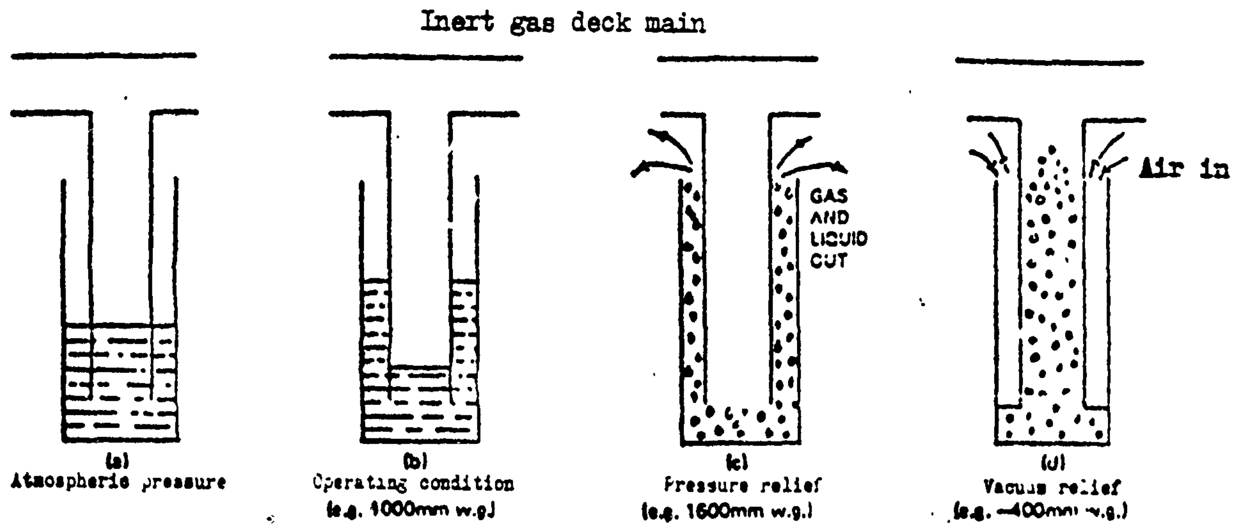


Figure 16. Principles of liquid filled pressure-vacuum breakers

3.13.3 The designer should ensure that the characteristics of the deck water seal, pressure-vacuum breakers and pressure-vacuum valves and the pressure settings of the high and low inert gas deck pressure alarms are compatible. It is also desirable to check that all pressure-vacuum devices are operating at their designed pressure settings.

3.14 Instrumentation and alarms (Regulation 62(p) to (s))

3.14.1 Certain fixed and portable instruments are required for the safe and effective operation of an inert gas system. It is desirable that all instruments should be graduated to a consistent system of units.

3.14.2 Clear instructions should be provided for operating, calibrating and testing all instruments and alarms. Suitable calibration facilities should be provided.

3.14.3 All instrumentation and alarm equipment required in compliance with Regulation 62 should be suitably designed to withstand supply voltage variation, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered on board ships.

3.14.4 The arrangement of scrubber instrumentation and alarm should be as follows:

.1 The water flow to the scrubber should be monitored either by a flow meter or by pressure gauges. An alarm should be initiated when the water flow drops below the designed flow requirements by a predetermined amount and the inert gas blowers should be stopped automatically in the event of a further reduction in the flow. The precise setting of the alarm and shutdown limits should be related to individual scrubber designs and materials.

.2 The water level in the scrubber shall be monitored by a high water level alarm (see Regulation 62(s)(i)(2)). This alarm should be given when pre-determined limits are reached and the scrubber pump shut down when the level rises above set limits. These limits should be set having regard to the scrubber design and flooding of the scrubber inlet piping from the boiler uptakes.

.3 The inert gas temperature at the discharge side of the gas blowers shall be monitored. An alarm should be given when the temperature reaches 65°C and automatic shut down of the inert gas blowers should be arranged if the temperature reaches 75°C.

.4 If a precooler is necessary at the scrubber inlet to protect coating materials in the scrubber, the arrangements for giving an alarm in .3 above should apply to the outlet temperature from the precooler.

.5 To monitor the scrubber efficiency, it is recommended that the cooler water inlet and outlet temperatures, and the scrubber differential pressures are indicated.

.6 All sensing probes, floats and sensors required to be in contact with the water and gas in the scrubber should be made from materials resistant to acidic attack.

3.14.5 For the deck water seal, an alarm should be given when the water level falls by a pre-determined amount but before the seal is rendered ineffective. For certain types of deck water seals, such as the dry type, the water level alarm may require to be suppressed when inert gas is being supplied to the inert gas distribution system.

3.14.6 The pressure of the inert gas in the inert gas main shall be monitored (see Regulation 62(s)(i)(9)). An alarm should be given when the pressure reaches the set limit. The set limit should be set having regard to the design of cargo tanks, mechanical non-return valve and deck water seal.

3.14.7 The arrangement for oxygen analyser, recorder and indicating equipment should be as follows:

.1 The sampling point for the oxygen analyser and recorder unit should be located at a position in the pipework after the blowers and before the gas pressure regulating valve specified in Regulation 62. At the chosen position turbulent flow conditions should prevail at all outputs of the blowers. The sample point should be easily accessible and be provided with suitable air or steam cleaning connexions.

.2 The sampling probe should incorporate a dust filter in accordance with the instrument manufacturer's advice. The probe and filter should be capable of being withdrawn and cleaned or renewed as necessary.

.3 The sensing pipe from the sampling probe to the oxygen analyser should be so arranged that any condensation in the sensing pipeline does not prevent the gas sample reaching the oxygen analyser. Joints in the pipeline should be kept to a minimum to prevent the ingress of air.

.4 Any coolers required in the sensing pipes should be installed at the coldest point in the system; alternatively, in certain instances it may be prudent to heat the sensing pipes to prevent condensation.

.5 The position of the analyser should be chosen so that it is protected from heat and adverse ambient conditions, but it should be placed as close as practicable to the sampling point to reduce the time between the extraction of a sample and its analysis to a minimum.

.6 The recording unit and repeater indication required by Regulation 62(p) should not be located in positions subject to heat and undue vibration.

.7 The resistance of the connecting cables between the analyser and the recorder should be in accordance with the instrument manufacturers instruction.

.8 The oxygen analyser should have an accuracy of ± 1 per cent of the full scale deflection of the indicator.

.9 Dependent on the principle of measurement, fixed zero and/or span calibration arrangements should be provided in the vicinity of the oxygen analyser fitted with suitable connexions for portable analysers.

3.14.8 A sampling point should be provided between the automatic gas pressure regulating valve and the deck water seal for use with portable instruments.

3.14.9 The inert gas pressure sensor and recorder should obtain the signal from a point in the inert gas main between the deck isolating/non-return valve and the cargo tanks (see Regulation 62(p)(i)).

3.14.10 When the pressure in the inert gas main forward of the non-return devices falls below 50 millimetres water gauge means shall be provided to give an audible alarm or to shut down the main cargo pumps automatically (see Regulation 62(s)(vii)).

3.14.11 The alarms required by Regulation 62(s)(i)(7) should be given on the navigating bridge and in the machinery space.

3.14.12 In accordance with Regulation 62(q) portable instruments shall be provided for measuring oxygen and flammable concentration. With regard to the hydrocarbon vapour meter, it should be borne in mind that meters working on the catalytic filament principle are unsuitable for measuring hydrocarbon concentration in oxygen deficient atmospheres. Furthermore, meters using this principle cannot measure concentrations of hydrocarbon vapours above the lower flammable limit. It is, therefore, advisable to use meters using a principle which is not affected by oxygen deficiency and which are capable of measuring hydrocarbon concentration in and above the flammable range. For measuring below the lower flammable limit, provided sufficient oxygen is present, the catalytic filament meter is suitable.

3.14.13 All metal parts of portable instruments and sampling tubes requiring to be introduced into tanks should be securely earthed to the ship structure while the instruments and sampling tubes are being used. These portable instruments should be of an intrinsically safe type.

3.14.14 Sufficient tubing etc. should be provided to enable fully representative sampling of a cargo tank atmosphere to be obtained.

3.14.15 Suitable openings should be provided in cargo tanks to enable fully representative samples to be taken from each tank. Where tanks are subdivided by complete or partial wash bulkheads, additional openings should be provided for each such subdivision.

3.15 <u>Effluent and drain piping</u>

3.15.1 The effluent piping from scrubbers and deck water seal drain pipes, where fitted, should be of corrosion resistant material, or of carbon steel suitably protected internally against the corrosive nature of the fluid.

3.15.2 The scrubber effluent pipe and deck water seal drain pipe, where fitted, should not be led to a common drain pipe and the deck seal drain should be led clear of the engine room and any other gas safe space.

3.15.3 Piping made in glass reinforced plastic of acceptable manufacture, substantial thickness, pressure tested and adequately supported, may be acceptable for effluent piping from scrubbers under the following conditions:

.1 The effluent lines should, as far as possible, be led through cofferdams or ballast tanks and be in accordance with the load line regulations in force.

.2 Where effluent lines are led through machinery spaces the arrangements should include:

.2.1 a valve fitted to a stub piece at the shell and actuated both from inside and outside the machinery space by pneumatic or hydraulic means led through steel piping. The valve should close automatically in the event of failure of the operating media. The valve should have a a position indicator. This valve is to be closed at all times when the plant is not in operation as well as in the event of a fire in the machinery space. Suitable instructions to this effect are to be given to the master;

.2.2 a flap type non-return valve;

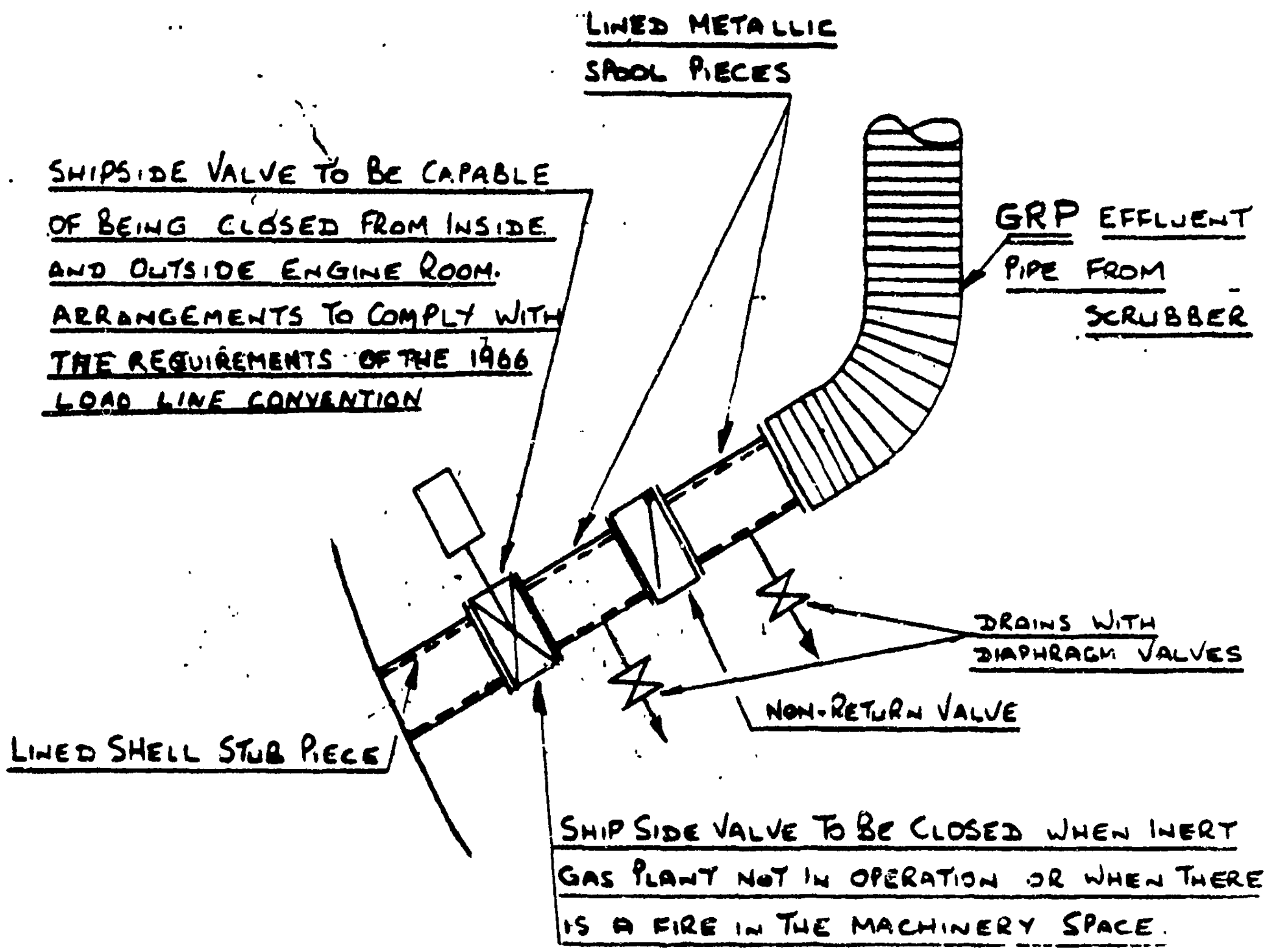
.2.3 a short length of steel pipe, or spool piece, lined internally and fitted between the valve referred to in .1 above and the non-return valve referred to in .2 above; this is to be fitted with a 12.5 millimetre diameter flanged drain branch pipe and valve;

.2.4 a further spool piece fitted inboard of, and adjacent to, the non-return valve referred to in .2 above, similarly fitted with a drain.

(Note: the purpose of this arrangement is to enable the tightness of the valves and non-return valves referred to in .1 and .2 above to be checked and to facilitate the removal of the non-return valve for examination and replacement.)

.2.5 Means should be provided outside the machinery space for stopping the scrubber pump.

A suitable arrangement is illustrated in figure 17.



SCRUBBER SEA WATER SUPPLY PUMPS TO BE CAPABLE OF BEING STOPPED FROM OUTSIDE ENGINE ROOM

Figure 17

3.15.4 A water seal in the shape of a 'U' bend at least 2 metres in depth should be fitted at least 2 metres below the equipment to be drained. Means should be provided for draining the lowest point of the bend. In addition the seal should be adequately vented to a point above the water level in the scrubber or deck water seal.

3.15.5 The diameter of the effluent and drain pipes should be adequate for the duties intended and the pipe run should be self draining from the water seal referred to in 3.15.4.

3.16 Seawater service

3.16.1 It is advisable that the main supply of water to the inert gas scrubber as required in Regulation 62(f)(i) should be from an independent pump. The alternative source of supply of water may be from another pump such as the sanitary, fire, bilge and ballast pumps provided that the quantity of water required by the inert gas scrubber is readily available and the requirements of other essential services are not thereby impaired.

3.16.2 The requirement for two separate pumps to be capable of supplying water to the deck water seal (see Regulation 62(j)(iii)) can be met by any of the pumps referred to under alternative source of supply in 3.16.1 subject to the same provisions applying as are recorded in that paragraph.

3.16.3 The pumps supplying water to the scrubber and the deck water seal should be such as to provide the required throughput of water at light draught conditions. The quantity of water at all other draught conditions should not flood the scrubber or increase the gas flow resistance excessively.

3.16.4 Loops in the piping of the deck water seal to prevent the backflow of hydrocarbon vapour or inert gas should be positioned outside the machinery space and suitably protected against freezing, for example by steam tracing. With reference to the deck water seal arrangement, provisions should be made to prevent a pneumatically controlled system from freezing (see Regulation 62(j)(v) and (vi)).

3.16.5 Vacuum breakers provided to prevent the water loops being emptied should vent to a position on the open deck.

4 OPERATION OF INERT GAS PLANT

4.1 Though flue gas systems differ in detail certain basic principles remain the same. These are:

.1 starting up the inert gas plant;

.2 shutting down the inert gas plant;

.3 safety checks when the inert gas plant is shut down.

In all cases the manufacturer's detailed instructions should be followed.

4.2 Start-up procedures should be as follows:

.1 Ensure boiler is producing flue gas with an oxygen content of 5 per cent by volume or less (for existing ships 8 per cent by volume or, wherever practicable, less).

.2 Ensure that power is available for all control, alarm and automatic shutdown operations.

.3 Ensure that the quantity of water required by the scrubber and deck water seal is being maintained satisfactorily by the pump selected for this duty.

.4 Test operation of the alarm and shutdown features of the system dependent upon the throughput of water in the scrubber and deck seal.

.5 Check that the gas-freeing fresh air inlet valves where fitted are shut and the blanks in position are secure.

.6 Shut off the air to any air sealing arrangements for the flue gas isolating valve.

.7 Open the flue gas isolating valve.

.8 Open the selected blower suction valve. Ensure that the other blower suction and discharge valves are shut unless it is intended to use both blowers simultaneously.

.9 Start the blower.

.10 Test blower "failure" alarm.

.11 Open the blower discharge valve.

.12 Open the recirculating valve to enable plant to stabilize.

.13 Open the flue gas regulating valve.

.14 Check that oxygen content is 5 per cent by volume or less, (for existing ships 8 per cent by volume or, wherever practicable, less) then close the vent to atmosphere between the gas pressure regulating valve and the deck isolating valve.
Note: Some oxygen analysers require as much as two hours to stabilize before accurate readings can be obtained.

.15 The inert gas system is now ready to deliver gas to the cargo tanks.

4.3 Shutdown procedures should be as follows:

.1 When all tank atmospheres have been checked for an oxygen level of not more than 8 per cent and the required in-tank pressure has been obtained, shut the deck isolating/non-return valve.

.2 Open vent to atmosphere between the gas pressure regulating valve and the deck isolating/non-return valve.

.3 Shut the gas pressure regulating valve.

.4 Shut down the inert gas blower.

.5 Close the blower suction and discharge valve. Check that the drains are clear. Open the water washing system on the blower while it is still rotating with the power supply of the driving motor turned off, unless otherwise recommended by the manufacturer. Shut down the water washing plant after a suitable period.

.6 Close the flue gas isolating valve and open the air sealing system.

.7 Keep the full water supply on the scrubber tower in accordance with the manufacturer's recommendation.

.8 Ensure that the water supply to the deck water seal is running satisfactorily, that an adequate water seal is retained and that the alarm arrangements for it are in order.

4.4 Safety checks when inert gas plant is shutdown should be as follows:

.1 The water supply and water level in the deck seal should be ascertained at regular intervals, at least once per day depending on weather conditions.

.2 Check the water level in water loops installed in pipework for gas, water or pressure transducers, to prevent the backflow of hydrocarbon gases into gas safe spaces.

.3 In cold weather, ensure that the arrangements to prevent the freezing of sealing water in the deck seals, pressure vacuum breakers, etc. are in order.

.4 Before the pressure in the inerted cargo tanks drops to 100 millimetres they should be re-pressurized with inert gas.

4.5 Possible failures of inert gas system and actions to be taken include:

.1 High oxygen content which may be caused or indicated by the following conditions:

.1.1 poor combustion control at the boiler, especially under low load conditions;

.1.2 drawing air down the uptake when boiler gas output is less than the inert gas blower demand, especially under low load conditions·

.1.3 air leaks between the inert gas blower and the boiler uptake;

.1.4 faulty operation or calibration of the oxygen analyser;

.1.5 inert gas plant operating in the recirculation mode; or

.1.6 entry of air into the inert gas main through the pressure vacuum valves, mast risers etc. due to maloperation.

.2 If the inert gas plant is delivering inert gas with an oxygen content of more than 5 per cent, the fault should be traced and repaired. Regulation 62(s)(iv) requires, however, that all cargo tank operations shall be suspended if the oxygen content exceeds 8 per cent unless the quality of the gas is improved.

.3 Inability to maintain positive pressure during cargo discharge or deballasting operations which may be caused by:

.3.1 inadvertent closure of the inert gas valves:

.3.2 faulty operation of the automatic pressure control system;

.3.3 inadequate blower pressure; or

.3.4 a cargo discharge rate in excess of the blower output.

.4 The cargo discharge or deballasting should be stopped or reduced depending on whether or not the positive pressure in the tanks can be maintained while the fault is rectified.

5 APPLICATION TO CARGO TANK OPERATION

The inert gas system should be used during the full cycle of tanker operation as described in this section.

5.1 Inerting of tanks

5.1.1 Tanks that have been cleaned and gas-freed should be re-inerted preferably during the ballast voyage to allow the inert gas system to be fully tested prior to cargo handling. Purge pipes/vents should be opened to atmosphere. When the oxygen concentration of the atmosphere in the tank has fallen below 8 per cent the purge pipes/vents should be closed and the tank pressurized with inert gas.

5.1.2 During the re-inerting of a tank following a breakdown and repair of the inert gas system, non-gas-free and non-inerted tanks should be re-inerted in accordance with 5.1.1. During inerting, no ullaging, dipping, sampling or other equipment should be inserted unless it has been established that the tank is inert. This should be done by monitoring the efflux gas from the tank being inerted until the oxygen content is less than 8 per cent by volume and for such a period of time as determined by previous test records when inerting gas-free tanks to ensure that the efflux gas is fully representative of the atmosphere within the tank.

5.1.3 When all tanks have been inerted, they should be kept common with the inert gas main and maintained at a positive pressure in excess of 100 millimetres water gauge during the rest of the cycle of operation.

5.2 Discharge of water ballast

5.2.1 Before discharge of cargo tank ballast is undertaken, the following conditions should be checked:

.1 All cargo tanks are connected up to the inert gas system and all isolating valves in the deck pipework are locked open.

.2 All other cargo tank openings are shut.

.3 All valves isolating the mast risers from the inert gas system are shut.

.4 The arrangements required by Regulation 62(m)(iv)(1) are used to isolate the cargo main from the inert gas main.

.5 The inert gas plant is producing gas of an acceptable quality.

.6 The deck isolating valve is open.

5.2.2 During the deballasting operation, the oxygen content of the gas and its pressure in the inert gas main should be continuously recorded (see Regulation 62(p)(i)(1) and (2)).

5.3 Loading

When loading cargo the deck isolating valve required by Regulation 62(j)(viii) should be closed and the inert gas plant may be shut down unless other cargo tanks are being deballasted simultaneously. All openings to the cargo tanks except the connexions to the mast risers or equivalent venting arrangements should be kept closed to minimize flammable vapour on deck. Before loading commences the flame screens in the mast risers or equivalent venting arrangements should be inspected and any stop valves isolating the cargo tanks from the inert gas main locked in the open position.

5.4 Loaded condition

5.4.1 During the loaded passage a positive pressure of inert gas of at least 100 millimetres water gauge should be maintained in the cargo tanks and topping up of the pressure may be necessary. When topping up the inert gas pressure in the cargo tanks, particular attention should be paid to obtaining an oxygen concentration of 5 per cent or less in the inert gas supply before introducing the gas into the cargo tanks.

5.4.2 On motor tankers, the boiler loading may have to be increased in order that the low oxygen concentration in the inert gas supply can be achieved. It may also be necessary to restrict the output of the inert gas blowers to prevent air being drawn down the uptake during the topping up operation. If by these means inert gas of the quality defined in 5.4.1 cannot be achieved then inert gas from an alternative source of supply such as an inert gas generator might be used.

5.5 Cargo discharge

5.5.1 It may be necessary to relieve the inert gas pressure in the cargo tanks on arrival to permit manual measurement before cargo is discharged. If this is done, no cargo or ballasting operation is to be undertaken and a minimum number of small tank openings are to be uncovered for as short a time as necessary to enable these measurements to be completed.

5.5.2 The tanks should then be re-pressurized before discharge commences.

5.5.3 Cargo discharge should not be commenced until all the conditions have been checked and are in order.

5.5.4 During discharge the oxygen content and pressure of the inert gas in the inert gas main should be continuously recorded (see Regulation 62(p)(i)(1) and (2)).

5.6 Crude oil washing (see section 5 of the Crude Oil Washing Operations and Equipment Manual)

5.6.1 Before each tank is crude oil washed, the oxygen level shall be determined at a point 1 metre below the deck and at the middle region of the ullage space and neither of these determinations shall exceed 8 per cent by volume. Where tanks have complete or partial wash bulkhead, the determination should be taken from similar levels in each section of the tank. The oxygen content and pressure of the inert gas being delivered during the washing process should be continuously recorded (see Regulation 62(p)(i)(1) and (2)).

5.6.2 If, during the crude oil washing:

.1 the oxygen level of the inert gas being delivered exceeds 8 per cent by volume; or

.2 the pressure of the atmosphere in the tanks is no longer positive;

then washing must be stopped until satisfactory conditions are restored. Operators should also be guided by 4.5.2.

5.7 Ballasting of cargo tanks

The conditions for ballasting of cargo tanks are the same as those for loading in 5.3. When, however, simultaneous discharge and ballasting is adopted, then a close watch should be kept on the inert gas main pressure.

5.8 Ballast condition

5.8.1 During a ballast voyage, tanks other than those required to be gas-free for necessary tank entry should be kept inerted with the cargo tank atmosphere at a positive pressure of not less than 100 millimetres water gauge having an oxygen level not exceeding 8 per cent by volume especially during tank cleaning.

5.8.2 Before any inert gas is introduced into cargo tanks to maintain a positive pressure it should be established that the inert gas contains not more than 5 per cent by volume of oxygen.

5.9 Tank cleaning

Cargo tanks should be washed in the inert condition and under a positive pressure. The procedures adopted for tank cleaning with water should follow those for crude oil washing in 5.6.

5.10 Purging prior to gas-freeing

When it is desired to gas free a tank after washing, the concentration of hydrocarbon vapour should be reduced by purging the inerted cargo tank with inert gas. Purge pipes/vents should be opened to atmosphere and inert gas introduced into the tank until the hydrocarbon vapour concentration measured in the efflux gas has been reduced to 2 per cent by volume and until such time as determined by previous tests on cargo tanks has elapsed to ensure that readings have stabilized and the efflux gas is representative of the atmosphere within the tank.

5.11 Gas-freeing

5.11.1 Gas-freeing of cargo tanks should only be carried out when tank entry is necessary (e.g. for essential repairs). It should not be started until it is established that a flammable atmosphere in the tank will not be created as a result. Hydrocarbon gases should be purged from the tank (see 5.10).

5.11.2 Gas-freeing may be effected by pneumatically, hydraulically or steam driven portable blowers, or by fixed equipment. In either case it is necessary to isolate the appropriate tanks to avoid contamination from the inert gas main.

5.11.3 Gas-freeing should continue until the entire tank has an oxygen content of 21 per cent by volume and a reading of less than 1 per cent of lower flammable limit is obtained on a combustible gas indicator. Care must be taken to prevent the leakage of air into inerted tanks, or of inert gas into tanks which are being gas-freed.

5.12 Tank entry

5.12.1 The entry of personnel to the cargo tank should only be carried out under the close supervision of a responsible ship's officer and in accordance with national rules and/or with the normal industrial practice laid down in the International Safety Guide for Oil Tankers and Terminals.* The particular hazards encountered in tanks which have been previously inerted and then gas freed are outlined in 9.2.8, 9.3.3 and Chapter 10 of that Guide.

5.12.2 Practical precautions to meet these hazards include:

.1 securing the inert gas branch line gas valves and/or blanks in position or, if gas freeing with the inert gas blower, isolating the scrubber from the flue gases;

.2 closing of any drain lines entering the tank from the inert gas main;

.3 securing relevant cargo line valves or controls in the closed position;

.4 keeping the inert gas deck pressure in the remainder of the cargo tank system at a low positive pressure such as 200 millimetres water gauge. This minimizes the possible leakage of inert or hydrocarbon gas from other tanks through possible bulkhead cracks, cargo lines, valves, etc.;

.5 lowering clean sample lines well into the lower regions of the tank in at least two locations. These locations should be away from both the inlet and outlet openings used for gas-freeing. After it has been ascertained that a true bottom sample is being obtained, the following readings are required:

* ISGOTT published by the International Chamber of Shipping and the Oil Companies International Marine Forum.

.5.1 21 per cent on a portable oxygen analyser; and

.5.2 less than 1 per cent of lower flammable limit on a combustible gas indicator;

.6 the use of breathing apparatus whenever there is any doubt about the tank being gas-free, e.g. in tanks where it is not possible to sample remote locations. (This practice should be continued until all areas, including the bottom structure, have been thoroughly checked.);

.7 continuously ventilating and regularly sampling the tank atmosphere whenever personnel are in the tank;

.8 carefully observing normal regulations for tank entry.

5.13 Re-inerting after tank entry

5.13.1 When all personnel have left the tank and the equipment has been removed, the inert gas branch line blank, if fitted, should be removed, the hatch lids closed and the gas pressure regulating valve re-opened and locked open to the inert gas main where appropriate. This will avoid any risk of structural damage when liquids are subsequently handled.

5.13.2 As soon as a gas-free tank is reconnected to the inert gas main it should be re-inerted (as described in 5.1) to prevent transfer of air to other tanks.

6 PRODUCT CARRIERS

The basic principles of inerting are exactly the same on a product carrier as on a crude oil tanker. However, there are differences in operation of these vessels as outlined below.

6.1 Carriage of products having a flashpoint exceeding 60°C (closed cup test) as determined by an approved flashpoint apparatus.

6.1.1 Regulation 55(a)(i) of Part E, Chapter II-2, 1974 SOLAS Convention as amended by the 1978 Protocol implies, inter alia, that Regulation 60 and 62 do not apply to tankers carrying petroleum products having a flashpoint exceeding 60°C; in other words, product carriers may carry bitumens, lubricating oils, heavy fuel oils, high flashpoint jet fuels and some diesel fuels, gas oils and special boiling point liquids without inert gas systems having to be fitted, or, if fitted, without tanks containing such cargoes having to be kept in the inert condition.

6.1.2 If cargoes with a flashpoint exceeding 60°C, whether heated or otherwise, are carried at temperatures near to or above their flashpoint (some bitumen cut-backs and fuel oils), a flammable atmosphere can occur (Regulation 62(a) refers). When cargoes with a flashpoint exceeding 60°C are carried at a temperature higher than 5°C below their flashpoint they should be carried in an inerted condition.

6.1.3 When a non-volatile cargo is carried in a tank that has not been previously gas-freed, then that tank shall be maintained in an inert condition.

6.2 Product contamination by other cargoes

Contamination of a product may affect its odour, acidity or flashpoint specifications, and may occur in several ways; those relevant to ships with an inert gas main (or other gas line) inter-connecting all cargo tanks are:

.1 Liquid contamination due to overfilling a tank.

.2 Vapour contamination through the inert gas main. This is largely a problem of preventing vapour from low flashpoint cargoes, typically gasolines, contaminating the various high flashpoint cargoes listed in 6.1.1, plus aviation gasolines and most hydrocarbon solvents. This problem can be overcome by:

.2.1 removing vapours of low flashpoint cargoes prior to loading; and

.2.2 preventing ingress of vapours of low flashpoint cargoes during loading and during the loaded voyage.

When carrying hydrocarbon solvents where quality specifications are stringent and where it is necessary to keep individual tanks positively isolated from the inert gas main after a cargo has been loaded, pressure sensors should be fitted so that the pressure in each such tank can be monitored. When it is necessary to top up the relevant tanks, the inert gas main should first be purged of cargo vapour.

6.3 Contamination of cargoes by inert gas

For a well designed and operated flue gas system experience suggests that petroleum cargoes traditionally carried on product tankers do not suffer contamination from the flue gas itself, as opposed to contamination from other cargoes. However, unacceptable contamination from the flue gas may be encountered if proper control is not exercised over fuel quality, efficiency of combustion, scrubbing and filtering.
The more critical petrochemical cargoes which may be carried by product carriers can be contaminated by flue gas.

6.4 Contamination of cargoes by water

All lubricating oils and jet fuels are acutely water critical. Current practice requires full line draining and mopping up of any water in tanks before loading. Water contamination may occur on inerted ships due to:

.1 water carry-over from the scrubber and/or deck water seals due to inadequacies in design or maintenance of the various drying arrangements; and

.2 condensation of water from warm, fully saturated flue gas delivered to the tanks.

6.5 Additional purging and gas freeing

Gas-freeing is required on non-inerted product carriers more frequently than on crude carriers, both because of the greater need for tank entry and inspection, especially in port, and for venting vapours of previous cargoes. On inerted product carriers any gas-freeing operation has to be preceded by a purging operation (Regulation 62(b)(iv)), but gas-freeing for purely quality reasons may be replaced by purging only. In addition purging may be required on the basis outlined in 6.1.3 above.

It should be recognised that:

.1 there are increased risks of air leaking into inert tanks and of inert gas leaking into a tank being entered;

.2 purging is not a prerequisite of gas-freeing when the hydrocarbon gas content of a tank is below 2 per cent by volume;

.3 the operation of gas-freeing for product purity and where tank entry is not contemplated does not require the atmosphere to have an oxygen content of 21 per cent by volume.

7 COMBINATION CARRIERS

The basic principles of inerting are exactly the same on a combination carrier as on a tanker. However, there are differences in the design and operation of these vessels and relevant considerations are outlined below.

7.1 Slack holds

It is particularly important for combination carriers to have their holds inerted because whenever a hold in an OBO carrier (which could extend to the full breadth of the ship) is partially filled with clean or oily ballast, water agitation of this ballast can occur at small angles of roll and this can result in the generation of static electricity. The agitation is sometimes referred to as 'sloshing' and it can happen whenever the ullage above the liquid level of the hold is more than 10 per cent of the depth of the hold, measured from the underside of the deck (see figure 18 for remedy condition).

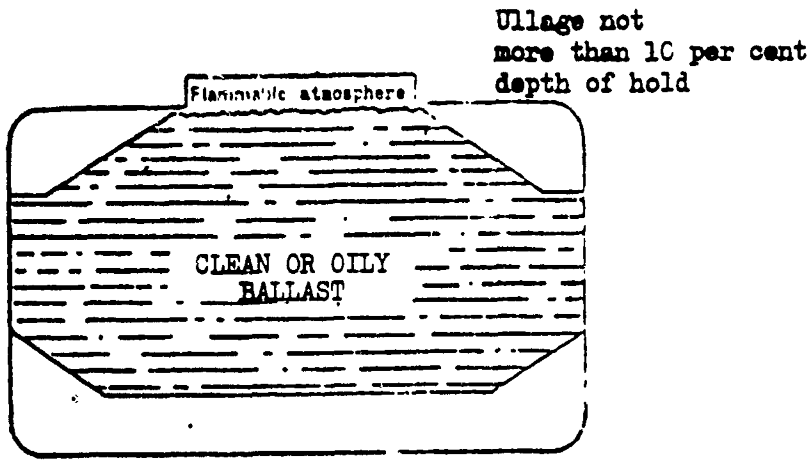


Figure 18.

7.2 Leakage

To ensure that leakage of tank gas, particularly through the hatch centre-line joints, is eliminated or minimized, it is essential that the hatch covers are inspected frequently to determine the state of their seals, their alignment, etc. When the hatch covers have been opened, particularly after the ship has been carrying a dry bulk cargo, the seals and trackways should be inspected and cleaned to remove any foreign matter.

7.3 Ballast and void spaces

The cargo holds of combination carriers are adjacent to ballast and void spaces. Leakages may occur in pipelines or ducts in these spaces, or by a fracture in the boundary plating; in this event there is a possibility that oil, inert gas and hydrocarbon gas may leak into the ballast and void spaces. Consequently gas pockets may form and difficulty with gas-freeing should be anticipated due to the considerable steelwork, acting as stiffening, which is characteristic of these spaces. Personnel should be alerted to this hazard.

7.4 Inert gas distribution system

Due to the special construction of combination carriers, the vent line from the cargo hatchway coaming is situated very close to the level of the cargo surface. In many cases, the inert gas main line passing along the main deck may be below the oil level in the hold. During rough weather oil or water may enter these lines and completely block the opening and thus prevent an adequate supply of inert gas during either tank cleaning or discharge. Vent lines should therefore have drains fitted at their lowest point and these should always be checked before any operation takes place within the cargo hold.

7.5 Application when carrying oil

On combination carriers the inert gas system should be utilized in the manner described in section 5 when the ship is engaged exclusively in the carriage of oil.

7.6 Application when carrying cargoes other than oil

7.6.1 When a combination carrier is carrying a cargo other than oil it should be considered as a tanker unless the requirements in 7.6.8 are complied with.

7.6.2 When cargoes other than oil are intended to be carried it is essential that all holds/cargo tanks other than slop tanks referred to in 7.6.6 and 7.6.7 are emptied of oil and oil residues, and cleaned and ventilated to such a degree that the tanks are completely gas free and internally inspected. The pumproom, cargo pumps, pipelines, duct keel and other void spaces are to be checked to ensure that they are free of oil and hydrocarbon gas.

7.6.3 Where holds are required to carry cargo other than oil they should be isolated from the inert gas main and oil cargo pipeline by means of blanks which should remain in position at all times when cargoes other than oil are being handled or carried.

7.6.4 During the loading and discharging of solid cargoes and throughout the intervening periods all holds/cargo tanks other than the slop tanks referred to in 7.6.6 and 7.6.7, cargo pumprooms, cofferdams, duct keels and other adjacent void spaces should be kept in a gas free condition and checked periodically at intervals of not more than two days to ensure that:

.1 there has been no generation of hydrocarbon gas or leakage of hydrocarbon gas from the slop tanks referred to in 7.6.6 and 7.6.7. If concentrations of more than 20 per cent of the lower flammable limit are detected, the compartments concerned should be ventilated;

.2 there is no deficiency of oxygen which could be attributable to leakage of inert gas from another compartment.

7.6.5 As an alternative to 7.6.4, those cargo tanks which are empty of cargo may be re-inerted in accordance with 5.1, provided they are subsequently maintained in the inert condition and at a minimum pressure of 100 millimetres water gauge at all times, and provided that they are checked periodically at intervals of not more than two days to ensure that any generation of hydrocarbon gas does not exceed one per cent by volume. If such a concentration is detected the compartments concerned should be purged in accordance with 5.10.

7.6.6 Slops should be contained in a properly constituted slop tank and should be:

.1 discharged ashore and the slop tanks cleaned and ventilated to such a degree that the tanks are completely gas-free and then inerted; or

.2 retained on board for not more than one voyage when, unless the vessel reverts to carrying oil, the slop tank should be treated as in 7.6.5.

If slops are retained on board for more than one voyage because reception facilities for oily residues are not available, the slop tank should be treated as in 7.6.5 and in addition a report should be forwarded to the Administration.

7.6.7 Slop tanks which have not been discharged should comply not only with the requirements of 7.6.6, but also with Regulation 62(k)(ii)(2) which requires that they be isolated from other tanks by blank flanges which will remain in position at all times when cargoes other than oil are being carried, except as provided for in these Guidelines. In this connexion reference is made to 7.6.3. On combination carriers where there are also empty cargo tanks which are not required to be isolated from the inert gas main then the arrangement for isolating the slop tanks from these tanks should be such as to:

.1 prevent the passage of hydrocarbon gas from the slop tanks to the empty tanks; and

.2 facilitate monitoring (see Regulation 62(p)(iii)(1)) of and, if necessary, topping up of the pressure in slop tanks and in any empty cargo tanks if the latter are being kept in the inert condition as referred to in 7.6.5.

A suggested arrangement is shown in figure 19.

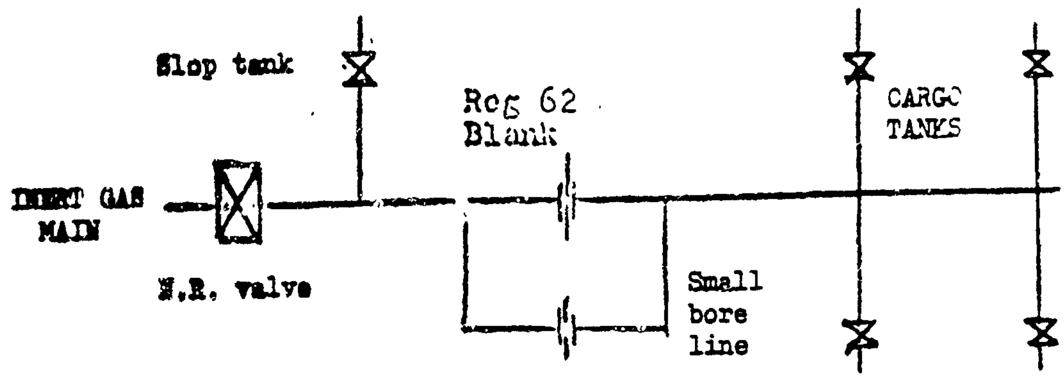


Figure 19. Proposed by-pass arrangement for topping up cargo tanks.

In addition, all cargo pipelines to or from the slop tanks should be blanked off.

7.6.8 Instead of complying with the requirements in 7.6.2 to 7.6.7, a combination carrier may be operated as a bulk carrier without having to use its inert gas system if either:

.1 it has never carried a cargo of oil; or

.2 after its last cargo of oil, all its cargo tanks, including slop tanks, the pumproom, cargo pumps, pipelines, cofferdams, duct keel and other void spaces are emptied of oil and oil residues, cleaned and completely gas-free and the tanks and void spaces internally inspected to that effect. In addition the monitoring required in 7.6.4 should be continued until it has been established that generation of hydrocarbon gas has ceased.

8 EMERGENCY PROCEDURES

8.1 In the event of total failure of the inert gas system to deliver the quality and quantity of inert gas to maintain a positive pressure in the cargo tanks and slop tanks, action must be taken immediately to prevent any air being drawn into the tank. All cargo tank operations should be stopped, the deck isolating valve should be closed, and the vent valve between it and the gas pressure regulating valve should be opened.

8.2 If it is considered to be totally impracticable to effect a repair to enable the inert gas system to deliver the quality of gas and maintain a positive pressure in the cargo tanks, cargo discharge and deballasting may only be resumed provided that the following precautions are taken:

.1 The flame screens are checked to ensure that they are in a satisfactory condition.

.2 The valves on the vent mast risers are opened.

.3 No free fall of water or slops is permitted.

.4 No dipping, ullaging, sampling or other equipment should be introduced into the tank unless essential for the safety of the operation. If it is necessary for such equipment to be introduced into the tank, this should only be done after at least 30 minutes have elapsed since the injection of inert gas ceased. All metal components of equipment to be introduced into the tank should be securely earthed. This restriction should be applied until a period of five hours has elapsed since injection of inert gas had ceased.

8.3 If it is essential to clean tanks following the failure of the inert gas system, and inerted conditions as defined in Regulation 62(b)(ii) cannot be maintained, further precautions are necessary. These are listed below:

.1 Tank washing should only be carried out on one tank at a time.

.2 The tank should be isolated from other tanks and from any common venting system or the inert gas main and maximum ventilation output should be concentrated on that tank both before and during the washing process. Ventilation should provide as far as possible a free flow of air from one end of the tank to the other.

.3 The tank bottom should be flushed with water and stripped. The piping system including cargo pumps, cross-overs and discharge lines should also be flushed with water.

.4 Washing should not commence until tests have been made at various levels to establish that the vapour content in any part of the tank is below 10 per cent of the lower flammable limit.

.5 Testing the tank atmosphere should continue during the washing process. If the vapour level rises to within 50 per cent of the lower flammable limit washing should be discontinued until the vapour level has fallen to 20 per cent of the lower flammable limit or less.

.6 If washing machines with individual capacities exceeding $60m^3$/hour are to be used, only one such machine shall be used at any one time on the ship. If portable machines are used, all hose connexions should be made up and bonding cables tested for continuity before the machines are introduced into the tank and should not be broken until after the machines have been removed from the tank.

.7 The tank should be kept drained during washing. If build-up of wash water occurs, washing should be stopped until the water has been cleared.

.8 Only clean, cold sea water should be used. Recirculating systems should not be used.

.9 Chemical additives should not be used.

.10 All deck openings, except those necessary for washing and designed venting arrangements, should be kept closed during the washing process.

8.4 During cargo operations in port, more stringent regulations of the port Authorities shall take precedence over any of the foregoing emergency procedures.

8.5 The attention of the ship's master should be drawn to Regulation 11(c) of Chapter I of the 1978 SOLAS Protocol in the event of the inert gas system having become inoperative.

9 MAINTENANCE AND TESTING

9.1 General

9.1.1 The safety arrangements are an integral part of the inert gas system and it is important for ship's staff to give special attention to them during any inspection.

9.1.2 Inspection routines for some of the main components are dealt with in this section.

9.2 Inert gas scrubber

9.2.1 Inspection may be made through the manholes. Checks should be made for corrosion attacks, fouling and damage to:

.1 scrubber shell and bottom;

.2 cooling water pipes and spray nozzles (fouling);

.3 float switches and temperature sensors;

.4 other internals such as trays, plates and demister filters.

9.2.2 Checks should be made for damage to non-metallic parts such as:

.1 internal linings;

.2 demisters;

.3 packed beds.

9.3 Inert gas blowers

9.3.1 To a limited degree, internal visual inspection will reveal damage at an early stage. Diagnostic monitoring systems should be used as they greatly assist in maintaining the effectiveness of the equipment. By fitting two equal sized blowers or, alternatively, supplying and retaining on board a spare impeller with a shaft for each blower, an acceptable level of availability is ensured. Visual inspection through the available openings in the blower casing are adequate for this purpose.

9.3.2 An inspection of inert gas blowers should include:

.1 internal inspection of the blower casing for soot deposits or signs of corrosive attack;

.2 examination of fixed or portable washing system;

.3 inspection of the functioning of the fresh water flushing arrangements, where fitted;

.4 inspection of the drain lines from the blower casing to ensure that they are clear and operative;

.5 observation of the blower under running conditions for signs of excessive vibration, indicating too large an imbalance.

9.4 Deck water seal

9.4.1 This unit performs an important function and must be maintained in good condition. Corroded inlet pipes and damage to float controlled valves are not uncommon. The overboard drain line and connexion are also possible sources of trouble.

9.4.2 An inspection of the deck water seal should include:

.1 Opening for internal inspection to check for:

.1.1 blockage of the venturi lines in semi-dry type water seals;

.1.2 corrosion of inlet pipes and housing;

.1.3 corrosion of heating coils;

.1.4 corroded or sticking floats for water drain and supply valves and level monitoring.

.2 Testing for function:

.2.1 automatic filling and draining: check with a local level gauge if possible;

.2.2 presence of water carry-over (open drain cocks on inert gas main line) during operation.

9.5 Non-return valve

The non-return valve should be opened for inspection to check for corrosion and also to check the condition of the valve seat. The functioning of the valve should be tested in operation.

9.6 Scrubber effluent line

The scrubber effluent line cannot normally be inspected internally except when the ship is in dry dock. The ship side stub piece, referred to in 3.15.3.2 and the overboard discharge valve should be inspected at each dry-docking period.

9.7 Testing of other units and alarms

9.7.1 A method should be devised to test the correct functioning of all units and alarms and it may be necessary to simulate certain conditions to carry out an effective testing programme.

9.7.2 Such a programme should include checking:

.1 all alarm and safety functions;

.2 the functioning of the flue gas isolating valves;

.3 the operation of all remotely or automatically controlled valves;

.4 the functioning of the water seal and non-return valve (with a backflow pressure test);

.5 the vibration level of the inert gas blowers;

.6 for leakages: in systems four years old or more deck lines should be examined for gas leakage;

.7 the interlocking of the soot blowers;

.8 oxygen-measuring equipment, both portable and fixed, for accuracy by means of both air and a suitable calibration gas.

9.8 Suggested maintenance programme

Component	Preventive maintenance	Maintenance interval
Flue gas isolating valves	Operate the valve	Before start-up and one week
	Cleaning with compressed air or steam	Before operating valve
	Dismantling for inspection and cleaning	Boiler shutdown
Flue gas scrubber	Water flush	After use
	Cleaning of demister	Three months
	Dismantling of level regulators and temperature probes for inspection	Six months
	Opening for full internal inspection	Dry docking
Overboard pipes and valve from flue gas scrubber	Flushing with scrubber water pump for about one hour	After use
	Dismantling of the valve for overhaul, inspection of pipeline and overboard end	Dry-docking/repair period
Blowers	Vibration check	While running
	Flushing	After use
	Internal inspection through hatches	After flushing and six months
	Dismantling for full overhaul of bearings, shaft tightenings and other necessary work	Two years or more frequently if required/dry-docking

Component	Proventive maintenance	Maintenance interval
Deck water seal	Dismantling of level regulators/ float valves for inspection	Six months
	Opening for total internal inspection	One year
	Overhaul of auto-valves	One year
Deck mechanical non-return valve	Moving and lubricating the valve if necessary	One week and before start
	Opening for internal inspection	One year/18 months
Pressure-vacuum valves	Operating and lubricating the valves	Six months
	Opening for full overhaul and inspection	One year
Deck isolating valve	Opening for overhaul	One year
Gas pressure regulating system	Removal of condensation in instrument, air supply	Before start
	Opening of gas pressure regulating valves for overhaul	As appropriate
Liquid filled pressure-vacuum breaker	Check liquid level when system at atmospheric pressure	When opportunity permits and every six months

10 TRAINING

10.1 General

10.1.1 An inert gas installation is an important feature of a tanker's safety system and training in its use is essential.

10.1.2 The requirements for training depend upon the policies of the shipping company concerned as well as the Administration of the country in which the ship is registered. This chapter is not intended to specify any particular training policy but to set out a number of alternatives which can be suitably adapted.

10.2 Personnel requiring training

10.2.1 It is not the intention of this section to spell out in detail a syllabus for courses in the design, operation and maintenance of inert gas systems, but it is suggested that any syllabus should cover the same ground as that contained in these Guidelines.

10.2.2 However, such practical training can only be given if those in charge of, and responsible for, the vessel's safety and performance are themselves completely familiar with the type of installation fitted, and the hazards associated with its use. It is recommended that the training of both deck and engine room personnel is co-ordinated to ensure a common understanding of the procedures.

10.2.3 Administrations should make sure that the vessel is equipped with the necessary manufacturers' manuals and instructions to give the necessary information about how to carry out the various operations.

10.3 Location of training

Training may take place aboard or ashore. If shore training in basic design and operation is given, personnel should be made familiar with the equipment on board ship.

10.4 Some training methods

There are currently three methods used in training. Companies may practise one, or a permutation of the following:

.1 On board by shipping company staff

This may be carried out either by a senior member of the ship's company who has been made responsible for training or by a specialist who joins the vessel for part of a voyage. Such a training programme can be enhanced by films and other suitable audio-visual aids, if they are available. Under these circumstances, it should be possible to deal with the theoretical as well as the practical aspects.

.2 Specialist shore-based training

This can be undertaken by nautical colleges either in consultation with shipping companies or with manufacturers.

It has been found that a one-week course should cover the subject adequately.

.3 Shore based by shipping company staff

Training under this heading may occur either as part of a company cargo course, or, for example, as part of a senior officer's seminar where appropriate time may be devoted to a discussion of inert gas and operating problems.

11 INSTRUCTION MANUAL(S)

Instruction Manuals required to be provided on board by Regulation 62(u) should contain the following information and operational instructions.

11.1 A line drawing of the inert gas system showing the positions of the inert gas pipework from the boiler or gas generator uptakes to each cargo tank and slop tank; gas scrubber; scrubber cooling water pump and pipework up to the effluent discharge overboard; blowers including the suction and discharge valves; recirculation or other arrangements to stabilize the inert gas plant operation; fresh air inlets; automatic gas pressure regulating stop valve; deck water seal and water supply, heating and overflow arrangements; deck non-return stop valve; water traps in any supply, vent, drain and sensing pipework; cargo tank isolation arrangement; purge pipes/vents; pressure/vacuum valves on tanks; pressure/vacuum breakers on the inert gas main; permanent recorders and instruments and the take-off points for their use, arrangements for using portable instruments, complete and partial wash bulkheads, mast risers, mast riser isolating valves; high velocity vents; manual and remote controls.

11.2 A description of the system and a listing of procedures for checking that each item of the equipment is working properly during the full cycle of tanker operation. This includes a listing of the parameters to be monitored such as inert gas main pressure, oxygen concentration in the delivery main, oxygen concentration in the cargo tanks, temperature at the scrubber outlet and blower outlet, blower running current or power, scrubber pump running current or power, deck seal level during inert gas discharge to cargo tanks at maximum rate, deck seal level at nil discharge, etc. Established values for these parameters during acceptance trials should be included, where relevant.

11.3 Detailed requirements for conducting the operations described in sections 4 and 5 particular to the installation of the ship such as times to inert, purge and gas-free each tank, sequence and number of tanks to be inerted, purged and gas-freed, sequence and number of purge pipes/vents to be opened or closed during such operations, etc.

11.4 Dangers of leakage of inert gas and hydrocarbon vapours and precautions to be taken to prevent such leakages should be described relating to the particular construction and equipment on board.

11.5 Dangers of cargo tank overpressure and underpressure during the various stages in the cycle of tanker operation and the precautions to be taken to prevent such conditions from arising should also be described in detail relating to the particular construction or the equipment on board.

12 SOME SAFETY CONSIDERATIONS WITH INERT GAS SYSTEMS

12.1 Backflow of cargo gases

To prevent the return of cargo gases or cargo from the tanks to the machinery spaces and boiler uptake, it is essential that an effective barrier is always present between these two areas. In addition to a non-return valve, a water seal and vent valve should be fitted on the deck main. It is of prime importance that these devices are properly maintained and correctly operated at all times.

An additional water seal is sometimes fitted at the bottom of the scrubber (see also 3.9.6).

12.2 Health hazards

12.2.1 Oxygen deficiency

Exposure to an atmosphere with a low concentration of oxygen does not necessarily produce any recognizable symptom before unconsciousness occurs, when the onset of brain damage and risk of death can follow within a few minutes. If the oxygen deficiency is not sufficient to cause unconsciousness, the mind is liable to become apathetic and complacent, and even if these symptoms are noticed and escape is attempted, physical exertion will aggravate the weakness of both mind and body. It is therefore necessary to ventilate thoroughly to ensure that no pockets of oxygen-deficient atmosphere remain. When testing for entry a steady reading of 21 per cent oxygen is required.

12.2.2 Toxicity of hydrocarbon vapours

Inert gas does not affect the toxicity of hydrocarbon gases and the problem of toxicity is no different from that of ships without an inert gas system. Because of possible gas pockets, regeneration, etc. gas-freeing must continue until the entire compartment shows a zero reading with a reliable combustible gas indicator or equivalent, or a 1 per cent of the lower flammable limit reading should the instrument have a sensitivity scale on which a zero reading is not obtainable.

12.2.3 Toxicity of flue gas

The presence of toxic gases such as sulphur dioxide, carbon monoxide and oxides of nitrogen can only be ascertained by measurement. However, provided that the hydrocarbon gas content of an inerted tank exceeds about 2 per cent by volume before gas-freeing is started, the dilution of the toxic components of flue gas during the subsequent gas freeing can be correlated with the readings of an approved combustible gas indicator or equivalent. If by ventilating the compartment, a reading of 1 per cent of the lower flammable limit or less is obtained in conjunction with an oxygen reading of 21 per cent by volume, the toxic trace gases will be diluted to concentrations at which it will be safe to enter. Alternatively, and irrespective of initial hydrocarbon gas content, ventilation should be continued until a steady oxygen reading of 21 per cent by volume is obtained.

12.3 Tank pressure

When an inerted cargo tank is maintained at a positive pressure, personnel should be advised of the practical hazards of this pressure. Such pressure must be adequately reduced before any tank-lids, ullage plugs or tank washing openings are opened.

12.4 Electrostatic hazards

12.4.1 Small particulate matter carried in flue gas can be electrostatically charged. The level of charge is usually small, but levels have been observed well above those encountered with water mists formed during tank washing.

12.4.2 Because cargo tanks are normally in an inerted condition, the possibility of electrostatic ignition has to be considered only if the oxygen content of the tank atmosphere rises as a result of an ingress of air or if it is necessary to inert a tank which already has a flammable atmosphere (see 5.1).

12.5 Repair of inert gas plant

12.5.1 Inert gas is asphyxiating. Great care must be exercised when work on the plant is undertaken. Although the worker may be in the open air, inert gas leaking from the plant could render him unconscious very quickly. Before opening up any equipment therefore it is recommended that the inert gas plant is completely gas-freed.

12.5.2 If any unit (e.g. the inert gas scrubber) is to be examined internally, the standard recommendations for entering enclosed spaces must be followed. Blind flanges should be fitted where applicable or the plant should be completely isolated.

Materials Aspects of Inert Gas Systems for Cargo Tank Atmosphere Control

The National Research Council

NATIONAL ACADEMY OF ENGINEERING · NATIONAL ACADEMY OF SCIENCES · INSTITUTE OF MEDICINE

Commission on Sociotechnical Systems

National Materials Advisory Board

NMAB-372

NATIONAL RESEARCH COUNCIL
COMMISSION ON SOCIOTECHNICAL SYSTEMS

NATIONAL MATERIALS ADVISORY BOARD

Chairman:

Mr. William D. Manly
Senior Vice President
Cabot Corporation
125 High Street
Boston, MA 02110

Past Chairman:

Mr. Julius J. Harwood
Director, Materials Science Laboratory
Engineering and Research Staff
Ford Motor Company
P. O. Box 2053
Dearborn, MI 48121

Members

Dr. George S. Ansell
Dean, School of Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

Dr H. Kent Bowen
Professor, Ceramic and Electrical Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139

Dr. Van L. Canady
Senior Planning Associate
Mobil Chemical Company
150 E. 42nd Street, Room 746
New York, NY 10017

Dr. George E. Dieter, Jr.
Dean, College of Engineering
University of Maryland
College Park, MD 20742

Dr. Joseph N. Epel
Director, Plastics Research and Development Center
Budd Corporation
356 Executive Drive
Troy, MI 48084

Dr. Larry L. Hench
Professor and Head
Ceramics Division
Department of Materials Science and Engineering
University of Florida
Gainesville, FL 32601

Dr. Robert E. Hughes
Professor of Chemistry
Executive Director, Materials Science Center
Department of Chemistry
Cornell University
Ithaca, NY 14850

Dr. John R. Hutchins III
Vice President and Director of Research and Development
Technical Staff Division
Corning Glass Works
Sullivan Park
Corning, NY 14830

Dr. Sheldon E. Isakoff
Director, Engineering Research and Development Division
E. I. DuPont de Nemours & Co., Inc.
Wilmington, DE 19898

Dr. Frank E. Jaumot, Jr.
Director of Advanced Engineering
Delco Electronics Division
General Motors Corporation
P. O. Box 1104
Kokomo, IN 46901

Dr. James W. Mar
Professor, Aeronautics and Astronautics
Building 33-307
Massachusetts Institute of Technology
Cambridge, MA 02139

Dr. Frederick T. Moore
Industrial Advisor
Industrial Development and Finance Department
World Bank
1818 H Street, N.W., Room D422
Washington, DC 20431

Dr. R. Byron Pipes
Director, Center for Composite Materials
Department of Mechanical and Aerospace Engineering
University of Delaware
Newark, DE 19711

Dr. Allen S. Russell
Vice President-Science and Technology
Aluminum Company of America
1501 Alcoa Building
Pittsburgh, PA 15219

Dr. John J. Schanz, Jr.
Senior Specialist
Congressional Research Service-ENR
Library of Congress
Washington, DC 20540

Dr. Arnold J. Silverman
Professor, Department of Geology
University of Montana
Missoula, MT 59801

Dr. Dorothy M. Simon
Vice President and Director of Research
AVCO Corporation
1275 King Street
Greenwich, CT 06830

Dr. William M. Spurgeon
Director, Manufacturing and Quality Control
Bendix Corporation
24799 Edgemont Road
Southfield, MI 48075

Dr. Roger A. Strehlow
Professor, Aeronautical and Astronautical Engineering
University of Illinois at Urbana
101 Transportation Building
Urbana, IL 61801

Dr. Michael Tenenbaum
1644 Cambridge
Flossmoor, IL 60422

Dr. William A. Vogely
Professor and Head, Department of Mineral Economics
Pennsylvania State University
University Park, PA 16802

Dr. Albert R. C. Westwood
Director, Martin Marietta Labs
Martin Marietta Corporation
1450 South Rolling Road
Baltimore, MD 21227

NMAB Staff

W. R. Prindle, Executive Director
R. V. Hemm, Executive Secretary

(1/18/80)

MATERIALS ASPECTS OF INERT GAS SYSTEMS FOR CARGO TANK ATMOSPHERE CONTROL

Report of

The Committee on Problems of Inert Gas Systems for Cargo Tank Atmosphere Control

NATIONAL MATERIALS ADVISORY BOARD
Commission on Sociotechnical Systems
National Research Council

Publication NMAB-372

National Academy of Sciences
Washington, D.C.

1980

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competence and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine.

This study by the National Materials Advisory Board was conducted under Contract No. DOT-CG-821349-A with the U.S. Coast Guard.

This report is for sale by the National Technical Information Service, Springfield, Virginia 22151.

Requests for permission to reproduce this report in whole or in part should be addressed to the National Materials Advisory Board.

Printed in the United States of America.

ABSTRACT

This study was undertaken to identify materials problems that might arise in inerting systems in cargo tankers. Inerting systems provide a means of replacing the atmosphere over the cargo in a ship's tanks with an inert gas to reduce the possibility of explosion. This study identifies design and materials requirements for the hot gas area, piping systems, blowers, valves, instrumentation, and control and alarm systems comprising inerting systems.

NATIONAL MATERIALS ADVISORY BOARD

COMMITTEE ON PROBLEMS OF INERT GAS SYSTEMS
FOR CARGO TANK ATMOSPHERE CONTROL

Chairman

CAPT. PERRY W. NELSON U.S.N. (ret.), Executive Vice President, M. Rosenblatt & Son, Inc., New York, New York.

Members

MR. ALEXANDER DELLI PAOLI, Design Manager, Tanker Department, Exxon International Company, Florham Park, New Jersey.

PROF. NORBERT D. GREENE, Department of Metallurgy, Institute of Materials Science, University of Connecticut, Storrs, Connecticut.

MR. THOMAS J. KEHOE, Manager, Technical Services, Beckman Instruments Corporation, Fullerton, California.

MR. ARTHUR MCKENZIE, Director, Tanker Advisory Center, Inc., New York, New York.

MR. C.G. MUNGER, Consultant, Coatings and Corrosion, Fallbrook, California.

MR. STEVEN E. SABO, Section Manager, Marine Sales, Combustion Engineering, Inc., Windsor, Connecticut.

CAPT. DONALD H. VOGE, Manager, Port Maintenance and Repair Hull Division, Sun Transport, Inc., Division of Sun Oil, Inc., Claymont, Delaware.

Liaison Representatives

MR. SUDHEER CHAND, American Bureau of Shipping, New York, New York.

MR. ALDO FURNO, Chemical Engineer, U.S. Bureau of Mines, Pittsburgh, Pennsylvania.

MR. EDWARD C. MARCH, Director (Alternate, MR. JOSEPH J. COX), Office of Maritime Safety Standards, Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C.

MR. JOHN G. O'NEILL, Fire Detection and Control Systems Program, Center for Fire Research, National Bureau of Standards, Washington, D.C.

PRECEDING PAGE BLANK-NOT FILMED

MRS. MARLENE R.B. PHILLIPS, Maritime Transportation Research Board, National Transportation Research Board, National Academy of Sciences, Washington, D.C.

MR. DANIEL F. SHEEHAN, Technical Advisor, Office of Merchant Marine Safety, U.S. Coast Guard Headquarters, Washington, D.C.

MR. GEORGE SORKIN, Materials and Mechanics Division, Naval Sea Systems Command, Washington, D.C.

NMAB Staff

JOSEPH R. LANE, Staff Metallurgist

CONTENTS

TABLES AND FIGURES

Chapter 1

INTRODUCTION

Inerting systems provide a means of replacing the atmosphere over the cargo in a ship's tanks with an inert gas to reduce the possibility of explosion. A properly designed, maintained, and operated inerting system can hold the oxygen content of the gases over the cargo below the level at which ignition can occur.

These systems are of two general types. In one type the inert gas is flue gas produced in firing the ship's boilers. In the other type the inert gas is produced in a separately fired gas generator. Gas-generator systems are used on diesel-powered ships and on ships whose boiler capacity is too small to provide enough flue gas for the inerting system.

U.S. Coast Guard regulations have required all new U.S.-flag tankers over 100,000 dead weight tons (dwt) to operate with inerting equipment. The Coast Guard has proposed that the requirement be extended to tankships* and combination carriers of 20,000 dwt or more, and the United States has proposed to the Intergovernmental Maritime Consultative Organization (IMCO) that the requirement be made worldwide.

This study was undertaken by the National Materials Advisory Board to identify materials problems that might arise after the new regulations covering small tankers are imposed. The objective was stated as follows:

> The committee will assess the materials aspects of Inert Gas Systems. The scope of the study will be limited to flue gas systems and separately fired gas generators. It will be concerned with the selection (and treatment) of materials and with the design objectives related to component performance. The study will consider the major components of a typical flue-gas inert-gas system from the boiler uptake to the gas distribution piping. For each component, the relevant maintainability, reliability and safety aspects will be addressed. The study will not consider: operating requirements, overboard discharge of effluent, detailed design aspects, alternate systems (e.g., nitrogen), nor identification of specific manufacturers.

Inerting does not guarantee freedom from accident for at least two reasons. First, the equipment must be operated and maintained properly. Systems installed by the Military Sealift Command on several of its ships operated by contractors were later removed, partly because it was recognized that operations were lax, so that the systems were engendering a false sense of security. Second, should an inerting system fail, problems might arise that would not occur in the absence of the system. Such problems include generation of static charges and pyrophoric iron sulfide,

*Each U.S.-flag tankship that is certified to carry Grades A, B, C, D, and some E liquids.

which can ignite spontaneously or emit sparks when scratched or struck. Both of these situations are beyond the scope of this committee. They have been recognized and have been, and can be, dealt with by proper contingency planning and training. Nevertheless, there have been major explosions in ships equipped with inert gas systems.

This report does not present a bill of materials for an inerting system. The design of a ship and its elements is an exercise in engineering judgment in which performance, initial cost, upkeep costs, maintenance schedules, and anticipated manner of operation are considered. Most of these factors involve tradeoffs. Specific materials and design solutions can be arrived at only during the actual design of a specific ship. Therefore, what follows are the identification of problem areas and suggested materials (and, in a few cases, design options) which should be considered to produce a relatively trouble-free inerting system.

Throughout the report specific generic materials and proprietary products are cited. No endorsement is intended. Rather, the materials cited are representative of the types satisfactory for the service being discussed.

Chapter 2

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Hot Gas Area

- The components that comprise the hot gas area of the inert gas system are exposed to an extremely corrosive environment.
- Certain components require high-grade alloys to perform reliably. These materials are currently available.
- Compromises in materials for certain components should not be accepted.
- When selecting equipment for a particular application, the type of fuel that will produce the flue gas and the maximum temperature to which each component may be exposed are significant factors.
- Components should be inspected on a regular schedule through suitable access openings, particularly in those areas most susceptible to corrosion.

Piping

- Contaminated sea water from the scrubber system is much more corrosive than clean sea water.
- The most reliable corrosion-resistant materials must be used wherever there may be contact with contaminated sea water.
- Acceptable materials are commercially available.
- Application or use of these materials is critical. Proper and careful application of coatings and installation of pipe is essential.
- Interior inspection of scrubber piping systems is required at regular intervals. Cleaning and any required repair must be done at this time.

Blowers

- Blowers in inert gas generator systems are not exposed to the hostile environment experienced by blowers in a flue gas system. They present no unusual problems and, therefore, require no special material considerations beyond normal marine design considerations and practice.

- Suitable materials are available for blowers in flue gas inerting systems, but design, operation, and service life must be balanced with maintenance requirements.

- The materials selected for the components of the system are not totally independent of design or operating considerations and practices. (This is true of other parts of the system as well.) For example, washing of the blower materials after each use can permit use of a less exotic material (from an anticorrosive point of view) than would be the case with a blower that was not washed after each use, all other things being equal.

Valves

- The body, lining, and seat must be of mutually compatible materials.

- Valves must be removed from the line, cleaned, and inspected at each biennial drydock period. Ease of repair between drydock periods is a consideration.

- Soot should not be allowed to accumulate.

Instrumentation; Control and Alarm Systems

- Instrumentation to assure the reliability, maintainability, and safety of the inert gas system includes the continuous measurement of temperature, pressure, flow, water level, and oxygen concentration.

- Measurement of the oxygen concentration in the inert flue gas is of prime importance. Several reliable ways to measure oxygen concentration are available. The degree of sample conditioning (primarily filtration) prior to the analyzer will depend on the quality and pressure of the flue gas available.

RECOMMENDATIONS

Table 1 provides specific recommendations on material selection and certain additional recommendations for the hot gas area, piping, blowers, and valves.

TABLE 1 Specific Recommendations

	Material Selection: Primary	Material Selection: Secondary	Additional Recommendations
Hot Gas Area			
Boiler Offtakes	Suitable corrosion resistant steel		1. Locate above economizer 2. As far below top of stack as possible 3. With rotary gas regenerative air heater locate before air heater and away from seal area
Flue Gas Piping	Heavy-gauge galvanized or Corten mild steel		1. Well lagged 2. Keep lines as short as possible 3. Spectacle flanges or gater blinds before and after scrubber
Expansion Bellows	Hastelloy C276 or Inconel 625 or Incoloy 825	Nonmetallic if suitable for temp	1. Fitted vertically if possible 2. Do not weld into flue gas line 3. Internal support sleeve should not collect soot
Boiler Uptake Valves	1. Body - cast or nodular iron 2. Disk - cast or nodular iron 3. For high temp meehanite or cast steel 4. Shaft - 316 stainless or equivalent		1. Butterfly type with metallic seats 2. Air sealing system should be installed 3. Compressed air or steam for valve seat cleaning 4. Interlock between uptake valve and sootblower system 5. Inspection opening adjacent to uptake valve
Inlet Foot to Scrubber	Incoloy 825 or Titanium	Hastelloy C276 International Ni.FER 53	
Scrubber Base	Mild steel covered with rubber or glass - reinforced epoxy (amine cured)	Mild steel clad with Incoloy 825, Inconel 625 or equal	1. Care must be taken in preparing and welding
Scrubber Tower	Mild steel with ebonite rubber or glass - reinforced amine cured epoxy lining	Or equivalent	1. Avoid sharp corners 2. Avoid welding 3. Fittings of corrosion-resistant materials 4. Suitably stiffened 5. Install suitable access doors
Gas Scrubbing or Bubbling Trays	Incoloy 825 or polypropylene lined	Or equivalent	1. Holding bolts - Incoloy 825 or equal 2. Packing bars - fiberglass 3. Impingement plates - Incoloy 825
Water Tower Spray Nozzles and Water Lines	90/10 copper-nickel or nickel-aluminum-bronze	Or equivalent	1. If in hotter area - Incoloy 825
Demister Pads	Polypropylene knitted material		
Holding Trays	Incoloy 825, or 316 stainless steel	Or equivalent	

TABLE 1 Specific Recommendations (cont.)

	Material Selection		Additional Recommendations
	Primary	Secondary	
Hot Gas Area (cont.)			
Gas Recirculating Line	Heavy wall steel lined with coal tar epoxy	Lined with: 1. pure epoxy, 2. epoxy phenolic	1. Routed to return gases and water spray
Scrubber of a separately fired I.G. Generator	316 stainless steel	Or equivalent	1. Spray nozzles trays and attachments of 316 stainless steel
Piping			
Cooling Water Piping	90/10 copper-nickel or aluminum-bronze	Glass-reinforced plastic (GRP)	1. GRP used only in interior spaces
Scrubber Drain and Scrubber Seal Drain Piping	Glass-reinforced plastic made from acid resistant resins	Rubber-lined steel pipe-flanged	1. Shell penetration - schedule 160 steel pipe - rubber, lined or fitted with PVC insert 2. Discharge valve - flanged steel, rubber lined 3. If GRP piping used additional nonreturn valve inboard of overboard discharge, valve usually required
Inert Gas Piping	Heavy wall steel lined with coal tar epoxy	Lined with: 1. pure epoxy 2. epoxy phenolic	1. Use flanged or dresser couplings for removal to clean 2. Clean out sections recommended 3. Lines installed to drain to low point with drain opening 4. Test for coating imperfections
Water separator, fan and deck seal drains	Glass reinforced plastic made with acid resistant resins	Rubber lined steel-flanged	1. GRP used only in interior spaces
Blowers			
Impellers	Nickel-aluminum-bronze	Low-carbon austenitic stainless steel	1. Stress relieve welded construction 2. Fresh water rinse highly desirable 3. Both side pedestal-mounted bearings preferred 4. Riveted construction of impellers should be avoided.
Shaft	Nickel-aluminum-bronze	Low-carbon austenitic stainless steel	1. Impeller to be keyed to shaft 2. Bearings and seals accessible for inspection

TABLE 1 Specific Recommendations (cont.)

	Material Selection		
	Primary	Secondary	Additional Recommendations
Blowers (cont.)			
Casing	Welded carbon steel lined internally with: rubber or fiberglass reinforced plastic	Glassflake filled polyester resin coated steel	1. Suitable thickness to prevent panting 2. Provision for removal of rotor without disconnecting piping 3. Install expansion bellows between casing and piping 4. Bellows to be steel ring reinforced nitrile rubber 5. Connections to be flanged for through-bolting 6. Access door both upper and lower half
Couplings	Forged steel	Cast steel	1. Preferred non-lubricated 2. Keyed to shaft 3 Guards should be fitted
Valves			
Blower Suction and Discharge Valves	Cast steel with rubber liner	Cast Iron with rubber liner	1. Butterfly type recommended 2 Glass flake coating (30 mils DFT) either polyester or amine cured epoxy resin base may be used as can amine cured coal tar epoxy 3. For disc and spindle use 316L stainless or bronze
Regulating Valve	Disc - 316 stainless seat removable Teflon® Spring - stainless	Disc - bronze seat - Viton	1. Inspection port adjacent to valve on scrubber side 2. Moving parts keep free moving
Deck Nonreturn Valve	Body - cast steel Seat - stainless Clapper - stainless Spindle - stainless	Body - stainless	1. Exposed steel parts coated with polyester glass flake or amine cured coal tar epoxy 2. Always mount in horizontal and fore-and-aft position
Deck Isolation Valve	Body - cast steel Disc - stainless Spindle - stainless	Body - stainless	1. Preferably butterfly type 2. Coated with glass flake or coal tar epoxy 3 Removable Teflon® or Viton® desirable
Deck Water Seal (Wet Type)	Casing - mild steel Demister - polypropylene mesh mounted on 316 stainless	Demister - mild steel rubber lined	1. Internal coating of ebonite - external coating of inorganic zinc and epoxy 2. Steam coils - copper nickel 90/10 or 70/30 3 Level floats encapsulated in PVC recommended 4. Use glass ports for visual inspection

Chapter 3

TYPICAL INERT GAS SYSTEM

Figure 1 shows, in schematic form, a typical inert gas system using flue gas produced in firing the ship's boilers and exhausted through the boiler uptakes. The flue gas is drawn from the uptakes through the boiler uptake valve. The gas is then passed through the scrubber where it is cleaned and cooled. Regardless of the type of scrubber used, excess water must be removed either by demisters or a separate water separator.

Blowers distribute the inerting gas to the tanks.

Valves in the system include the blower discharge valve, the main regulating valve, a deck nonreturn valve, and a deck isolation valve and tank valves.

A deck water seal is installed to prevent hydrocarbon gases from the tanks from flowing to the fan or engine room.

A recirculating line between the blower outlet and the scrubber inlet protects against those periods when the system is in operation and no inert gas is required, and also allows start-up without sending air to the tanks.

Salt water pumps provide sea water for the water seals and the scrubber.

A drain system is provided for the water seals, the scrubbing tower, the water separator, and the fans.

Some installations contain a fresh water wash system for the fans, the water separators, and the scrubber.

Figure 2 shows, in schematic form, a typical inert gas system using gas from a separately fired generator. Such systems, as noted earlier, are used on diesel-powered ships and ships whose boiler capacity is too small to provide enough flue gas for the inerting system.

The subsequent chapters will discuss materials problems and requirements for each element of the flue gas system.

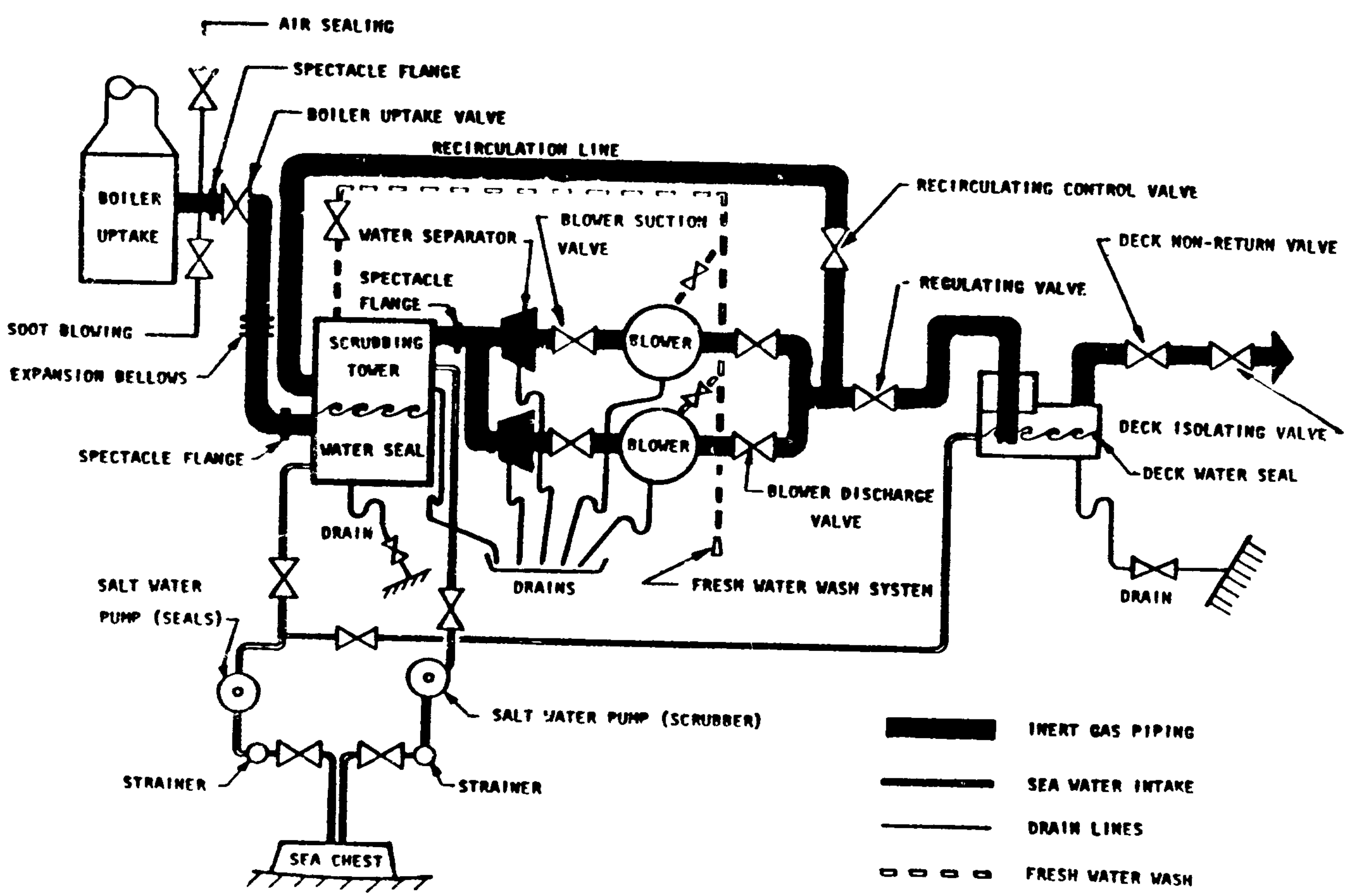


FIGURE 1 Typical Inert Gas System

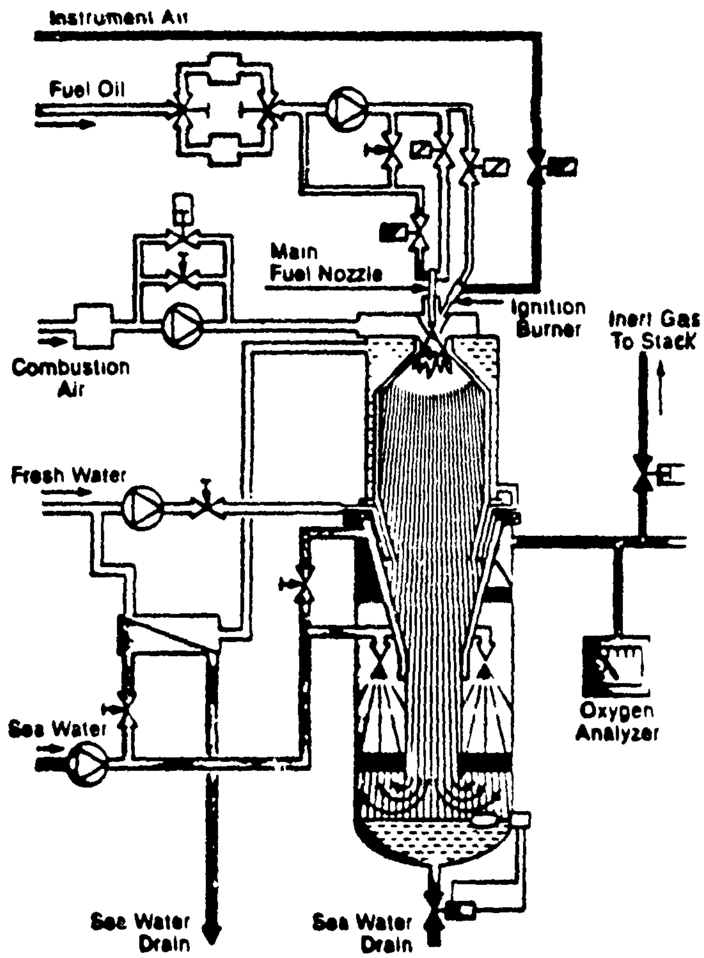


FIGURE 2 Inert Gas Generator

Chapter 4

HOT GAS AREA

Inert gas systems contain a number of distinctive areas from a corrosion viewpoint. Those items installed from the boiler uptake to the scrubber—boiler offtakes, flue gas piping, boiler uptake valves, and scrubbers—make up the hot gas area. Each component is exposed to hot corrosive gases and must be made of suitably corrosion-resistant materials if it is to perform reliably.

Boiler Offtakes

The inerting system draws its inert gas from the stack at the boiler offtake. Boiler offtake points should be carefully located above the economizer to prevent the formation of ferrous salts and hard soots as a result of fresh water washing of the economizer. Offtakes should not, however, be so close to the top of the stack that the inerting system draws fresh air down along the inside edge of the stack into the inerting system. This can be a problem, particularly when the inerting system is operating and the boiler is steaming at low load; the problem should be considered during the early design stages of the installation.

When installing an inerting system aboard a vessel that will use a rotary gas regenerative air heater for heat recovery, the uptake points should be located before the air heater and away from the seal area between the gas and air sides within the heater. Consideration should also be given to the direction of rotation of a rotary air heater relative to the uptake connection below the air heater to minimize the possibility of air carry-over. Seal leakage of fresh air across the heater into the flue gas will decrease the effectiveness of the inerting system.

Boiler scoops, if used, should be made of corrosion-resistant steel similar to that being used for the boiler uptakes, such as CORTEN®, galvanized mild steel, or their equivalent. Boiler scoops may, however, affect the reliability and safety of the inerting system, particularly the uptake valves, because they may trap and direct soot into the inerting system, particularly during noninerting modes of operation. This could eventually result in an accumulation of soot in the area of the uptake valves. Boiler scoops have not been widely used, however, and should not be required if the stack design is properly evaluated and the flue gas uptake points are properly located in the stack relative to the boiler heat recovery equipment.

Flue Gas Piping from Boiler Uptake to Scrubber

The flue gas piping between the boiler uptake and the scrubber (Figure 3) provides a gas-tight means of transporting the hot flue gases into the inerting system. The boiler uptake valves and expansion bellows (if required) are located in this piping. Conditions within this piping are quite severe because the gases are hot and corrosive, particularly when the ship is burning currently available Bunker C fuels, and contain significant quantities of soot.

PRECEDING PAGE BLANK-NOT FILMED

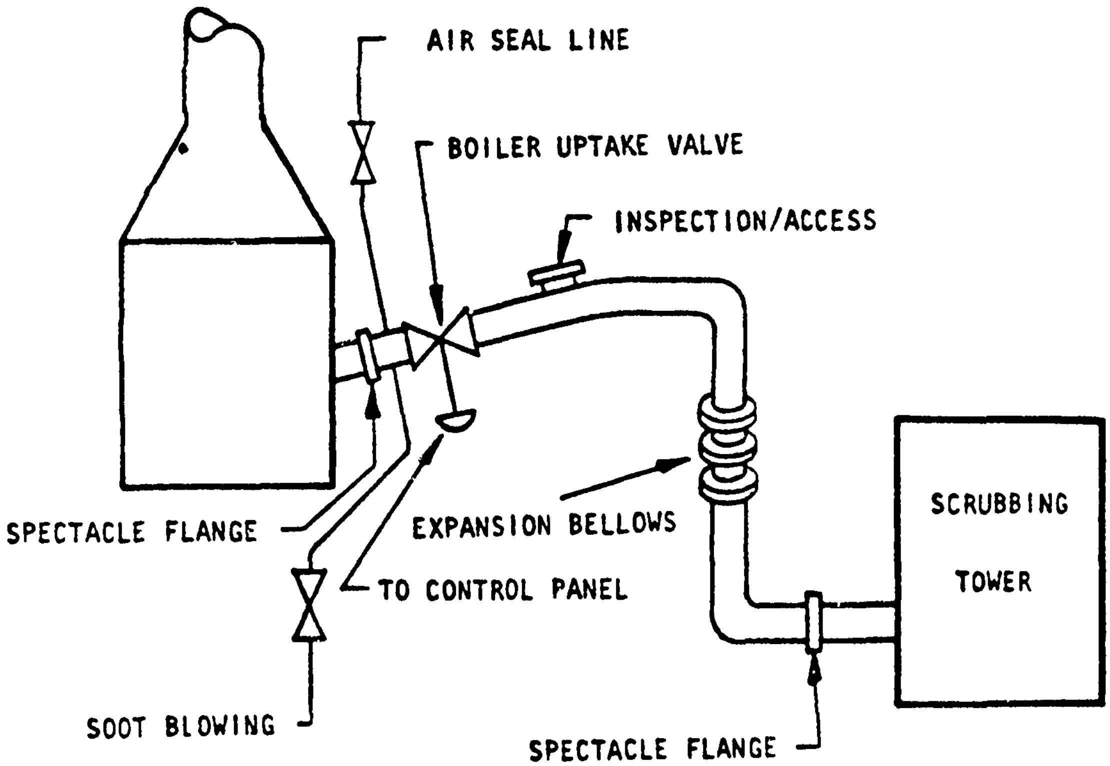


FIGURE 3 Flue Gas Piping from Boiler Uptake to Scrubber

Generally, the flue gas line is made of heavy-gauge galvanized mild steel or CORTEN®. It should be well lagged to maintain the temperature of the gas above the SO_2 dewpoint. Lines should be kept as short as possible and free of pockets to prevent accumulation of soot. If an expansion bellows is fitted, ideally it should be fitted in a vertical position. The bellows should be of acid-resistant materials such as Hastelloy C276, Inconel 625, or Incoloy 825. Nonmetallic bellows can also be considered, but they must be made of materials suitable for the temperatures associated with the particular installation.

Bellows should be flanged, not welded, into the flue gas line to facilitate maintenance. The design of the flue gas line must consider proper application of the expansion bellows for both lateral and axial movement and proper support considering high vibration levels to be encountered. If an internal support sleeve is required, it should be fitted so that it will not accumulate soot.

Boiler Uptake Valves

Boiler uptake valves protect the ducts, scrubber, and blowers from infiltration of flue gas, which can cause corrosion in the ducts. These valves also prevent air from being drawn into the inerting system from the uptake of an idle boiler when the system is operating on only one boiler.

At least one boiler uptake valve should be installed in each duct from the boiler uptake to the scrubber. The valve should be of the butterfly type with metallic seats having small positive clearances in the cold condition. The valve body and disc should be of cast or nodular iron; however, for higher temperature applications, Meehanite HA, cast steel, or their equivalent should be considered. The valve shaft should be of at least 316 stainless steel or equivalent. Each valve should have a pneumatic operator, limit switches, and position indicators.

During the shut-down condition, flue gas can enter the uptake piping if the flue gas valves leak. Leaks can result from corrosion or from a build-up of soot and salts that prevent the uptake valves from closing completely. Leaks are probably the major maintenance and reliability problem associated with uptake valves. Valves can, however, be kept relatively free from corrosion or buildup of deposits by installing an air sealing system as well as a soot blowing system for each valve.

An air sealing system should be installed on either the uptake side of the flue gas valve or between the valve and scrubber. This sealing air will help prevent flue gas from leaking into the inerting system. If sealing air is introduced downstream of the isolating valve, however, it must be secured when operating the inert gas system with one boiler idle. Sealing air can be obtained by tapping off the boiler-forced draft fan(s); however, during low-load operation, the effectiveness of this system is questionable. Alternatively, small independent sealing blowers can be installed to supply the sealing air when the valves are shut; these have proven quite effective. Two flue gas isolating valves may be used for each uptake, thereby permitting the sealing air to be introduced between the valves. Another arrangement would be a double disc valve with sealing air between the discs.

Each valve should have some means of keeping the seat clean. Compressed air or steam may be used and should be automatically controlled by the valve shutoff actuator to clean the valve each time just prior to closing. Two cleaning heads for each valve, or a circumferential blowing arrangement, have proven suitable. Compressed dry instrument air (if enough is available) is often preferred inasmuch as it prevents the introduction of moisture into the uptake area, which could contribute to the corrosion of the materials present.

An interlock must be provided between the inerting system uptake valves and the vessel's boiler soot-blower system to preclude the blowing of soot when the uptake valves are open and the inerting system is operating. A hamer blind or spectacle flange should be provided between the boiler uptake connection and the boiler uptake valve to allow for maintenance and valve removal when the boiler is operating. It is also recommended that an inspection opening be provided adjacent to the uptake valve on the scrubber side of the valve to allow for inspection without valve removal.

Flue Gas Scrubber

Boiler stack gas can be processed to provide a continuous, reliable source of inert gas. The system is based on a highly efficient scrubber whose purpose is to cool the inert gas and remove soot and SO_2. It is located between the uptake valves and the inert gas fans in a flue gas system (Figure 1) or directly after the inert gas generator in a separately fired inert gas generating system (Figure 2). The scrubber should efficiently cool the flue gas and remove a large portion of the soot and SO_2 through direct contact between the flue gas and large quantities of seawater.

There are many different types of scrubbers, but most of them basically employ bubble cap trays, packed trays, or impingement and agglomeration. Each type has its own particular design features and characteristics but performs essentially the same basic function.

On entering the scrubber tower, the flue gas is cooled by being passed through a water spray or bubbled through a water seal. This water seal, if provided, may also be designed to serve as an additional safety device to prevent backflow of gas to the boiler uptake.

The inlet area to the scrubber is one of the most demanding, as far as construction materials are concerned, in the entire inert gas system. This area, often called the inlet foot, must cope with the rigors of hot condensing sulfuric acid, cold salt water, and various combinations resulting from the mixing of the two. Although they can help to cool the gases, seawater sprays and associated cold seawater piping should be avoided in this area of a flue gas system, if possible, because of the hot corrosive conditions. If used, however, the sprayers and piping should be made from acid-resistant materials such as Hastelloy C276, Inconel 625, or their equivalent.

The inlet foot itself should be made from Incoloy 825 or titanium, both of which have performed quite well even in hotter applications. Other materials which appear quite suitable for this area are Hastelloy C276 and International Nickel EPE 5.

The scrubber base acts as a foundation for the scrubber and, in certain designs, may also provide a water seal. This area is also subject to severe corrosive conditions. Mild steel covered with rubber or glass-reinforced epoxy lining has proven quite successful. Mild steel clad with Incoloy 825, Inconel 625, or the equivalent, should be considered, however, in hotter applications. Care must be taken in preparing and welding these materials since dilution of the weld with material of inferior corrosion resistance will prove self-defeating. Painted steel in the area should be avoided.

After entering the scrubber through the inlet foot, the gases move upward into the scrubber tower through the downward flowing seawater. To maximize contact between flue gas and seawater, several layers of spray nozzles, pack trays, impingement trays, venturi nozzles, slots, or any combination of these are installed.

The scrubber tower should be fabricated from mild steel with an ebonite rubber or glass-reinforced epoxy lining or the equivalent. To obtain a good bond, sharp corners should be avoided and care should be taken during the installation of the lining. Welding in this area should be avoided, for obvious reasons, once the lining is applied. Fittings in this area should be made from corrosion-resistant materials such as polypropylene, Incoloy, stainless steel, or the equivalent. Externally, the scrubber should be suitably stiffened to preclude inward deflection because of fan suction, which can cause separation of the internal lining. The scrubber tower could be fabricated of Inconel 625 if a need existed for the best of all possible materials. This, however, has not been the case to date.

Where gas scrubbing or bubbling trays are used, they should be fabricated from Incoloy 825, polypropylene, or the equivalent. Holding-bolts should be fabricated from Incoloy 825 or its equal. Whenever packing bars are used they should be fabricated from fiberglass. Slotted impingement plates should be made from Incoloy 825.

Spray nozzles and water lines in the scrubber tower should be made from 90/10 copper-nickel, nickel-aluminum-bronze, or equivalent materials. When they are located in hotter areas of the scrubber, Incoloy 825 should be considered.

Because of the scrubbing interaction between the flue gas and seawater, some moisture will become trapped in the gas. A significant portion of this moisture, as well as additional soot, can be removed by demister pads, cyclone separators, or a combination of the two. The demisters or cyclone separators may be separate units or integral to the scrubber tower. When demister pads are used, they should be made from knitted polypropylene. Holding trays which support the pads can be fabricated from Incoloy 825, 316 stainless steel, or the equivalent.

If large quantities of soot are anticipated, it might be prudent to use a cyclone separator in lieu of demister pads, as the latter may easily become clogged and require frequent cleaning. Cyclone-type separators, if used, should be fabricated of mild steel lined with glass-reinforced epoxy lining, or noncorrodible reinforced plastic.

Float switches, if fitted in the scrubber base, should be plastic coated. Any associated fittings that are exposed to the salt water and gas should be fabricated of nickel alloy. Alternatively, by using polyvinylchloride encapsulated ultrasonic leveling devices, float valves can be removed from the corrosive environment of the scrubber base.

Installing a means of fresh water washing of the inlet foot and the scrubber tower after each use can greatly enhance the life of the scrubber materials.

Suitable access doors, preferably of the quick release type, should be installed to allow easy access to the scrubber for inspection and removal of scrubber internals, especially in those areas most susceptible to corrosion. In addition, spectacle flanges or hamer blinds should be provided before and after the scrubber to preclude the possibility of gas leakage when the scrubber is opened for inspection and maintenance.

If a gas recirculation line is installed, it should be protected with the coatings used for gas distribution piping described on pages 19 and 20 of this report. The line should be routed in such a way that gases and water spray that may enter the line are returned rather than held in a low point of the piping system.

Separately fired inert gas generators usually are not exposed to the severe environment encountered in flue gas systems inasmuch as they normally use a much better grade of fuel oil to produce the inert gas. Therefore, less exotic materials can usually be used to fabricate scrubbers for use with separately fired inert gas generators.

The gas generator and scrubber often are combined into an integral unit. After the gas leaves the generating area, where it is partially cooled by the combustion chamber cooling water, it enters the scrubbing portion which can be a series of spray nozzles or a combination of spray nozzles and trays. The scrubber is normally made of 316 stainless steel or equivalent materials, as are the spray nozzles, trays, and attachments.

If a particular application of a gas generator requires very clean gas, a secondary scrubber may be installed. This scrubber usually made of materials similar to those used for the scrubbing towers of flue gas systems.

Chapter 5

PIPING

This chapter covers the requirements of the cold water supply piping system, the seawater drain piping system, and the inert gas distribution system.

Cold Water Supply Piping System

The cold water supply piping system supplies cold seawater at moderate pressures to the scrubbing tower, the scrubber seal, and the deck seal. The piping materials for all three applications are similar; the materials currently used are 90/10 copper-nickel pipe, glass-reinforced plastic pipe, and aluminum-bronze pipe. Of the three types, the glass-reinforced plastic is the most corrosion-resistant and requires the least maintenance. The copper-nickel and aluminum-bronze pipe have been used in greater volume for this purpose until the present because the glass-reinforced plastic pipe has only recently been approved by the regulatory agencies for shipboard use. Reliability of each type of pipe is good; glass-reinforced plastic may be somewhat more reliable than the other two.

Seawater Drain Piping System

Seawater drain sources, in descending order of corrosion severity, are scrubber drain, scrubber seal drains, water separators in gas line from scrubber, fan drains, and deck seal.

Conditions for the scrubber drain and the scrubber seal drain are the most severe; conditions in the other drains are only slightly less corrosive. The conditions are: seawater; temperature (approximately 5^{o}F above ambient seawater); pH 2-3; and seawater containing sulfur dioxide, carbon dioxide, oxygen, and soot. Accumulations of soot can be strongly corrosive to local areas, and piping systems should be designed to eliminate spots where such concentrations can occur. The piping materials in use for these very severe conditions are glass-reinforced plastic pipe (GRP) made with acid-resistant polyester resins, and rubber-lined steel pipe. The shell penetration for overboard discharge of effluent is made with Schedule 160 steel pipe welded into the hull with a flange connection close on the interior of the hull. This outlet is rubber-lined (neoprene or hard rubber) or designed with a PVC insert. The overboard discharge valve is a flanged steel valve, rubber-lined. If GRP is used for effluent piping, an additional nonreturn valve inboard of the overboard discharge valve usually is required. This valve must be of similar construction to the overboard discharge valve. These piping systems are critical because of the severely corrosive conditions. If perforations occur, flooding results. Glass-reinforced plastic pipe has proven most effective and trouble free.

Inert Gas Distribution System

Inert gas distribution systems consist of piping that carries inert gas from scrubber to fans, from fans to deck seal, and from deck seal to main distribution line; individual tank piping; and vent lines.

The diameter of the piping in the inert gas distribution system ranges from 30 inches to approximately 8 inches. The pipe sections are flanged, or use Dresser couplings for connectors so that sections can be removed if corrosion or damage occur. Many installations also include clean-outs every 40 feet downstream of the deck seal for removing soot and corrosion. These clean-outs usually consist of a flanged Y or T with a blind flange covering the clean-out opening. The conditions within the pipe are: gas at ambient temperature; gas of an average composition of nitrogen (81%), carbon dioxide (12-14%), oxygen (2-4%), sulfur dioxide (0.002-0.003%), water vapor (the remainder); soot accumulation; and water condensate mixed with soot. Thus, serious corrosive conditions usually can be found in areas where the protective coating is deficient, such as along welds, on the interior edge of flanges, and in the pipe adjacent to flanges or couplings. The water condensation can be acidic because of the sulfur dioxide and carbon dioxide in the gas. The distribution lines must drain to a low point with a drain opening so the corrosive condensate does not concentrate.

The materials used for the inert gas distribution piping are heavy-walled steel pipe lined with:

- A coal tar epoxy lining which generally consists of an epoxy primer with a high-build, amine-cured coal tar epoxy lining applied to a total dry-film thickness of approximately 20 mils.

- A so-called pure epoxy coating which is an amine-cured epoxy applied as a primer and two finish coats, with a total dry-film coating thickness of not less than 10 mils.

- An epoxy phenolic coating with a total thickness of approximately 10 mils, preferably baked or stoved for maximum resistance.

The application of any coating exposed to the above corrosion conditions is critical. Before installation, each section of pipe should be tested with a nondestructive holiday (uncoated area) detector for coating imperfections.

The pipe lining that has been used most frequently in the inert gas distribution piping systems is the coal tar epoxy coating. It has proven effective providing it has been applied with care.

Periodic inspection of the lining is required at the usually scheduled drydock and repair periods. Necessary maintenance can be done at this time. The valves used in the gas distribution system are primarily cast iron or steel butterfly valves, rubber lined or epoxy coated. Rubber-lined valves have been the most trouble-free and reliable.

The conditions in each of the above piping systems are strongly corrosive. The most reliable piping and the most resistant lining material should be used to assure trouble-free operation and maximum safety.

Chapter 6

BLOWERS

This chapter identifies desirable material and design characteristics of blowers in inerting systems using boiler flue gas.

Inerting systems that use separate gas generators also require blowers, but they handle only air. The blowers in these systems are located upstream of the combustion chambers, much like the forced draft fans which provide the combustion air for the ship's boiler(s). The service environment has no impact on materials selection for these blowers, which present no unusual problems. They are treated only briefly here. A straight-forward engineering approach, considering the service requirements, capacity and pressure, and the usual marine environmental requirements, is sufficient for selecting materials.

Blower Service

The blowers determine the quantity of gas delivered to the tanks and must, therefore, be designed to deliver the proper quantity under the designated condition. Operations of the inert gas system which affect the design requirements of the blowers are:

- Pumping cargo - during which the flow of inert gas to the tanks must exceed or at least equal the flow of liquid from the tanks.

- Purging tanks and re-inerting after gas freeing - during which inert gas blown into tanks replaces air or hydrocarbons, which are discharged to atmosphere by either mixing or displacement.

- Tank washing - similar requirement to that which exists for pumping cargo, but with lower flow rates.

- Topping up inert gas pressure on ballast or loaded voyage - to maintain pressure in tanks above atmospheric. Gas flow initially at high rate but low pressure and, as the tanks fill, concludes at low flow rates but high pressure.

- Gas freeing - with fresh air to allow personnel to enter tanks. Flow characteristics are the same as for purging tanks.

Pumping cargo is the most important of the above operations since entry of air during pumping must be avoided. Most classification societies and government authorities require that inert gas systems be designed to deliver at least 125% of the maximum rated capacity of the cargo pumps. It is strongly recommended that each blower in an inerting system be sized for the full design capacity of the system, although this is not usually required by classification societies. This recommendation is based on experience that has indicated that the blowers are the system component most prone to failure.

The requirement that blower capacity be 25 percent above the rated capacity of the cargo pumps allows for the variations in system head/capacity characteristics that are encountered in service at the various discharge terminals, where cargo discharge rates can go beyond normal maximum pump ratings at lower than rated heads. In such cases the cargo discharge would have to be slowed down. With proper design, which is beyond the scope of this document, this remote possibility can be avoided. It is, in the main, a question of the proper shape of the blower head/capacity curve, associated with controls which monitor where one is operating on the curve. This control system precludes operation in certain areas of the curve where the blower/head capacity and systems-resistance curves are not properly matched.

Blower Type

System design head/capacity requirements coupled with the need to control oxygen content determine whether a blower or compressor is selected for any given system. With the characteristics required in today's systems utilizing flue gas, a centrifugal blower is the optimum choice. With the hostile environment in which the blowers operate, this is a simple, effective solution to the maintenance problems that would be encountered with a compressor.

When system pressures are higher and there is also a need for close control of gas quantity (for control of oxygen content), a compressor is called for. These conditions exist with inert gas generator systems (Figure 2), but not with flue gas systems. In the former instance, only air is handled, as noted earlier; hence, conventional marine equipment is satisfactory.

Blower Component Requirements

Impellers

The usual choices of materials for impellers are nickel-aluminum-bronze or low-carbon austenitic stainless steel. Welded impeller construction is often subject to corrosion or brittle fracture in the case of nickel-aluminum-bronze if stresses are not relieved properly. Riveted or cast construction could eliminate problems caused by improper welding; however, riveted aluminum-bronze units are prone to severe wastage from the inner edges of the vanes. Riveted construction of impellers is not recommended.

Since most blower failures are caused by corrosion or erosion of the impeller, which leads to imbalance, a fixed fresh water rinsing system for the blowers is highly desirable. The blower manufacturer should be consulted about nozzle placement and method of rinsing to ensure that erosion is not aggravated by the rinsing procedure.

Impellers supported on both sides by pedestal-mounted bearings are generally preferred to overhung impellers, to minimize balancing and vibration problems, which can be expected to appear with age.

Shaft

Impeller shaft materials usually are nickel-aluminum-bronze or low-carbon austenitic stainless steel, the same as for the impeller. Impellers should be keyed to the shaft and secured by set screws or interference fit.

Bearings and Seals

Shaft bearings and seals should be accessible for inspection without having to dismantle ducts or casings. Bearing housings of the pedestal type, mounted remote from the casing, are, therefore, preferred. Consideration should be given to using split-type ball or roller bearings designed to permit removal without dismantling the shaft, disconnecting the coupling, or moving the blower or motor. Shaft seals must be gas-tight to prevent leakage into the surrounding space or ingress of air in the case of bearings on both sides of the impeller.

Casing

The blower casing should be constructed of welded carbon steel of suitable thickness and adequate stiffening to prevent panting. It is preferable that the casing be of a split design which will permit removal of the rotor without dismantling any connections to ducts or piping. An acceptable alternative design is a horizontal split casing, provided that the arrangement of piping allows removal of casing and rotor without removing more than the expansion bellows and transition piece. Expansion bellows should be fitted between the fan casing and connecting piping to ensure that no loads are transferred to the casing. Expansion bellows should be nitrile rubber reinforced with steel rings. Woven asbestos with steel rings has proven unsatisfactory.

All connections to the casing should be flanged for through-bolting. Threaded connections should be avoided on the casing. Access doors should be provided on the upper and lower half of the casing to allow for inspection of the impeller and insertion of a lance for water washing. The access doors should be retained by a single strongback for ease of opening for inspection. A flanged drain connection, a minimum of 2 inches in diameter, should be provided at the low points of the casing.

The casings should be lined internally with rubber or fiberglass-reinforced plastic. Fiberglass linings have the advantage of easy repair, but may be more affected by abrasion than rubber. Coal tar epoxy has also been used, but with far less success than the rubber or fiberglass linings because of coating breakdown through erosion and subsequent corrosion. Glass-flake-filled polyester resin coating is being used to repair failed coal tar epoxy coatings.

Couplings

The coupling between the blower and driver should be a forged or cast steel flexible coupling, preferably nonlubricated. The coupling should be keyed to the shafts. Coupling guards should be fitted.

Bedplate and Resilient Mounting

The blower and driver should be fitted on a common bedplate with a suitable drainage arrangement. Naturally, the shafts of the blower and driver should be aligned parallel to the vessel's centerline to minimize the effect of roll. The bedplate should be stiff enough to prevent distortion and misalignment. This is particularly important when bearings are pedestal-mounted remote from the casing.

The bedplate and foundation should be deep enough to allow access to drain connections and piping beneath the casing.

Drivers

Electric motors or steam turbines have been the usual choices for blower drivers. Electric motors are preferred because they have proven more reliable than turbines. Totally enclosed fan-cooled motors with space heaters and insulation suitable for their location in the ship have generally proven most reliable.

Chapter 7

VALVES

Blower Suction and Discharge Valves

The purpose of the blower suction and discharge valves is to isolate one or both blowers from the system. Butterfly valves are recommended. The first choice of material is cast steel. Cast iron may also be used; it is less expensive, but more difficult to repair. In either case, the body should be rubber-lined, with the rubber liner forming the seat. Glass flake coating (30 mils dry film thickness), based on polyester or amine cured epoxy resin, is a good alternative to rubber because it is easily repaired. A Teflon® seat can be inserted and is easily replaced on board, especially if the valve is the butterfly type, which is handily removed from the line.

When choosing a rubber-lined valve, avoid those with bonded liners because they are difficult to repair to their original state and will have to be sent to an outside repair facility. Amine cured coal tar epoxy and polyester glass flake are both possible linings. The former may wear slightly less well than the latter, but can be repaired just as readily. Both linings require grit blasting before application. Replaceable rubber liners should be used because of ease of replacement in the field.

For the disc and spindle, 316L stainless steel is a good choice. Bronze is an alternative, but the spindle should also be bronze so as to avoid electrolytic corrosion.

Whatever the material, these valves will certainly have to be removed from the line, cleaned, and inspected at each drydock period.

Even if the seat, disc, and linings are in good condition, there will almost certainly be a build-up of soot that must be periodically removed to prevent impairment of the sealing capability of the valve, which would render it useless as an isolating device.

Regulating or Main Control Valve

The main control valve is fitted downstream of the blowers, generally close to the final bulkhead that separates the safe from the hazardous area. Its primary purpose is to ensure constant pressure to the deck distribution system. Excess pressure is relieved by venting gas to the atmosphere or sending it back to the scrubber via a recirculation line and valve.

The regulating and recirculating valves together incorporate important safety features into the system; the regulating valve must be automatically actuated or may be a dead-weight valve. When one of these valves closes, the other opens, keeping a constant predetermined pressure on the deck mains. The safety aspect results from the regulating valve closing to automatically prevent backflow of gas. This can be triggered by failure of the inert gas blowers, scrubber pump, etc., or by failure of the deck water seal and mechanical nonreturn valve so that the pressure of gas in the tank exceeds the blower discharge pressure, e.g., during simultaneous stripping and ballasting. The regulating and recirculating valves should have a fail-safe capability to ensure closure upon failure of actuating power. An inspection opening should be provided adjacent to the regulating valve on the scrubber side of the valve to allow for inspection without valve removal.

The regulating and recirculating valves operate in the same environment as the blower isolating valves, so the same options for materials apply. The relative simplicity of a dead-weight valve makes it a good choice as a recirculator. Whether the valve is operating can readily be determined with a positioning arm. A dead-weight valve should be mounted in a horizontal and fore-and-aft position. Hinges and other moving parts must be maintained to keep them operating freely. Good choices for the disc of the dead-weight valve are 316 stainless steel or aluminum bronze. The seat may be of removable Teflon® or, if rubber-lined, of rubber or Viton®. A suitable material for a spring, if fitted, is 316L stainless steel.

<u>Deck Mechanical Nonreturn Valve</u>

The deck mechanical nonreturn valve is a further precaution to avoid backflow of gas from the cargo tanks; it also prevents backflow of liquid that may enter the inert gas main if the cargo tanks are overfilled. This valve should be fitted forward of the deck seal and should operate automatically at all times. It is available in a fairly elaborate form or as a simple dead-weight or spring-operated valve. The simpler is the better choice, because the simpler the system the less chance of mishap.

A cast steel body with a 316L stainless steel seat, clapper, and spindle is a good selection. All exposed steel parts should be coated with a polyester glass flake or amine cured coal tar epoxy coating. If a stainless steel body is used, a removable Teflon® seat would be better.

This valve should always be mounted in a horizontal and fore-and-aft position. The amount of water carryover depends on the type of water seal employed; it could require more frequent internal inspection to clean out accumulated soot and ensure that internal parts are moving freely.

Deck Isolating Valve

The deck isolating valve is fitted just downstream of the nonreturn valve to provide positive isolation of the deck main from the deck water seal and the remainder of the system. An inspection opening should be fitted between the nonreturn valve and deck isolating valve to allow for inspection of both valves without their removal.

This valve may be either a hand or remote operated valve, preferably a butterfly type. It should be a coated cast steel valve with a 316L stainless steel disc and spindle. If polyester glass flake or amine cured coal tar epoxy coatings are used, a removable Teflon® or Viton® seat is desirable. Reliability and maintenance of the deck isolating valve are similar to those of the nonreturn valve because they perform the same kind of service.

Deck Water Seal

The deck water seal is the principal barrier to leakage of hydrocarbon gas back into the space occupied by the blowers and scrubbers. A water trap is fitted that permits inert gas to be delivered to the deck main but prevents any backflow of cargo gas, even when the inert gas plant is shut down. It is vital that a supply of water to the seal be maintained at all times, particularly when the inert gas plant is shut down, so, two independent supplies should be provided. Both water inlet pipe and drain from deck seal overboard should be fitted with water traps that vent to the open deck. In addition, drains should be led directly overboard and not passed through machinery spaces.

Several types of deck water seal are available. The simplest is the wet type; its drawback is water carryover downstream. To reduce this, and the obvious consequence of corrosion downstream, a demister (a mesh that entrains water droplets, preventing their carryover downstream) is fitted. An outer casing of mild steel with an internal coating has proven satisfactory, e.g., mild steel grit-blasted to SA 2-1/2 and coated outside with an inorganic zinc primer and epoxy topcoat and inside with 3 mm of ebonite. Repairing a rubber-lined interior can be difficult; care should be taken to ensure that no welding is done on the exterior casing because it would destroy the lining. The acidic conditions so prevalent in the scrubber are less severe in the deck seal, but nonetheless must still be reckoned with.

A compromise lining for the seal interior is a polyester glass flake or amine cured coal tar epoxy lining, in that order. These should be applied to a grit-blasted surface (SA-3) with spray equipment to a dry film thickness of 30 mils. Either system is easily repaired by spot blasting and touch-up.

If the wet type of seal is used, a demister is required. Polypropylene mesh is strongly recommended, with a demister mounting material of 316L stainless steel. A weir arrangement is also used in this type. Mild steel, rubber lined, has proven trouble-free. That portion of the gas inlet pipe always awash has been kept corrosion-free when constructed of Incoloy 825, as have the venturi inlets in the dry types of seal. An acceptable alternative is coated mild steel.

Care must be exercised to prevent rapid erosion in the area of the weld. Extreme care must be used when welding dissimilar metals; the proper rod must be used, and an extremely smooth weld must be achieved.

Copper-nickel 90/10 or 70/30, is a good selection for steam coils and drains. It welds more easily than aluminum-bronze and gives a good, smooth profile.

Static, ultrasonic level floats encapsulated in PVC have proven extremely reliable. Monel floats, unprotected, have been found wasted within a year.

The part of the gas inlet pipe above the water level should be coated inside and out. Means should be provided to check the condition of this pipe easily. Should it develop holes, the seal will not perform properly in shutdown condition.

Glass ports should be provided in the seal to allow visual inspection of level and conditions. Thorough internal inspection must be made at least every two years. This inspection should include the system as a whole. This would be the minimum for good maintenance. Inspection, at intervals established by a classification society, should, of course, be carried out by a competent, certified inspector.

Chapter 8

INSTRUMENTATION; CONTROL AND ALARM SYSTEMS

Instrumentation required or recommended to assure the realiability, maintainability, and safety of the inert gas system should measure continuously the following parameters:

- Temperature
- Pressure
- Flow
- Liquid level
- Oxygen concentration

Flue-Gas System

Figure 4 illustrates the instrumentation recommended for an inert gas system employing flue gas from the ship's boilers. This illustration starts at the flue-gas scrubber, since combustion control and boiler operation instrumentation is assumed to be already in place and is not the primary concern of the inert gas system.

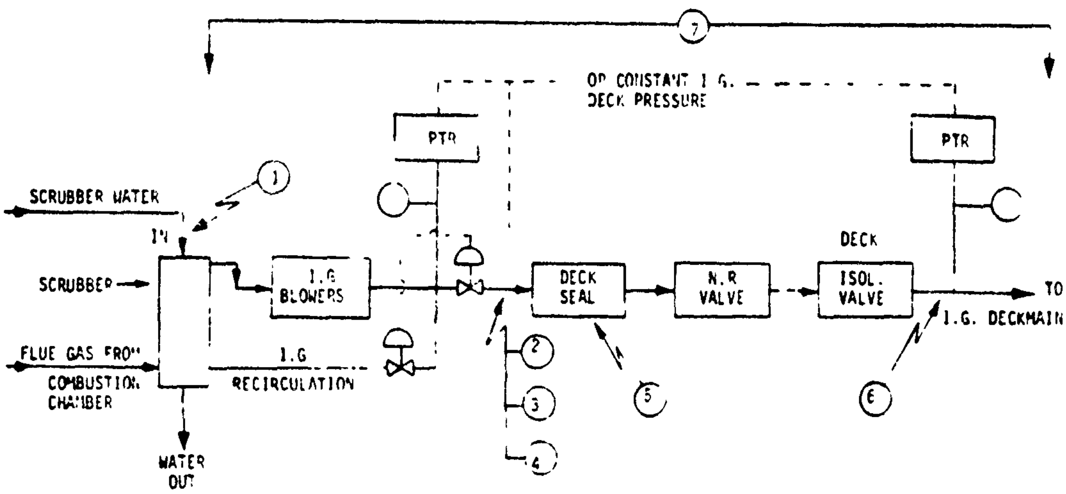


FIGURE 4 Instrumentation for Inert Gas System Using Flue Gas

Table 2 is an instrumentation guide that augments Figure 4 by identifying sample points, measurement involved, type of readout and alarm, and automatic control requirements. Locations for readouts and alarms are also recommended.

Inert Gas Generator System

The instrumentation recommended for an inerting system using an inert gas generator is necessarily more elaborate since the reliability of the combustion process and its auxiliary monitors and controls must be included in the system.

Figure 5 illustrates a typical flow sheet of an inert gas generator with the instrumentation parameters involved.

Table 3 identifies sample points, measurements involved, readout requirements, alarm recommendations, automatic control-shutdown requirements, and suggested readout locations.

Instrumentation Requirements

As mentioned above, the instrumentation on an inert gas system includes instruments for measuring pressure, temperature, flow, and level. Most of the instruments are relatively simple and reliable; they have long been employed, both on shipboard and throughout the industry, and need not be further described here. However, the required continuous oxygen measurement, because of its importance to the safety of the inert gas system, deserves further discussion. Also, the conditioning of the sample that must be delivered continuously to the oxygen analyzer is of equally vital importance to the success of the measurement in respect to reliability, maintainability, and safety.

Oxygen Analyzers

There are a variety of ways to measure continuously the oxygen concentration of gases. The three most common methods are:

Magnetic susceptibility—the oldest technique, but still widely employed for many applications throughout industry. The gas stream being analyzed must be reasonably free of particulates. The sensor is somewhat sensitive to shock and tilt compared with the other types. However, this type of analyzer has an excellent history in tanker fleets. Speed of response is excellent (90 percent in less than one minute).

Polarographic measurement—a newer technique that has found excellent acceptance. The sensor consists of an electrochemical cell into which the oxygen diffuses through a porous membrane. The sensor is very rugged and can tolerate reasonable amounts of particulates.

TABLE 2 Instrumentation Guide for Flue Gas Systems

No.	Sample Point	Measurement	Readout and Alarm: Indicator	Readout and Alarm: Recorder	Readout and Alarm: Alarm	Auto. Controls Requirements
1	Scrubber Water Supply	Pressure	Yes	No	Yes-Lo	Blower Shutdown
2	Blower Discharge	Temperature	Yes	No	Yes-Hi	Blower Shutdown
3	Blower Discharge	Pressure	Yes	No	Yes-Lo	
4	Blower Discharge	O_2 Level	Yes	Yes	Yes-Hi	
5	Deck Water Seal	Level + Flow or Pressure	Yes	No	Yes-Lo	Blower Shutdown
6	IG Deck Main	Pressure	Yes	Yes	Yes-Lo	
7	Power to Instrument	Elec. On/Off	Yes	No	Yes-Off	

The siting of the above indicators, recorders, and alarms to be in Engine Room (or at hand for the engineer of the watch).

It is required that the Temperatures (2), O_2 Level (4), and IG deck pressure (6) also be indicated at the cargo control room.

An IG deck pressure indicator also should be located on the bridge.

Source: (1978). ICS/OCIMF "Further Development of International Standards for Inert Gas Systems." Inert Flue Gas Safety Guide, FP/224.

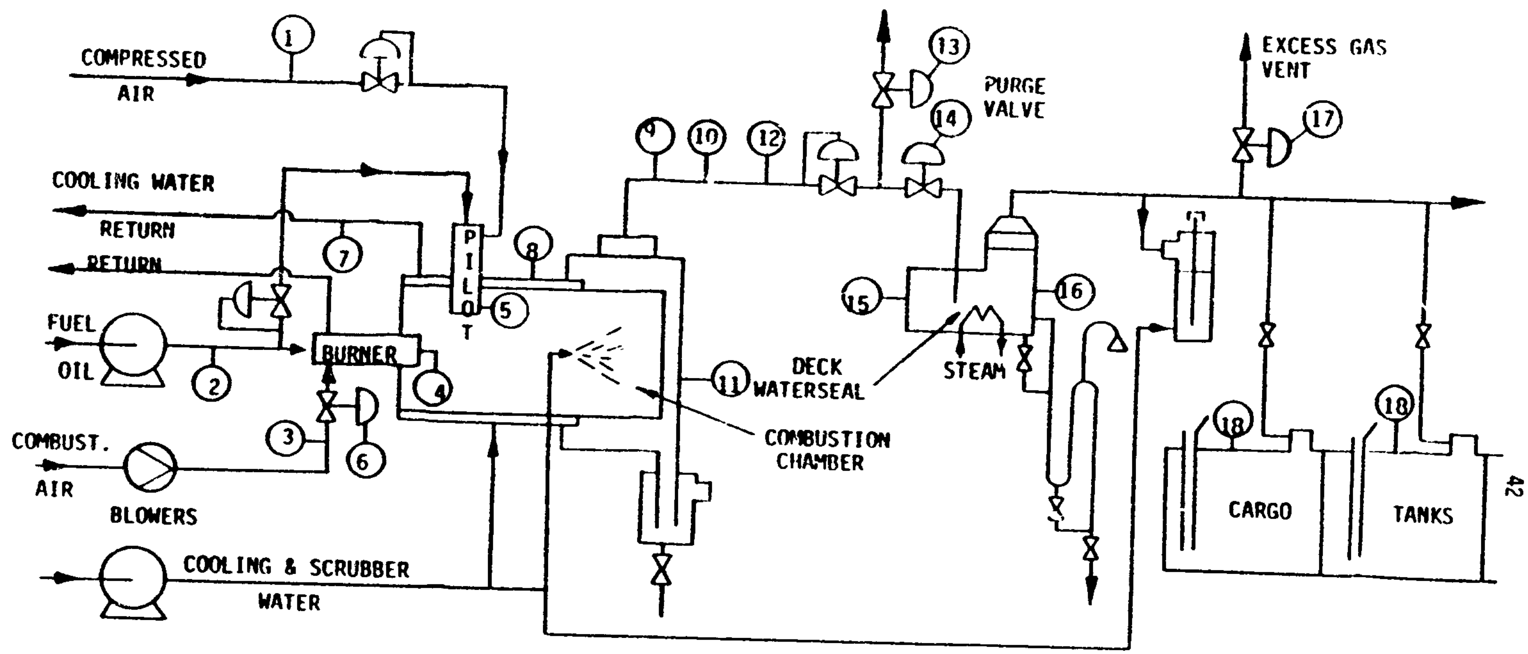


FIGURE 5 Flow Chart of an Inert Gas Generator

TABLE 3 Instrumentation Guide for Inert Gas Generator Systems

No.	Sample Point	Measurement	Readout/Alarm Indicator	Readout/Alarm Recorder	Alarm	Auto. Emergency Shutdown	Readout Locations Eng. Rm.	Readout Locations I.G. Gen. Cont. Panel	Readout Locations Bridge
1	Compressed air	Pressure	Yes	No	Yes	Yes	Yes	Yes	No
2	Fuel oil supply	Pressure	Yes	No	Yes	Yes	Yes	Yes	No
3	Combustion Air	Pressure	Yes	No	Yes	Yes	No	Yes	No
4	Flame status - Main	Scanner	No	No	Yes	Yes	No	Yes	No
5	Flame status - Pilot	Scanner	No	No	Yes	Yes	No	Yes	No
6	Combustion Air	Remote Manual Cont.	Yes	No	No	No	Yes	No	No
7	Cool water return	Temperature	No	No	Yes	Yes	No	Yes	No
8	Cool water supply	Pressure	Yes	No	Yes	Yes	Yes	No	No
9	Inert gas	Temperature	Yes	Yes	Yes	Yes	Yes	Yes	No
10	Inert gas	O_2 Analysis	Yes	Yes	Yes	No	Yes	Yes	Yes
11	Cool. water (scrubber)	Level	Yes	No	Yes	Yes	No	Yes	No
12	Inert gas	Pressure	Yes	No	Yes	Yes	No	Yes	No
13	Inert gas purge	Pressure	Yes	No	Off/On	No	Yes	No	No
14	Inert gas delivery	Pressure	Yes	No	Off/On	No	Yes	No	No
15	Deck seal water	Flow or Pressure	Yes	No	Yes	Yes	Yes	Yes	Yes
16	Deck seal water	Level	No	No	Yes	Yes	Yes	Yes	Yes
17	Inert gas deck main	Pressure	Yes	Yes	Yes	No	Yes	No	Yes
18	Cargo tank gas	Provisions (taps) for local manual check							

The solid oxide "fuel cell"—is a newer method that employs a heated (850°C) zirconium oxide sensor. It is widely used in combustion control processes. However, its usefulness in this application may be questioned because of the potentially hazardous condition it might create when the sample gas exceeds the lower explosive limit. Because of this aspect, the method is not recommended unless special means are provided to guarantee that the sensor cannot be a source of ignition.

For assistance in selection, Table 4 compares the recommended types of analyzers.

TABLE 4 Comparison of Oxygen Analyzers

Type	Accuracy	Shock Sensitivity	Speed of Response	Sensitivity to Dirt	Simplicity
Magnetic Susceptibility	A	B	B	C	B
Polarographic	B	A	B	B	A

(A = Best, B = Good, C = Acceptable)

Both the magnetic susceptibility and polarographic analyzers are available as portable battery-operated instruments or continuous monitors.

The range of the analyzer, ideally, should be 0-10 percent O_2 (by volume) to permit a mid-scale 5 percent maximum allowable O_2 and with an alarm to be set at 8 percent. The analyzer also should have a selectable 0-25 percent O_2 range to permit periodic air calibration (21 percent O_2). Automatic alarm deactivation during calibration should be coupled to this high-range position.

Materials of construction recommended for sensor, tubing, and fittings exposed to sample stream include PVC, polypropylene, fluorinated hydrocarbon, 316 stainless steel, ceramic (alumina, etc.), fluorinated hydrocarbon-lined steel, and synthetic or natural rubber gasketing and O rings.

Analyzer calibration by use of ambient air (21 percent O_2) should be performed daily. Routine preventive maintenance, and replacement of consumable parts should be performed every 30 days or at a frequency recommended by the analyzer manufacturer.

Sample Handling Requirements for Continuous Oxygen Analysis

The major parameters requiring attention in the sampling of gases from combustion involve:

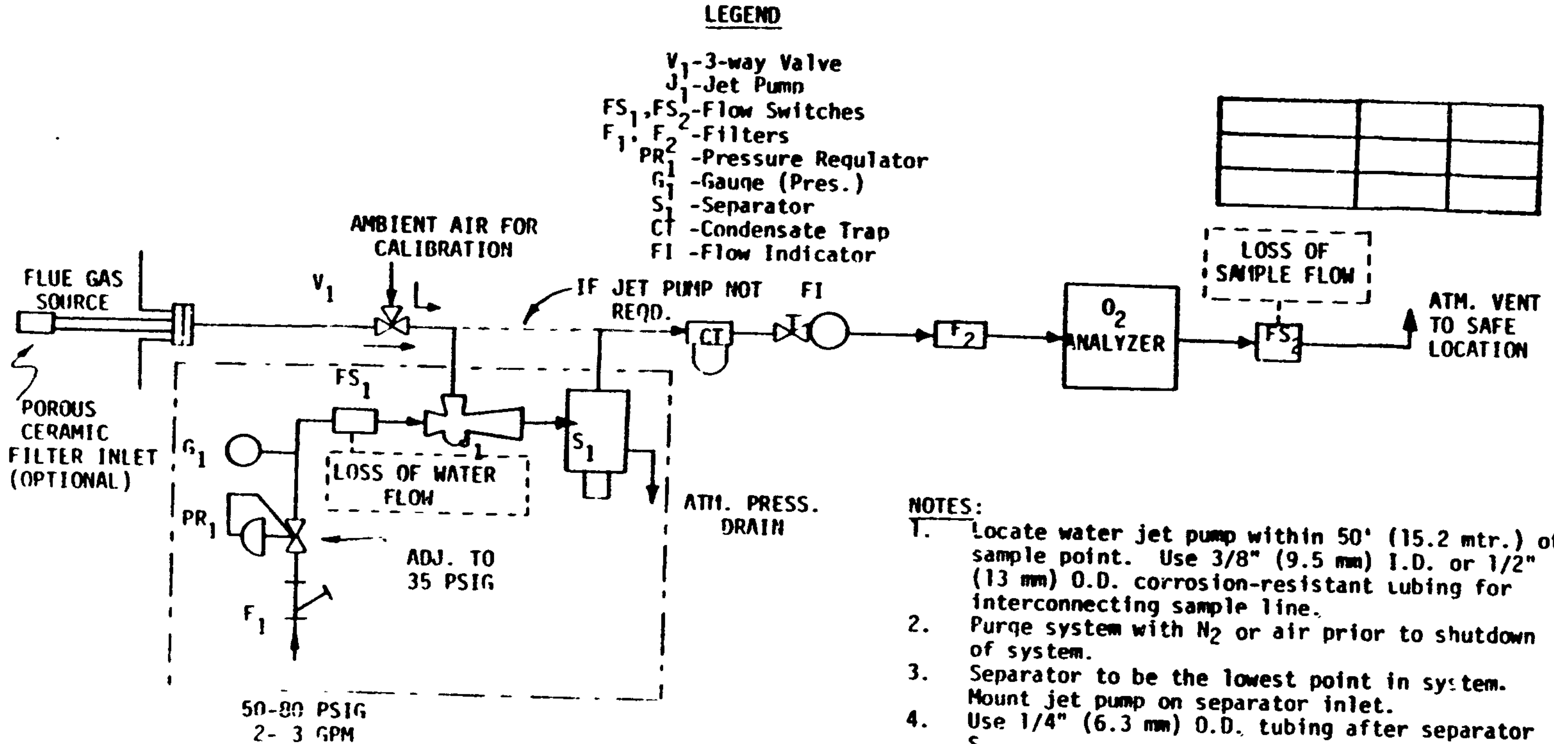
- Particulates
- Condensate and saturated water vapor
- Corrosivity
- Temperature

From a maintenance standpoint, particulates are the major problem. Typically, they can be removed by various porous ceramic filters at sample intake (Figure 6) followed by a spool-type large area fiberglass or woven plastic filter downstream. These devices are subject to blinding, increasing pressure drop across the filter, and eventual loss of flow unless they are replaced or cleaned regularly. The spool-type guard filter should be replaced monthly or as needed.

Although a positive pressure will exist downstream from the blowers, it may be variable and not adequate for the sample flow to the analyzer. If this is the case, it is recommended that a water eductor be employed (Figure 6). This will require 2-3 GPM of seawater at 50-80 psig. Sample flow should be about 250 cc/min. If employed, the eductor will also serve as a further particulate remover to provide a cool, particulate-free sample to the analyzer. Flow switches on the eductor and sample stream leaving the analyzer are recommended to provide audible and visible alarms should either flow stop.

The analyzer can be calibrated manually or automatically (manual operation shown) simply by opening the sample line ahead of the eductor and drawing in ambient air. If an eductor is not used, it will be necessary to stop the sample flow and force ambient air into the analyzer. With the polarographic sensor, an alternate method of calibration is simply to remove the sensor from its holder and expose it to ambient air. Since the analyzer typically will be on a 0-10 percent O_2 range, it will be necessary to switch to a higher range, such as 0-25 percent O_2, to calibrate at the 21 percent O_2-in-air level. During this interval, the true oxygen level of the flue gas must be "frozen" to avoid alarm actuation. Again, this and the complete calibration procedure can be automated.

All components shown in the sample handling system can be obtained in fluorinated hydrocarbon, 316 stainless steel, Hastelloy C, and/or appropriate plastic materials. The sample line from the blower discharge to the three-way air-calibrate valve should be 1/2-inch armored fluorinated hydrocarbon; thereafter, 1/4-inch fluorinated hydrocarbon tubing should be used.



NOTES:

1. Locate water jet pump within 50' (15.2 mtr.) of sample point. Use 3/8" (9.5 mm) I.D. or 1/2" (13 mm) O.D. corrosion-resistant tubing for interconnecting sample line.
2. Purge system with N_2 or air prior to shutdown of system.
3. Separator to be the lowest point in system. Mount jet pump on separator inlet.
4. Use 1/4" (6.3 mm) O.D. tubing after separator S_1.
5. Protect interconnecting sample line from freezing (heat trace as required by customer).

FIGURE 6 Flow to Oxygen Analyzer

Portable Oxygen and Combustibles Analyzers

As mentioned above, both the magnetic susceptibility and polarographic analyzers are generally available as battery-operated portable instruments. Older portable oxygen analyzers, based on chemical reaction colorimetric/volumetric techniques, also are available.

The combustibles analyzer typically reads out in 0-100 percent lower explosive limit (LEL). Usually it consists of an active and reference catalytic element within a Wheatstone bridge. Hydrocarbons diffusing into the cell are oxidized, causing a rise in temperature and change in resistance within the bridge. Thus a measure of percentage under the LEL is obtained. These are simple, rugged analyzers that are available for continuous or portable spot-check duty.

Since most portable oxygen and combustibles analyzers are battery operated and theoretically capable of producing a spark, care must be exercised in sampling from individual cargo hold taps. Various battery-powered or manual air pumps are available to pull the sample through the analyzers if necessary. It is recommended that portable analyzer inlets be equipped with flame arresters as a further precaution.

Auxiliary Supplies and Spare Parts

Because of the importance of the oxygen level in the inert gas, it is recommended that an interchangeable sensing element be maintained as a replacement in the event of sensor malfunction or failure.

A number of spare filter elements or cartridges should be stocked.

The combustibles analyzer must be calibrated against a standard hydrocarbon gas such as methane or propane. Typically, a 50 percent LEL gas blend is supplied in a pressurized cylinder for calibration purposes. As mentioned earlier, ambient air is all that is required for calibrating the oxygen analyzers.

The recommendations of the suppliers for both analyzers and sample handling system components should be followed in respect to recommended spare parts.

BIBLIOGRAPHY

Bell, A. "Inert Gas System: Design of Components." Presented at the Asia Marine 1979 Conference, Institute of Marine Engineers, February 1979.

Day, C.F., D.H.W. Platt, M.A. Telfer, and R.P. Tetreau. "The Development and Operation of an Inert Gas System for Oil Tankers." Transactions of the Royal Institute of Naval Architects, Vol. 114, 1972.

Day, C.F. and M.J. Johnson. "An Operator's Experience and Views on Inert Gas Systems for Oil Tankers." Presented at the Asia Marine 1979 Conference, Institute of Marine Engineers, February 1979.

Franklin, E.R. "Inert Gas: How and Why It Is Used in Tankers to Prevent Explosion." Marine Engineering/Log Magazine, June 1977.

Hatlen, P. "Application of IGS to Existing Tankers." Ship Research Institute of Norway. Trondheim, Norway, 1979.

Hickman, W.W. "Flue Gas Inerting Systems: One Contractor's Experience." Marine Technology, Vol. 15, No. 4, October 1978, pp. 411-415.

Intergovernmental Maritime Consultative Organization (IMCO), Committee on Fire Protection. "Further Development of International Standards of Inert Gas Systems." ICS/OCIMF Inert Flue Gas Safety Guide, November 1978.

Levens, M. "Metallurgy of Inert Gas Systems." Transactions of Institute of Marine Engineers, Vol. 90, Series A, Part 1, 1978.

Levens, M. "Materials for Inert Gas Systems." Presented at Asia Marine 1979 Conference, Institute of Marine Engineers, February 1979.

Riksheim, Jens B. and Johannes Nesse. "Inert Gas Systems in Oil Tankers (Project Report No. 2) - Experiences from Operations of Inert Gas Systems." Norske Veritas, February 1977.

Shaw, P.V. and C.E. Heil. "Retrofitting of Inert Gas Systems on Oil Tankers." Presented at A.P.I. Tanker Conference, 1978.

Soesman, H. "Independent Inert Gas Generators: Their Application on Various Types of Vessels." Presented at the Asia Marine 1979 Conference, Institute of Marine Engineers, February 1979.

Stanford, Alfred E. "What Inert Gas Systems Mean to a Marine Operator." Presented at Annual Meeting, S.N.A.M.E., November 1963.

THE NATIONAL ACADEMY OF SCIENCES was established in 1863 by Act of Congress as a private, non-profit, self-governing membership corporation for the furtherance of science and technology, required to advise the federal government upon request within its fields of competence. Under its corporate charter the Academy established the National Research Council in 1916, the National Academy of Engineering in 1964, and the Institute of Medicine in 1970.

THE NATIONAL ACADEMY OF ENGINEERING was founded in 1964 as a non-profit membership institution, by action of the National Academy of Sciences under the authority of its congressional charter of 1863 establishing it as a private, self-governing corporation to further science and technology and to advise the federal government. The two Academies share those purposes in their fields.

THE NATIONAL RESEARCH COUNCIL was established in 1916 by the National Academy of Sciences to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy by authority of its Congressional charter of 1863 as a non-profit, self-governing membership corporation. Administered jointly by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine (all three of which operate under the charter of the National Academy of Sciences), the Council is their principal agency for the conduct of their services to the government and the scientific and engineering communities.

THE COMMISSION ON SOCIOTECHNICAL SYSTEMS is one of the major components of the National Research Council and has general responsibility for and cognizance over those program areas concerned with physical, technological, and industrial systems that are or may be deployed in the public or private sector to serve societal needs.

THE NATIONAL MATERIALS ADVISORY BOARD is a unit of the Commission on Sociotechnical Systems of the National Research Council. Organized in 1951 as the Metallurgical Advisory Board, through a series of changes and expansion of scope, it became the Materials Advisory Board and, in January 1969, the National Materials Advisory Board. In consonance with the scope of the two Academies, the general purpose of the Board is the advancement of materials science and engineering, in the national interest. The Board fulfills its purpose by: providing advice and assistance, on request, to government agencies and to private organizations on matters of materials science and technology affecting the national interest; focusing attention on the materials aspects of national problems and opportunities, both technical and nontechnical in nature, and making appropriate recommendations as to the solution of such problems and the exploitation of these opportunities; performing studies and critical analyses on materials problems of a national scope, recommending approaches to the solution of these problems, and providing continuing guidance in the implementation of resulting activities; identifying problems in the interactions of materials disciplines with other technical functions, and defining approaches for the effective utilization of materials technologies; cooperating in the development of advanced educational concepts and approaches in the materials disciplines; communicating and disseminating information on Board activities and related national concerns; promoting cooperation with and among the materials-related professional societies; maintaining an awareness of trends and significant advances in materials technology, in order to call attention to opportunities and possible roadblocks, and their implications for other fields, and recognizing and promoting the development and application of advanced concepts in materials and materials processes.

Note: Additional copies of this and previous volumes are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151 at above cost per paper bound copy or $1.45 in microfiche. When ordering, use title and report number.