Guidance
Manual for

Material Selection and Inspection of Inert Gas Systems

1980

American Bureau of Shipping
Incorporated by Act of the Legislature of
the State of New York 1862.

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Contents

Foreword

This Manual is intended to summarize available information on the suitability of various materials for the many components of inert gas systems used on board merchant ships, and incidental information relating to maintenance, inspection, and testing. This information is based on a review of available technical literature, discussions with inert gas system manufacturers, and comments from the ABS Special Committee on Ship Operations and its Ad Hoc Committee on Inert Gas Systems. The document is intended to describe the state of the art as reported to the Bureau and should not be construed as an expression of ABS recommendation or preference.

The Bureau has established a program to acquire further information relative to the service performance of various materials in inert gas systems and expects to include the results of this study in a future revision of this Manual.

Guidance Manual for Material Selection and Inspection of Inert Gas Systems

1.0 Introduction

1.1 General

This Manual is intended to provide information relative to the selection, maintenance, inspection and testing of materials for inert gas systems using flue gas derived from ships' boilers. Separate gas generating plants which generally use low sulphur fuels have less corrosive environments and some of the comments contained herein may not be applicable.

1.2 Application

This Manual should be applied in conjunction with a careful assessment of the conditions associated with the particular design and maintenance schedule of the inert gas system under consideration, so that the guidelines can be applied to establish requirements for the expected service conditions.

1.3 Flue Gas Composition

This Manual is based upon a typical flue gas composition as shown below. It is expected that minor variation could be expected in operation.

Gas	*% Vol.* [1]
N_2	80
CO_2	12–14
O_2	2–4[2]
SO_2	0.2–0.3[3]
CO	Traces
NO	Traces
Water Vapor & Solid Particles	Remainder

Notes

1 It is recommended that the oxygen content of the flue gas be kept as low as possible by good combustion control in ships' boilers since higher oxygen content increases the corrosion of materials in the inert gas system.

2 The oxygen content of the flue gas may increase under the following conditions.

Poor combustion control at the boiler especially under part boiler load conditions.

Air being drawn down the uptake when boiler flue gas output is less than the inert gas blower demand especially under part boiler load conditions.

3 The sulphur dioxide content would vary depending upon the sulphur content of the fuel burnt.

1.4 Corrosion

The corrosion resistance of a particular alloy may be adversely affected by fabrication processes such as forming or welding. Some materials may also be susceptible to stress corrosion, particularly when the unit is not operating. When using dissimilar metals, the possible adverse effects of galvanic corrosion should be considered.

1.5 Maintenance

The units of the inert gas system should be located in such a way that inspection and repair work may be easily accomplished.

2.0 General Characteristics of Materials

2.1 Nonmetallic Materials and Nonmetallic Lined Materials

2.1.1 ***Overheating*** Rubber and fiberglass reinforced plastic (FRP) are degraded by exposure to elevated temperatures. Accordingly, special precautions should be taken to prevent such exposures. These precautions may provide for precooling of gases or suitable controls to prevent hot gas flow. To avoid inadvertent overheating, the outside surface of rubber or FRP lined pipe or chambers should be clearly marked to indicate "Welding or Heating not Permitted on this Surface".

2.1.2 ***Erosion or Vibration*** The use of materials lined with rubber or FRP should be avoided under conditions where they may be eroded by high velocity flows of air or water. For some applications, excessive vibration has been reported as a cause of damage of the bond to the underlying material.

2.1.3 ***Coating Soundness*** Particular care should be taken to assure the attainment and maintenance of an unbroken coating with a satisfactory bond in rubber or FRP coated materials during manufacture, installation, maintenance and inspection. The use of coating soundness tests such as spark testing should be considered. Close attention should be given to avoid coating failures since such failures are usually not detected until severe damage has occurred and such failures may not be easily repaired under field conditions.

2.1.4 ***Epoxy Paints and Tars*** Materials coated with epoxy paints or epoxy tars may be susceptible to erosion damage and peeling from minor surface flaws. These coatings are generally not considered as durable as rubber or FRP lined materials and should only be considered if appropriate supporting data is available to indicate their suitability for the intended service application. However, some instances where these coatings have proven to be satisfactory are indicated in 5.0. Zinc silicate paints are reported to exhibit excessive corrosion rates in acidic environments.

2.2 Ferrous Materials

2.2.1 ***Cast Iron*** These materials are considered generally satisfactory for inert gas valves, but should not be used without suitable linings or protective coatings in environments where acidic soot may accumulate.

2.2.2 ***Carbon Steels*** The carbon steels should not be used without suitable linings or protective coatings.

2.2.3 ***Austenitic Stainless Steels*** AISI 316L type stainless steel is generally used for less severe corrosive environments. It is not generally recommended for severe corrosive conditions or in areas where soot deposits may accumulate.

2.3 Nonferrous Alloys

2.3.1 ***Nickel Alloys*** Nickel rich alloys such as Inconel 625 and Incoloy 825 are considered generally satisfactory for the more corrosive environments. However, particular attention should be given to assure that appropriate welding procedures are used.

2.3.2 ***Copper Alloys*** Copper nickel alloys are used in the salt water cooling systems. Bronze and brass alloys do not perform as well as these applications but have been used on occasion.

2.3.3 ***Titanium Alloys*** Titanium alloys are satisfactory for use in severe corrosive conditions such as those encountered inside the scrubber. However, their relatively high cost minimizes their use.

3.0 Inspection

3.1 General

A general inspection to verify the condition of the components of the system should be accomplished at a frequency consistent with operating requirements and service. During the inspection, particular attention should be directed toward the detection of signs of operating conditions which indicate or may lead to material degradation resulting from corrosion or exposure to excessive temperatures. This should also include the checking of any of the controls, such as air or water flow check designs, intended to prevent exposure of nonmetallic materials to excessively high temperatures.

3.2 Valves

All valves, including valves at boiler uptakes, air seal valves at uptakes, scrubber isolating valve, fans inlet and outlet isolating valves, main isolating valve, recirculating valve (if fitted), pressure/vacuum breaker and cargo tanks isolating valves should be examined internally and externally.

3.3 IG Scrubber

Scrubber is to be examined internally and externally. Check should be made for corrosion attack, fouling, excessive accumulation of deposits or damage to the housing, pipes, spray nozzles, switches, sensors and nonmetallic parts such as demisters and packed beds. Internal linings should be carefully examined. Scrubber sea water pump, including valves, piping, and strainers, are to be examined internally and externally.

3.4 IG Blowers

Examinations should include the casing, seawater washing systems, freshwater flushing arrangements (if present), and drain lines. Appropriate measures should be taken if unusual accumulations of deposits are observed on the casing or any moving parts. Check should be made, under running conditions, for excessive vibration or other unusual operating characteristics. Blower drives, either electric motor or steam turbine should be examined.

3.5 Deck Water Seal

Particular attention should be paid to areas where corrosion is more likely to be encountered such as inlet pipes and housing, float control valves, drain lines, and heating coils. Check of the operational characteristics, so far as practical, should be indicated.

3.6 Expansion Bellows

Representative accessible expansion bellows should be examined internally and externally. An air pressure test of the flue gas line should be performed to detect any holed bellows.

4.0 Testing

Evidence of satisfactory testing for the functioning of all parts should be to the Surveyor's satisfaction. Testing schedules should include confirmation of proper functioning of alarms, and safety systems, valves, seals, leakages, interlocks, flow and gas analysis and vibration levels. Programs equivalent to those of the International Chamber of Shipping Inert Flue Gas Safety Guide 1978 will be considered to have met this requirement.

5.0 Applications

The following section offers examples of reported satisfactory and unsatisfactory material service as well as general guidelines for their use. As indicated in 1.2 and 1.4, the suitability of any material may vary widely, depending upon the specific service conditions involved and the behavior of the materials noted in the examples could be markedly affected adversely or beneficially by these conditions.

Some of the important factors are time of exposure, cycling, temperature, sulphur content, acidity, gas or liquid flow rates, soot or other solid accumulations, and vibration.

The effects of the combinations of the preceding factors may be modified by the presence of geometric irregularities (such as near some welds), the presence of washing systems, the functioning or malfunctioning and maintenance of seals and controls, especially those designed to control temperatures of gases and those intended to reduce exposures to corrosive environments during inoperative periods.

Note Where there is no comment on materials used, satisfactory service has been reported.

Uptake Valve

Valve should be located away from the economizer to avoid problems of valve jamming. Valves located close to the economizer have been prevented from closing through layers of ferrous salts washed into and hardened on the bottom of the valve body from fresh water washing of the economizer. An air sealing system and soot blowing of the valve seating and disc should be employed to improve the sealing function of the valve. The former excludes corrosive gases from the flue gas line by ensuring a positive air pressure downstream of the valve and the latter ensures the efficiency of the valve by effectively cleaning the valve disc and seat. An interlock between uptake valve and boiler soot blower system should be employed.

Materials: Cast iron
Ordinary $< 350C$
Nodular 350C to 450C
Heat resisting $> 450C$
Cast steel
Incoloy 825

Flue Gas Line

Any entry ports or temperature/gas take off points should be as flush as possible with the pipe walls to prevent accumulation of damp, acidic soot. If accumulation of acidic soot occurs penetration can occur rapidly. Gas line should drain to a low point to prevent accumulations of corrosive condensate.

Materials: Heavy gauge low alloy improved corrosion resistance steels such as ASTM A606, A607
Al coated mild steel

Expansion Bellows

Bellows should be fitted in vertical position to avoid soot accumulation. Bellows should be flanged to the flue gas line and not welded to facilitate maintenance. Bellows of high alloy material such as Incoloy 825 should not be welded to mild steel flanges as the welded junction may become amenable to corrosion. If the bellows are fitted with internal support sleeves then precautions should be taken so that soot does not accumulate.

Materials: AISI 316L
Inconel 625
Incoloy 825
Hastelloy C276

Rapid penetration of AISI 316L occurs due to pitting if soot accumulates.

Sea Water System

a *Sea Water Lines*

Materials: 90/10 Cu Ni
Al bronze
FRP

b *Valves*

Materials: Cast steel valves with rubber or FRP lined bodies
AISI 316L type shafts
Ni Al bronze discs with nylon coating.

c *Pumps*

Impellers

Materials: Monel
Ni Al bronze
Cast steel coated with abrasion resistant paints
Nonmetallics

Erosion problems due to casting porosity may occur with monel and Ni Al bronze.

Casing

Materials: Cast steel coated with abrasion resistant paints.

d *Fresh Water Lines*

When the piping is not transporting fresh water, it is being exposed to corrosive gases and salt water.

Materials: 90/10 Cu Ni—inside the scrubber
Mild steel—outside the scrubber
FRP

e *Sprayers*

The erosion resistance of the material used should be high to maintain dimensional precision.

Materials: Ni Al bronze
70/30 Cu Ni
AISI 316L
Incoloy 825

Incoloy 825 should be used for precoolers located in warm area of the scrubber close to the gas entry.

f *Effluent Lines*

As little effluent as possible should be left over in these lines as the effluent is highly acidic.

Materials: AISI 316L
90/10 Cu Ni
Al bronze
Steel lined with rubber, FRP, PVC or plastic
Rigid FRP or PVC

AISI 316L, 90/10 Cu Ni, Al bronze should be used in areas where acidic salt water does not accumulate. AISI 316L may pit under some normal design flow conditions. Steel lined with rubber, FRP, PVC or plastic should be used in area where effluent may accumulate. FRP lining may have laying and delamination problems.

Scrubber

a *Inlet Foot*

Materials: Incoloy 825
Titanium
Inconel 625
Hastelloy C276

All welding with Incoloy 825, titanium, and Inconel 625 should be done under controlled conditions.

b *Salt Water Inlet Pipe*

Materials: Monel 400
90/10 Cu Ni
Incoloy 825

Monel 400 has been found to last only a few months in service.

c *Bottom Part*

The bottom part of the scrubber could be under stagnant salt water during shut down and be subjected to warm acidic salt water and corrosive gases during inerting operation.

Materials: Steel lined with rubber
Steel lined with fibre glass reinforced epoxy resin
Steel lined with FRP
Incoloy 825
Ferralium

Steel lined with rubber cannot be efficiently repaired. It can stand up to higher temperature than FRP. Steel lined with FRP can suffer delamination if overheated. Its repair is generally easier and more satisfactory than that achieved with rubber lining.

d *Upper Part*

The materials satisfactory for the bottom part can be used satisfactorily for the upper part as the service condition is less severe.

Materials: Painted AISI 316L
Steel coated with coal tar epoxy
Steel lined with rubber or fibre glass reinforced epoxy resin

e *Float Switches*

Pressure switch or ultrasonic device may be used instead of float switch.

Materials: Monel
Stainless steel
Steel coated with stove epoxy, plastic, PVC or FRP

Monel and stainless steel are not satisfactory if kept immersed in stagnant water.

f *Internals*

Materials: AISI 316L
FRP
Incoloy 825

FRP can delaminate if exposed to high temperatures.

g *Demisters*

Materials: Polypropylene mesh mounted on coal tar epoxy coated steel
Polypropylene mesh mounted on AISI 316L
AISI 316L mesh and brackets

Coal tar epoxy coating is prone to erosion.

h *Recirculating Line*

This line should be protected near the scrubber at least, in a manner similar to the inside of the scrubber and the line should be arranged in such a way that the condensate and spray entering it are returned rather than held in a low point in the pipeline.

Materials: Steel lined with rubber or fibre glass reinforced epoxy resin
Steel coated with stove epoxy

Cold Gas Line

a *Blowers*

Impellers The shaft should be fully supported on both sides. Coated impellers should not be used as any loss of coating will result in severe unbalance and corrosion. A fresh water wash should be used to avoid buildup of soot, which could cause unbalance and corrosion problems.

Materials: Ni Al bronze
AISI 316L
Incoloy 825
Fabricated ferralium (25 Cr 5 Ni 2 Mo)
Cast ferralium
Hastelloy G (23 Cr 25 Ni 5 Mo)
INCO IN 862
Hastelloy C
Titanium
Inconel 625

There may be erosion and corrosion problems with Ni Al bronze if stress relieving is not performed after welding. An adequate fresh water wash for AISI 316L should be incorporated to prevent pitting. Incoloy 825 is not recommended due to fabrication problems. Fabricated ferralium is not recommended due to stress corrosion due to grain growth in the proximity of welds. Cast ferralium can be used for small impellers only. Hastelloy G is commonly used in hotter sections of power plant scrubbers. It is easily weldable and available in cast and wrought forms. Service experience in ship application not available but reported to have good potential. INCO IN 862, a new cast alloy, is reportedly suitable for this application. No service experience is available.

Casing The casing should be of the split design to permit ready access to the impeller. Expansion bellows should be fitted between the casing and piping so that no loads are transferred to the casing. Access doors should be provided for both upper and lower half to facilitate inspection.

Materials: Coal tar epoxy coated steel
Steel coated with stove epoxy or glass flake paints
Steel lined with rubber or FRP

Coal tar epoxy coated steel does not survive even after careful surface preparation due to severe erosion. Stove epoxy coating and glass flake paints need to be repaired after a few years service. There may be erosion and noise problems with rubber lining and it is more difficult to repair as compared to FRP lining.

Deck Water Seal (Wet Type)

a ***Inlet Pipe***

It should be highly resistant to corrosion by salt water and acidic soot deposits because if penetration of this pipe occurs then gases from downstream can pass directly to the upstream section and then to the engine room. It should be possible to inspect and replace this pipe easily.

Materials: Coal tar epoxy coated steel
Glass flake epoxy coated steel
Rubber lined steel
Incoloy 825
FRP

Reblasting and recoating is needed with coal tar epoxy coated steel.

b ***Lower Part***

Glass ports should be provided to allow visual inspection of water level and condition.

Materials: Coal tar epoxy coated steel
Glass flake epoxy coated steel
Rubber or FRP lined steel

Reblasting and recoating is needed with coal tar epoxy coated steel.

c ***Float switches***

Ultrasonic device may be used instead of a float switch.

Materials: Stainless steel
Monel
Plastic, PVC, fibre glass epoxy coated steel

Stainless steel and monel may be pitted in some instances.

d ***Overboard Drain***

Materials: Galvanized steel
Al bronze
90/10 Cu Ni
FRP

e ***Water Inlet Pipe***

Materials: Galvanized steel
Al bronze
90/10 Cu Ni

Deck Lines
The lines should be installed to drain at a low point.
Materials: Coal tar epoxy coated steel

Deck Isolation Valve
Butterfly type valve should be preferably used as gate valves do not retain their gas tightness due to damage to their seats. A fresh water wash should be incorporated to remove sooty deposits to achieve a better seal.
Materials: Rubber lined casing with Al bronze or Ni Al bronze discs

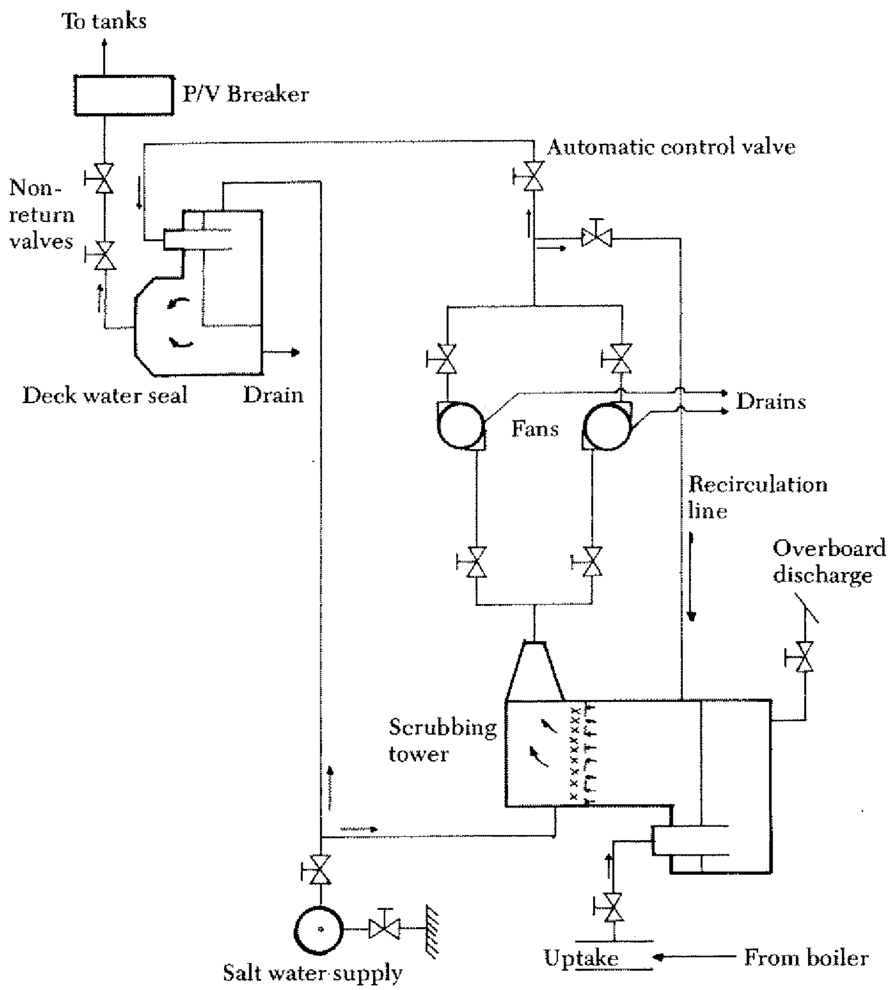
Deck Non-return Valve
Weight loaded valves should be used, as springs in spring loaded valves get corroded due to carbonic acid condensation. These valves can be made more gas tight if they are rubber seated and the flap is also rubber coated.
Materials: Coal tar epoxy, glass flake or rubber coated casing with Al bronze or Ni Al bronze discs

APPENDIX A

Typical Inert Gas System

FIGURE A.1

Typical Inert Gas System



APPENDIX **B**

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