SIGTTO

A Justification into the Use of Insulation Flanges (and Electrically Discontinuous Hoses) at the Ship/Shore and Ship/Ship Interface

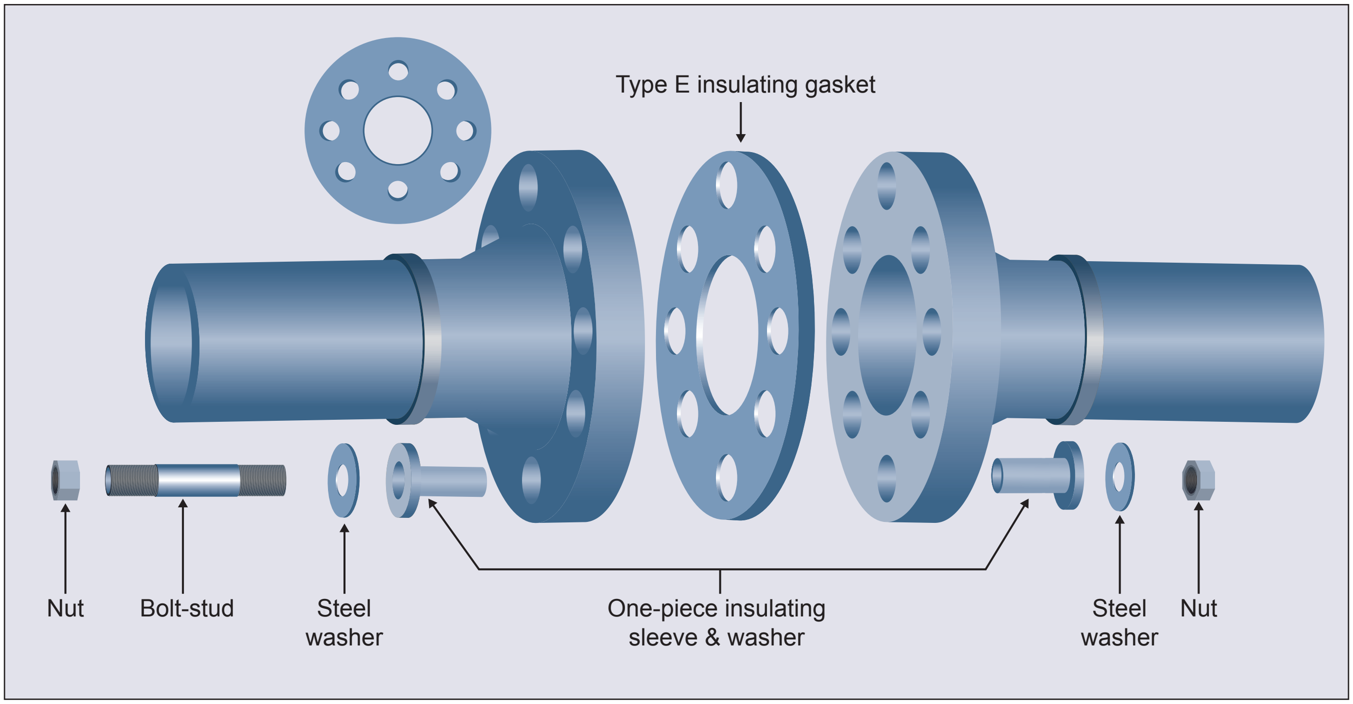
Contents

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

For details of SIGTTO publications:
WITHERBY Seamanship INTERNATIONAL
Web: www.witherbyseamanship.com

Insulation flanges have been in wide use for more than three decades and, while there have been no reported incidents of fires at tanker or gas carrier manifolds that may have been caused by arcing when connecting or disconnecting cargo hoses or arms, their use and effectiveness is still often challenged. This is particularly noticeable by operators with a background of road tanker operations, who are now supplying LNG as bunker fuel.

The purpose of this document is to provide an explanation of how insulation flanges provide protection against ignition caused by arcing. Unfortunately, much of the research that was undertaken to prove the benefit of insulation flanges has been lost over the last 30 or 40 years, and much of what is left is simply a reference to either *'ISGOTT'* (Reference 6) or to the IMO publication *'Recommendations on the Safe Transport of Dangerous Cargoes and Related Activities in Port Areas'* (Reference 10), which requires their use. Even a literature search of the IMO archives, which shows support for the use of insulation flanges as far back as 1977, does not have any references to the research that was undertaken in their favour. The purpose of this paper is to demonstrate their effectiveness, in support of ISGOTT and the IMO recommendations.



Double insulation set

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

Background

Vessels transferring low flash point flammable liquids, at marine terminals or during STS transfer operations, need to take precautions against potential sources of ignition. One possible source is the static charge caused by the passage of certain 'static accumulator' products through the cargo transfer system, which may discharge and cause a high voltage low current spark. Another possible source is the low voltage, high current, galvanic cell that may exist between the ship and shore, which could cause an incendive arc when connecting or disconnecting a 'conductor', such as a loading arm or electrically continuous hose, to the ship's manifold. Unless suitable precautions are taken, either of these sources have the potential to provide the minimum energy required to ignite hydrocarbon/air mixtures within the flammable range. However, it should be understood that they have different causes and require different remedies.

Protection against ignitions from static are well documented in numerous publications, including the API document '*Recommended Practice 2003 – Protection Against Ignitions Arising Out of Static, Lightning and Stray Currents*' (Reference 5), published in 2008, the Shell publication '*Static Electricity – Technical and Safety Aspects*' (Reference 4), and, of particular relevance to ship/shore operations, Chapter 3 of '*The International Safety Guide for Oil Tankers and Terminals (ISGOTT)*' (Reference 6). Protection is provided by shore pipelines being bonded together and then earthed onboard the ship, and metallic objects being bonded to the ship's structure, which is then effectively 'earthed' through the seawater, as stated in the Verheil (Reference 2) paper. To protect against the accumulation of static charge, bonding should have a maximum resistance to earth of 1 MΩ, as recommended in the API document '*Recommended Practice 2003*' (Reference 5).

Up until the middle of the 1960s it was commonly accepted that protection against low voltage, galvanic circuits could be achieved by the use of a ship/shore bonding wire. Arguably, with many oil product jetties having wooden piles and little electrical power infrastructure, this may have been partly true at this time. For example, Mullett and Johnstone (Reference 8), in their paper published in 1960, advocated the use of a bonding wire between ship and jetty when cathodic protection was installed.

This potential source of ignition from galvanic circuits is peculiar to the ship/shore interface, particularly when the ship is in salt or brackish water. Although familiar with precautions against static discharge, it is unlikely that operators of road tankers transporting low flashpoint products would have come across this phenomenon until they became involved in bunkering vessels with LNG.

In the 1960s and 70s considerable work was undertaken on this subject, resulting in the conclusion that bonding wires provided no protection against low voltage stray currents and could, in fact, be a source of ignition. This research introduced the concept of insulation flanges and demonstrated that they provide an acceptable level of safety. As an illustration of how rapidly research was being undertaken into the effectiveness of insulation flanges at this time, the 1st Edition of '*The International Safety Guide for Oil Tankers & Terminals (ISGOTT)*' (Reference 6), which was published in 1972, recognised bonding between ship and shore, but stated that *"consideration should be given"* to the use of insulating flanges. By the time the 2nd edition was published, in 1984, insulating flanges were the accepted method of providing protection against low voltage arcing across ship shore transfer systems and attention was drawn to the possible danger of using bonding wires, which is explained in the following section.

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

Although ISGOTT and the IMO publication 'Recommendations on the Safe Transport of Dangerous Cargoes and Related activities in Port Areas' (Reference 10), strongly recommended against their use some administrations still require the use of bonding wires. Where this is the case they should be attached to the ship outside of the cargo (or bunkering) area and be isolated by a switch in an Ex enclosure, which should only be closed once the bonding wire has been properly attached to the ship and opened before disconnection of the wire. One of the risks with bonding cables is that in the event of a ship breaking out of its moorings there is a chance that flammable cargo may be released and the bonding cable pulled away from the ship's structure igniting the spill. Furthermore its use may lead people not to worry about the importance of maintenance of the insulating flange, assuming they are fitted.

It is now accepted that protection against these low voltage high current circuits is achieved by the use of an insulation flange or a single electrically discontinuous hose in each transfer line. These have been in use at the ship shore interface since the 1970s. For example, in 1976 the Tees and Hartlepool Port Authority, in the UK, required their use, as did the Port of London Authority from 1981 when it amended its 'Petroleum Spirit Bye law No.16'. In 1978, the IMO BCH IV sub-committee, the forerunner of today's BLG sub-committee, endorsed the use of insulation flanges in document Inf.2. This is also a requirement of its current publication '*Recommendations on the Safe Transport of Dangerous Cargoes and Related activities in Port Areas*' (Reference 10).

In 1982 the API advised the USCG that a bonding wire was not a satisfactory method of protection and an insulating flange should be installed in the cargo transfer connections. The UK Health & Safety Commission, in its 1987 ACOP '*Dangerous Substances in Harbour Areas*' required insulating flanges to be fitted and also drew attention to the hazards of bonding. As already stated, in 1984 the 2nd edition of ISGOTT required their use and this is still valid for the current (5th), edition as well as its sister publication. '*The International Safety Guide for Inland Navigation Tank Barges and Terminals: 2010 (ISGINTT)*', (Reference 11).

These low voltage cells, typically between 200 and 700mV, are mainly generated by galvanic action between the ship and shore that results from different materials in the form of steels, sacrificial anodes and non-ferrous fittings being in a salt or brackish water electrolyte. Stray currents from high voltage systems, particularly if using earth return and impressed current cathodic protection systems, can also have considerable influence. The result is that the ship and jetty becomes a very large 'battery' with very low internal resistance, that has the ability to produce large currents. According to Verhiel (Reference 2) both ship and jetty can be fully bonded to earth from an *electrostatic* point of view, but this is quite different under *electrolytic* conditions.

It has been suggested that telluric currents caused by changes in the earth's magnetic field during periods of severe sun-spot activity can induce currents into pipelines, in a similar manner to the way in which a electrical generator works. However, there is no evidence that these present a hazard at the ship-shore interface (Reference 7).

It is sometimes suggested that switching off ship and/or jetty impressed current cathodic protection systems will equalize the potential between ship and shore and negate the need for an insulating flange. However, it may take many hours for the potential to drop to a safe level and there may still be stray currents from other sources. Therefore, this is not recommended as a

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

means of eliminating this potential source of ignition. In addition, it is often argued that the gangway or mooring wires can act as a 'bonding system', but the rope tails on mooring wires and insulating feet on the end of the gangway will prevent this.

A literature search has produced limited published data on any tests and calculations that were undertaken to corroborate these reports. However, the papers published by the Jet Propulsion Laboratory (Reference 1), Verheil (Reference 2) and the ERA (Reference 3), in particular, have provided a great deal of useful information and data to enable the effectiveness of insulation flanges to be demonstrated.

Research

The concerns about the effectiveness of bonding wires, that were raised in the early 1960s, resulted in a study being undertaken in 1963 by The British Electrical & Allied Research Association (Now ERA) (Reference 3) on behalf of the Institute of Petroleum (now the Energy Institute). This study showed that, given a potential difference between ship and shore of 1 volt, currents of 30 – 40 amps can flow through loading arms and electrically continuous flexible hoses. Unfortunately only the ERA report No. D/T 139 (Reference 3) can be found, which is a précis of the full report for the IP, although this does provide a considerable amount of useful information. Tests undertaken by the Jet Propulsion Laboratory in 1981 (Reference 1) at various oil terminals in the US, supported the conclusions of the ERA and Brown and Wadhwa in their paper '*Electrical safety at Docks for Ships Transferring Hazardous Cargoes*' (Reference 7), which estimated a current of 42A with a potential difference of 400mV. These numbers are of a similar order to those put forward in the ERA report.

At the same time, the ERA was undertaking work, on behalf of the UK's Safety in Mines Research Establishment (SMRE), on the ignition of flammable gases and vapours by break sparks. Nethercot and Riddlestone (Reference 9), noted that the tests carried out igniting propane air mixtures at voltages between 0.5 and 2V showed that, at low voltages, the inductance in the circuit supplied the predominant part of the energy in the arc.

At that time it was quite common to connect the ship to shore using a bonding wire attached to the ship, normally adjacent to the manifold. This wire had no relevance to static dissipation but, as stated in the introduction, it was an attempt to equalize the potential between ship and shore by preventing the possibility of an arc when connecting cargo hoses, or arms, to the ship. However, because of the large current availability, low voltage and high contact resistance, even if a very low resistance bonding cable is used it will not be possible to equalize this potential. In Verhiel's paper (Reference 2), he notes that dock operators undertaking tests reported that doubling the conductor size of a bonding wire almost doubled the current flow:

> *"in one case the current in a 2# AWG bonding cable at a ship-dock potential difference of 215mV was 15 amps, fitting a second cable of the same gauge in parallel resulted in a total current flow of 28.4 amps, which was sustained for 36 hours at which point the ship left the dock".*

Should such a cable be accidentally detached there would be an arc, which would have created the potential for ignition should a flammable atmosphere be present, particularly as these were invariably attached to the ship close to the manifold. Furthermore, as demonstrated by Verheil, the heavier the gauge of the bonding wire the greater the current it could carry, increasing the hazard. The work undertaken in the USA by the JPL (Reference 1), detected arcing when connecting bonding wires. Anecdotal information

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

from staff at a LNG terminal in Europe stated that it was quite common for there to be an arc when connecting and disconnecting the bonding wire to the vessel. This same terminal later fitted insulation flanges to the loading arms, but retained the bonding wire that was clamped well away from the manifold and operated through a switch in an Ex enclosure.

The ERA Report (Reference 3) stated that:

> *"a bonding cable with a resistance of 0.008Ω only reduced the potential difference from 235mV to 215mV. It is obvious that a separate bond has no appreciable effect unless the resistance is in the order of 0.001Ω... It is extremely unlikely that a total bond resistance this low could be maintained"* (given practical contact resistances in the bonding wire circuit.).

The recommended preventative measure given in the ERA report is the fitting of an insulating flange:

> *"A resistance of a few ohms would be adequate to reduce the current to a safe level".*

The report also raises the question as to whether or not the fitting of such a flange would contravene the requirement for the pipeline to be *"adequately and continuously earthed"* to prevent static accumulation. However the report concluded that:

> *"Electrostatic charge accumulation can only be a hazard when the resistance to earth of any section of the pipe is very great; values of 10^6 – 10^7 ohms being adequate for charge removal."*

The API Recommended Practice 2003 (Reference 5) stated that; *"a bond resistance as high as 1MΩ is adequate for static dispersal".* Therefore, the term 'insulation flange' is somewhat of a misnomer, as they are designed to have a sufficient electrical resistance such that low voltage high current flows from the galvanic cell are reduced to a safe level, but that high voltages created by static charging will be allowed to be dissipated across the flange joint. '*ISGOTT*' (Reference 6) requires that the flange should have a resistance of more than 10 kΩ, and when new and in service it may drop to 1 kΩ. However, it is strange that no upper limit is given in the current 5th Edition, while a value of 1 MΩ would comply with the API document to ensure static dissipation.

Electrical Characteristics of Cargo Transfer Hoses

'*ISGOTT*' (Reference 6) defines hoses for cargo transfer purposes as electrically continuous or electrically discontinuous. Electrically discontinuous hoses should have a flange to flange resistance, measured with a 500V tester, of not less than 25 kΩ. For electrically continuous hose a resistance of less than 0.75 Ohms per meter is stipulated. Therefore, it can be seen that the discontinuous hose has similar characteristics to the insulation flange. Section 17.5 of '*ISGOTT*' (Reference 6) states that a *single* length of electrical discontinuous hose in each hose string may be used ***instead*** of an insulation flange.

The term 'semi-continuous hose' has come into use for lightweight kink resistant hoses that are used in some STS operations. There is no internationally recognised technical standard or specification for these hoses and operators should satisfy themselves that their electrical characteristics provide protection against both galvanic currents **and** the build-up of static charge.

SIGTTO
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Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

Supporting Calculations

According to the ERA report section (7) Bonding Cables:

An open circuit difference in ship/shore potential was noted as 0.235 V

When a bonding wire of resistance 0.008Ω was connected between ship and shore the potential difference dropped to 0.215 V

Assuming that the ship/shore galvanic cell can be represented as a very large battery with an internal resistance of R_i and that the 'earthing' through the sea does not affect the galvanic cell as proposed by Verheil (Reference 2).

Where:

$V_{load} = V_{open} \times R_{load}/(R_i + R_{load})$

$V_{load} = 0.215v \quad V_{open} = 0.235V \quad R_{load} = 0.008\Omega$

Therefore, internal resistance of the 'cell'

$\mathbf{R_i = 0.00074\Omega}$

This is in the same order as suggested in the ERA report and Mullett & Johnstone (Reference 8) who state 0.001 Ω as the internal resistance of the 'cell'

This would give a current flow through a bonding wire resistance 0.008 Ω of:

$I = V/(R_l + R_i)$

$0.235/0.00874$

$= \mathbf{26.9A}$

If a 1000 Ω insulation flange was put in the system

$I = 0.235/(1000 + 0.00874)$

$= \mathbf{235\mu A}$

The ERA report states currents of 30 to 40 amps can flow through a loading arm at 1 V and may 'even be higher', although the resistance across the swivels must add some uncertainty to this.

Therefore, assuming 50A at 1 V

Resistance of loading arm will be; 1/50

$= \mathbf{0.02\Omega}$

Therefore, for a ship shore potential difference of 250mV and R_i of 0.001 Ω

$I = 0.250/(0.02 + 0.001)$

$= \mathbf{11.9A}$

For a ship shore potential difference of 500mV

$I = 0.500/(0.02 + 0.001)$

$= \mathbf{23.8A}$

These figures are similar to those obtained in the Jet Propulsion Laboratory test 3 (Reference 1) at Long Beach on 'Arco California' where 20.9A was measured at 456mV and 14.2A at 249mV and arcing was detected when connecting the bonding wire. This continued until the ship-shore potential dropped below 200mV and was considered a potential source of ignition. It should be noted that the JPL report states that arcing may still occur at voltages below 200mV if sufficient current is available.

If a 1000Ω insulation flange is put in series in a system with a 500mV potential difference, the current would be reduced to:

$0.5/(1000 + 0.021)$

$= \mathbf{500\mu A}$

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If the insulation flange is damaged and its resistance drops to 100Ω, with a 500mV potential difference the current would be:

0.5/(100 + 0.021)

= 5 mA

According to the work the ERA carried out on behalf of the SMRE, at the voltages considered minimum ignition current is more significant than minimum ignition energy and these currents are well below the minimum ignition current for methane in air for *resistive circuits,* which at 10V is >5A.

These calculations assume a resistive circuit, with negligible inductance, which may be true in a loading arm but would not be in a conductive hose with helical wire reinforcing, where there may be significant inductance.

Inductive Circuits

Using figures, supplied by Amnitech, for an 8 inch NB composite hose with two layers of spiral wire.

Resistance = 0.3Ω/metre

Pitch of coil = 2.5 cm

Mean diameter of inner wire coil (d1) = 20.9 cm

Mean diameter of outer wire coil (d2) = 24 cm

Therefore, for a 10 m length (l):

Resistance = 3Ω

Number of turns (t) = 400

L_1 = 0. 684 mH

L_2 = 0.9 mH

For inductors in Parallel

$$L_t = \frac{1}{(1/L_1 + 1/L_2)}$$

L_T = 1/2.58

Therefore, **L_T ~ 0.4 mH**

This gives an inductance of 0.4 mH and a resistance of 3 Ω for a 10 m length.

Similarly, for an Amnitec 10 m 4 inch NB hose:

Resistance = 0.33Ω/m

Pitch of coil = 2.0 cm

Mean Diameter of inner coil = 11.7 cm
L_1 = 0.21 mH

Mean Diameter of outer coil = 13.8 cm
L_2 = 0.3 mH

Therefore, $L_t = \frac{1}{(1/L_1 + 1/L_2)}$

Which gives an inductance of 0.12 mH and a resistance of 3.3 Ω for a 10 m length.

These values of inductance are in the same order as the ERA report 139 (Reference 3), which states that 3 mH is the maximum inductance likely to be found in "existing hose installations."

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

Examples Showing the Effects of Hose Resistance and Inductance

Hybrid LNG transfer systems have been proposed for LNG bunkering, consisting of an articulated arm and a length of cryogenic hose.

Assuming:

> The arm has the same resistance as suggested in the ERA report 0.02Ω (Reference 3)
>
> The hose is 10 m in length with a resistance of 0.3Ω/m i.e. 3Ω total
>
> Ship shore potential difference is 500mV
>
> The internal resistance of the cell is 0.001Ω
>
> I = 0.5/(3 + 0.02 + 0.001)
>
> **I = 165 mA**

If a 1000Ω insulation flange is fitted

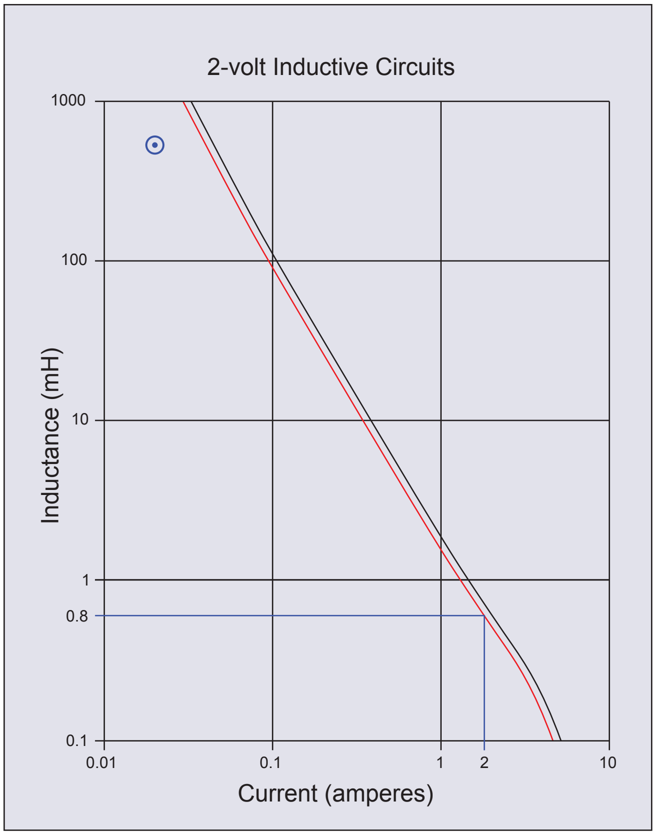
> I = 0.5/(1003 + 0.021)
>
> **I = 498μA**

STS using hose string

Assuming:

> Ship to ship potential of 500mV
>
> 8 inch Amnitec hose 0.3 Ω/m
>
> Hose length 20 m L ~ 0.8 mH R = 6 Ω
>
> Internal resistance of the 'cell' 0.001 Ω
>
> Resistance of steel pipework 0.01 Ω
>
> I = 0.5/6.011
>
> **83 mA**

If a 1000Ω insulation flange is fitted the current will drop to **497μA**



From: MSHA Minimum Ignition curves for Inductance at Known Voltage

As can be seen from the graph with an inductance of 0.8 mH the minimum igniting current is approximately 2A. Therefore, even without the insulating flange, given an electrical resistance in the transfer system of 3Ω and a potential difference of 500mV, the current is theoretically 1.8A below that required for ignition. Similarly, results obtained for the STS transfer system with an inductance of 0.8 mH and a resistance of 6.011Ω show that the current is below that which would ignite a flammable mixture.

Note that ship to ship potential may be quite low due to the similar materials of construction, and may be influenced significantly by the impressed current cathodic protection systems. However, given the possibility, according to the ERA report, that the potential difference between ship and shore may reach 1V, and the difficulty in ascertaining the resistance and inductance in the whole of the transfer system, **it should not be assumed that it is safe to omit the insulation flange**.

Effect of Capacitance

Dielectric constants:

Phenolic resin 5 (only to –50degC – propane only)

Silicon Glass 3.8 (LNG)

Epoxy resin 3.6

PTFE 2.1

Assume current will be DC

Using an estimated value of 100pF (say A = 1 m^2, d = 0.1 m and e = 10 pF/m, C = eA/d).

For a 16 in arm:

OD of a ASA 150 flange 23.5 in (0.6 m) & bore 16 in (0.4 m)

'Plate' area = 0.16 m^2

(Neglecting bore to give a conservative area = 0.28)

Assuming thickness of insulation d 0.1 m

Dielectric constant = 5

e = 8.85

C = keA/d

= $5 \times 8.85 \times 10^{-12} \times 0.16/0.1$ ($5 \times 8.85 \times 10^{-12} \times 0.28/0.1$)

= **71 pF (124 pF)**

This would depend, to a degree, on temperature of the material and frequency of the applied voltage.

'*IEC 60079-11 10.1.5.2*' (Reference 12) suggests that the MIC reference curve can be used if the total capacitance of the circuit is less than 1% of the value allowable in Table A2 of that document. The lowest voltage considered in the table is 5V, which is an order of magnitude above that assumed in the calculations for the ship to shore potential difference. The corresponding permitted capacitance for gas group IIC is 100uF (there is no limit given for IIB, IIA & I at lower voltages), giving a theoretical maximum of 1uF for a simple inductive circuit. This suggests that the contribution of the charge stored within the insulating flange to the spark energy available in the event of disconnection is negligible in comparison to that required to ignite any hydrocarbon vapour.

Multiple Loading Arms and Parallel Circuits

If, as is usually the case, 2 or more loading arms are connected, a parallel circuit will be formed. Assuming 4 arms, each with a resistance of 1000Ω, and all pipework is bonded, the total resistance of the transfer pipework will drop to 250Ω. Given a ship shore potential difference of 300mV, the total current flow through the system will be ≤1.2 mA and the current flow in each path will be 300μA. This means that there will be no increase in hazard.

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

Testing of Insulation Flanges

There has been considerable discussion on the correct method to test insulation flanges. One view is that, because it is an 'insulation flange' it should be tested with an insulation tester. The other view is that, because it is designed to protect against low voltages and has a relatively low resistance, a multimeter would be more suitable. The problem is that the insulation tester will most likely have a test voltage of 500 volts and the multimeter a driving voltage of 5 volts, neither of which are suitable for the purpose. '*ISGOTT*' (Reference 6) does not specify a suitable meter and only recommends

> *"should a suitable multimeter be identified it is recommended that users take care to verify that the equipment meets the strict interpretation of the recommendations contained in this Section".*

During the research undertaken for this paper, one terminal operator identified the 'Fluke 1507 Insulation Tester' which has several test voltages, the lowest being 50 volts. Interestingly, in the past they had used a 500 volt insulation tester and noted resistances in the order of 200 Ohms, while with the Fluke 1507 multimeter the values recorded were in excess of 1000 ohms.

Conclusions and Recommendations

It is clear that a properly installed and maintained insulating flange is absolutely vital to protect against the effects of stray electrical currents while allowing dissipation of static charge. However, it is difficult to see that a bonding cable would then add any extra protection and, should it be accidentally broken, is a potential source of ignition.

The bonding cable is likely to be ineffective against a static charge generated in the transfer system, which is the most likely source of incendive spark, and for the reasons given in the ERA and JPL reports (References 3 & 1), ineffective against the high current low voltage phenomena. Should a bonding wire be mandated by national regulation, it should be provided with a switch in a flame-proof enclosure and connected to the ship in a non-hazardous location. The switch should be closed after connection of the transfer system to the ship and opened before disconnection from the ship.

There is a lack of data on ship to ship potential differences and possible current flow, so it would be extremely useful, particularly in regard of the work that The Oil Companies International Marine Forum (OCIMF) is undertaking on 'Semi-Continuous Hoses', if tests similar to those undertaken by the Jet Propulsion Laboratory (Reference 1) for ship to shore were replicated for ship to ship.

In addition, the data that I have used was obtained from ships that almost certainly had 220 VDC or 440 VAC electrical distribution systems and many ships now, particularly LNGCs, are generating at 6.6kV so further tests would be useful. It is also suggested that tests should be performed at floating production facilities, where process plant may have both HV power systems and TN-S earthing.

Finally, perhaps, we should consider proposing that the term 'insulation flange' is changed to 'safety resistance flange' to give a better understanding of its purpose, and that an upper value of resistance is stipulated to ensure static dissipation.

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London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

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Definitions

1. Arc – a low voltage, high current electrical discharge that occurs at the instant two points, through which a large current is flowing, are separated.
2. Bonding – The practice of providing electrical connections between isolated conductive parts of a system to prevent voltage differences between the parts. A bond resistance as high as 1MΩ is adequate for static dissipation.
3. Flash point – the lowest temperature at atmospheric pressure, at which the application of an ignition source caused the vapour of the test portion to ignite and the flame to propagate across the surface of the liquid under test conditions.
4. Ignition temperature (also referred to as the auto-ignition temperature AIT) – the minimum temperature at which a material will ignite and sustain combustion when mixed with air at atmospheric pressure, without the ignition being initiated by a spark or flame.
5. Minimum ignition energy is a measure of the ignitability of flammable gases and vapours by electric sparks. Not only the minimum ignition energy but other characteristic data (e.g. minimum ignition current) serve to evaluate low-voltage circuits.
6. Minimum Ignition Current – MIC Minimum current in resistive or inductive circuits that causes the ignition of the explosive test mixture in the spark-test apparatus according to IEC 60079-11 (Reference 12).
7. Spark – The result of the sudden breakdown of the insulating strength of a dielectric, such as air, that separates two electrodes of different potential.

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

APPENDIX 1

Worst Case Potential Difference/Current Combinations

	Ship	Location	Ship/Shore P D mV	Current Amps	Date
1	Arco California	Long Beach	456	20.9	Oct 1980
2	Texaco Minnesota	Long Beach	514	28	Oct 1980
3	Texaco Georgia	Long Beach	303	16	Oct 1980
4	Union Sensinena	L A	202	9	Jan 1981
5	Not disclosed	Not disclosed	215	60	c 1968

Note: 1-4 were taken from the JPL paper (Reference 1) and 5 from Verheil (Reference 2)

SIGTTO
London Liaison Office, 17 St Helen's Place, London, EC3A 6DG
Tel: +44 (0) 207 628 1124 E-mail: secretariat@sigtto.org Fax: +44 (0) 207 628 3163

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