

Static Electric Discharge Hazard On Bulk Oil Tank Vessels

Phase 1 Report

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Section 1. Executive Summary

This report examines the problem of electrostatic ignition as the cause of explosions on tank vessels, recounts recent accident history, and surveys the safety guidance now available to industry. It is the deliverable product of Phase 1 of a two phase project to improve industry's safety record in this area.

The report finds that extensive safety information is available in a number of publications, which offer, for the most part, consistent guidelines to deal with the static electricity hazard. Much of the guidance is general in nature, and many companies do not fill information gaps with internally developed procedures and training. The problem has persisted as violations of many fundamental safety procedures have caused serious accidents.

A Coast Guard safety guide, issued as an enclosure to a Navigation and Vessel Inspection Circular (NVIC), could improve tank vessel safety if properly targeted at industry sectors, perhaps as separate volumes. A conference of industry, government, and standards experts would be a good first step in the development of such documentation.

The Volpe Center recommends that the Coast Guard proceed with Phase 2, the development of the safety field guide.

Section 2. Introduction and Background

The Engineering Branch of the Coast Guard Office of Marine Safety, Security, and Environmental Protection (G-MTH-2) has, as a result of several recent accidents involving substantial losses of life and property, recognized the persistent danger of tank vessel explosions caused by electrostatic discharge. The Volpe National Transportation Systems Center was tasked to study the incidence of these explosions and the pertinent safety measures currently in place. The physical phenomena of the static discharge hazard were not investigated for this report.

This report presents the results of the study with a compilation of safety standards, procedures, etc. promulgated by government and industry. The project plan calls for a second phase, in which a static electricity field guide will be developed for use by industry.

2.1 The Problem

Electrostatic discharge has long been known as a hazard associated with the handling of petroleum products. A monograph by Klinkenberg and van der Minne in 1958 [1] led to the development of anti-static additives by Royal Dutch/Shell. J.T. Leonard [2] has described many papers and publications from the 1960s and 1970s addressing both the hazard and related safety measures; they deal primarily with static generation during fuel loading.

The National Fire Protection Association (NFPA) states, in NFPA 77 "Static Electricity", that "Static electrification and the various effects that result from the positive and negative charges so formed may constitute a fire or explosive hazard. The generation of static electricity cannot be prevented absolutely, because its intrinsic origins are present at every interface" [3].

Static electricity is generated when liquids move in contact with other materials. This is a common occurrence when liquid is being moved through pipes, mixed, poured, pumped, filtered, or otherwise agitated. Other causative processes include the settling of solids or immiscible liquid through a liquid, the ejection of particles or droplets through a nozzle, and the splashing of a liquid against a solid surface. NFPA 77 states that "under certain conditions, particularly with liquid hydrocarbons, static may accumulate in the liquid", with the danger of subsequent sparking in a flammable vapor-air mixture.

The problem is broad-based, including the marine shipping industry (about 2000 tankers and upward of 4000 tank barges) and shore-based industries involved in vessel maintenance and repair. The latter includes 10,000 vacuum trucks in the United States which are commonly used for oil removal and hazardous waste transport. [4] The solution for government and industry is to communicate the various means of counteracting these phenomena to all concerned, including fleet and terminal operators, tankermen, and shipyards and other tank cleaning concerns.

2.2 Accident History

A number of serious accidents occurred when very large crude carriers (VLCC) first came into service in 1969 (MACTRA, MARPESSA, KONG HAAKON IV). Water washing techniques then in use caused the generation of large static charges in the cargo tanks, whose unprecedented size was a causal factor. Oil shippers took steps to control the atmosphere in the tanks by either 1) careful stripping and gas freeing or 2) assuring an over-rich mixture in the tanks. The problem in this particular sector has been largely eliminated by the use of crude oil washing (COW) techniques or of smaller water washing machines.

More recently, several tanker and tank barge explosions in which static discharge was a probable cause have refocused attention on the mechanisms of electrostatic discharge and the applicable safety standards. The SURF CITY, FIONA, AMERICAN EAGLE, CIBRO SAVANNAH (barge), tank barge TT 103, tank barge STC 410, and the tank barge Hollywood 1034 accidents each offered safety lessons to be (re)learned. In most cases, routine cargo tank operations such as loading, stripping, or cleaning were underway.

Correspondence with industry representatives has revealed a history of accidents caused by electrostatic discharge in tank trucks (particularly at loading racks) and storage tanks. One expert said that chemical storage tanks in particular have many static related explosions. Publicly available information on these incidents is, however, scant.

2.3 Safety Measures in Place

There is ample documentation in place describing safety precautions to be taken against static discharge. The most important industry publications are the following:

- International Safety Guide for Tankers and Terminals ISGOTT [5]: This is the industry standard and most often the basis for safety documents internally produced by the oil shippers. A copy of ISGOTT may be found on board most ships and in most terminals. It has the most thorough treatment of electrostatic hazards on tank vessels. ISGOTT is produced by a consortium of the Oil Companies Marine International Forum, the International Chamber of Shipping, and the International Association of Ports and Harbors.

- American Petroleum Institute Recommended Practice 2003 (API 2003) "Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents" [6]: This document presents current technology in the prevention of hydrocarbon ignition by static electricity, lightning, and stray currents. It contains good general principles of safety, but concentrates largely on land based oil storage and transportation. API 2003 refers often to ISGOTT on matters of marine transportation.
- NFPA 77 "Recommended Practice on Static Electricity " [2]: This document is a more general treatment of static hazard in all industries. It is short on the subject of tankers and barges, but a good source for general principles. NFPA 77 is prepared by the NFPA Technical Committee on Static Electricity, made up of experts from industry and government.
- American Waterways Shipyard Conference "Safety Guidelines for Tank Vessel Cleaning Facilities" [7]: This document was prepared expressly for shore based facilities involved in the cleaning of tank vessels, and uses relevant portions of ISGOTT and input from the affected industry.
- API Publication 2015 "Safe Entry and Cleaning of Petroleum Storage Tanks" [8]: This publication contains general guidance against all hazards associated with the cleaning of land based storage tanks. Static electricity is not addressed in great depth, nor are tank vessel cargo tanks. However, some good information is available in API 2015.

2.3.1 Oil shipping companies guidance. Some large oil shipping concerns have developed internal safety documents addressing electrostatic discharge hazards. These documents are usually based heavily on the above cited industry standards, but can also include additional required safety measures. Most firms rely exclusively on the previously cited industry standards for electrostatic discharge safety guidance.

Companies which have prepared safety documents pertaining to static electricity include Texaco, Shell International, and Dixie Carriers. It is worthy of note that the Sun Oil Company has undertaken to prepare a safety guide dedicated to the topic of electrostatic discharge, in roughly the same time frame as this project.

2.4 Project goals

This project aims to improve tank vessel safety by the prevention of electrostatic discharge hazards during routine tank operations. This will be accomplished by the following specific actions:

- Compilation of available accident data from recent tank vessel explosions thought to have been caused by electrostatic ignition, especially their causal factors and the conclusions and recommendations of investigating authorities.
- Research into safety standards and methods developed and used by government, industry, and academia.
- Development of an electrostatic hazard and-safety field guide for use by the oil shipping and associated industries. The first two items above comprise this report. The last will be undertaken as the second phase of the project after Coast Guard review of the report.

Section 3 Recent Accident History

Brief accounts of recent tank vessel accidents, in which electrostatic discharge was known or suspected to be a cause, are given. In each case, causal factors and the conclusions and recommendations of the investigating body are summarized.

3.1 FIONA (31 August 1988)

The forward cargo tank of the FIONA exploded while a surveyor measured cargo temperature prior to unloading, resulting in one death. The National Transportation Safety Board (NTSB) concluded that a steam leak in the tank caused static charge to be generated, that the charge accumulated on an ungrounded temperature probe and discharged as the probe was withdrawn from the tank, and that the resulting sparks ignited explosive vapors from the residue of the tank's previous cargo [9].

NTSB's recommendations addressed the foregoing items and other contributory factors:

- FIONA's cargo tanks should have been inerted, and the ISGOTT should state more clearly that the inert gas system (IGS) should be used with all cargoes unless tanks are gas free.
- The main source of the explosive vapors was contamination of the cargo (No. 6 fuel oil) by previous condensate cargo, while release of light hydrocarbons by the No. 6 fuel oil may have been contributory. Masters of vessels carrying Grade E cargoes should certify that explosive vapors are not present prior to sampling or measuring cargoes with a combustible gas indicator device.
- The static charge was generated by a steam leak in the cargo heating pipes and accumulated on an ungrounded temperature probe. Better maintenance might have prevented the casualty. · The probe lacked a precautionary nameplate stating the, need for grounding the instrument during use. Underwriters Laboratory UL) should adopt the Canadian Standards Association requirement for such a nameplate. The internal grounding wiring on these probes should also be checked periodically.

3.2 AMERICAN EAGLE (26, 27 February 1984)

The AMERICAN EAGLE, sailing in ballast, exploded and sank in the Gulf of Mexico with the loss of four lives. The NTSB concluded that the most probable cause of the explosion was the use of a steam powered air ventilator fitted with a long plastic sleeve in a non-gas free tank [10].

The ship had been carrying No. 2 fuel oil and gasoline. The tank in question had been washed, but not gas freed; an explosive mixture in the tank was possible. The probable cause of ignition was an incendive spark between the tank structure and charged steam condensate falling from the plastic sleeve through which the air was being driven.

The crew was unaware of the clear warning in ISGOTT against the introduction of steam into potentially explosive atmospheres. The use of non-conductive material contributed to the accumulation of static charge.

As a result of the accident, NTSB recommended that CG-174, "A Manual for the Safe Handling of Flammable and Combustible Liquids and Other Hazardous Products", be revised to thoroughly address static electricity hazards on tank vessels.

3.3 U.S. tank barge TT 103 (31 July 1986)

Tank barge TT 103 exploded and sank while loading gasoline at the pier. The NTSB concluded that the probable cause of the explosion was turbulence due to the high initial loading rate of the highly volatile, low conductivity gasoline and the possible contamination of the cargo with diesel fuel, an excellent static accumulator with very low conductivity. The source of the incendive spark could not be determined, although vessel structure or a foreign, conductive object in the tank were suspected [11].

The terminal operators were following existing guidance in API Recommended Practice 2003, which did not restrict initial loading rates for such highly volatile, flammable liquids. ISGOTT, however, specifies low initial loading rates for static accumulating fuels, defined as having conductivity lower than 50 picoSiemens/meter (pS/m).

The gasoline in this case had conductivity of 25 pS/m; that of the diesel fuel suspected of contaminating the cargo was 5 pS/m. The low initial loading rate recommended by ISGOTT would have applied in either case.

The NTSB recommended, as a result of their investigation, that API · 2003 be revised to include ISGOTT's initial loading rate restriction for static accumulating fuels. The 1991 edition of API 2003 only states that some companies limit initial loading rates to 1 meter per second (m/s) while others employ other measures to counter the hazard. It states further that high-vapor-pressure products (such as gasoline) quickly form an over rich vapor layer and that low initial loading rates are advisable only if a concern exists about the loading facility's physical condition or cargo contamination.

3.4 U.S. tank barge STC 410

Tank barge STC 410 exploded at the pier while JP-4 jet fuel was being stripped by a vacuum truck, killing four people. The NTSB did not find a most probable cause for the accident, but mentioned electrostatic discharge as one of six possible ignition sources [4].

Since JP-4 is a static accumulating fuel and a 17-foot long, non-conducting, PVC wand was used for the vacuuming operation, the possibility of an incendive spark caused by static discharge existed. Static generation from splashing or agitation of the residual cargo was very unlikely. The loading rate was thought to be below that which would static accumulation on the wand, but impurities in the residue could have caused more rapid generation of static charge, and accumulation of charge on the wand.

The NTSB recommended that API 2003 should include guidelines on the use of wands for vacuuming, and noted that wands should be constructed of conductive, non-sparking material and bonded to the hull during use (not really addressed anywhere yet).

3.5 Tank barge Hollywood I034 (4 November 1985)

The tank barge Hollywood 1034 exploded during tank stripping operations and sank, killing two people. The Coast Guard concluded that the most probable cause of ignition was a static electric discharge from an insulated metal coupling in the vacuum pickup tube to the side of the tank dome [12]. The stripping operation was being conducted without a certificated tankerman in charge and there was no evidence of electrical bonding on the barge, stripping equipment, or shore facility.

The Coast Guard concluded that the use of a vacuum "wand" with an insulated metallic conductor was contrary to API 2003 and that wands should be constructed of sufficiently conductive material to prevent static charge buildup.

3.6 Other accidents

Numerous additional tank vessel explosions have recently occurred in which no probable cause could be established, but where static electricity was listed among possible causes. In some cases, poor adherence to safe procedures was indicated, but not proven as causative. The continued occurrence of these accidents suggests a larger pattern of operational safety deficiencies.

3.7 Overview

It is clear that the problem of electrostatic discharge still exists in the oil shipping industry. All cases reviewed have in common the fact that primary or contributory causes occurred despite well documented precautions. Operators and other involved personnel, through errors of commission and omission, help foster the hazardous conditions required for electrostatic ignition accidents.

The applicable safety documents may vary in their approach to given safety issues, but enough information is certainly available to assure safe routine cargo tank operations. One goal of this project must be to ascertain whether an additional publication will have a positive impact in the industry.

Section 4 The Electrostatic Hazard

This section describes the specific elements which contribute to the four stages of hazardous electrostatic discharge and vapor ignition during routine operations in tank vessel cargo tanks.

4.1 The Four Conditions Required for Explosive Ignition

The clearest description of the required conditions for electrostatic hazard is perhaps in NFPA 77 [3], which states:

The development of (static) electrical charges may not be in itself a potential fire or explosion hazard. There must be a discharge or a sudden recombination of separated positive and negative charges. In order for static to be a source of ignition, four conditions must be fulfilled:

- (a) There must first of all be an effective means of static generation,
- (b) There must be a means of accumulating the separate charges and maintaining a suitable difference of electrical potential,

- (c) There must be a spark discharge of adequate energy, and
- (d) The spark must occur in an ignitable mixture.

4.2 Mechanisms for Producing Hazardous Conditions

4.2.1 Static generation Two differing substances in contact with each other will often become charged as one surrenders electrons to the other. Although the net charge remains constant, an electrical double layer is formed along the adjoining surfaces. The separation of the two substances often causes them to remain disparately charged, an effect which is exaggerated by increased speed of separation and increased mechanical work (friction) [3].

Piping of oil products Charge generation and separation occur when liquids move in contact with other materials, as in operations involving piping, filtering, mixing or agitating. Mechanisms which exacerbate static separation in cargo loading operations are the following:

- Turbulence and splashing of the fluid at the beginning of tank loading operations when the pipe opening is not yet covered with cargo, especially since it is most likely at this time for water to mix with incoming oil.
- Any mixing or filtering of the cargo, particularly micropore or clay filtering.
- Impurities such as water, metals, rust, or other product in the cargo.
- Disturbance of water "bottom".
- Pumping of entrained air or other gases bubbling in the tank.

The cargo is also disturbed during unloading operations, as the fluid moves past hull structure, piping, etc., particularly during stripping when tank levels are at their lowest. Discharge of slops and contaminated ballast also generates high amounts of static charge.

Displacing of lines using air and water is a static charge generator.

Water mist and steam Mists formed during water washing or from the introduction of steam can become electrostatically charged. The charge associated with water washing may be much higher if cleaning chemicals are used.

Steaming produces mist clouds much more highly charged than water washing, much more quickly, and can also cause the release of gases due to the heat and disturbance of the process.

Potentials are higher in large tanks than small ones, a fact born out by several serious accidents in the early VLCCs.

Loading overall Loading overall (from the top of the tank) can deliver charged liquid into a tank which breaks up into small droplets and splashes into the tank. This can produce a charged mist and an increased hydrocarbon gas concentration.

Air release in bottom of tanks Air or inert gas blown into the bottom of a tank can generate a strong electrostatic charge by bubbling action and agitation of the fluid.

Crude oil washing (COW) Mixtures of crude oil and water can produce an electrically charged mist if used for COW operations.

Oil/bulk ore carriers (OBO) Single cargo holds extending the full breadth of the ship are subject to severe sloshing effects if not pressed full, leading to the possible formation of electrostatically charged mists. The sloshing can also produce free flying slugs of water in ballasted tanks, a spark producer under the right conditions and a hazard if flammable gases are present.

4.2.2 Accumulation of charge and potential

Static accumulator and non-accumulator oils The conductivity of a liquid determines whether or not it retains the generated static charge. A non-accumulator oil, defined by an electrical conductivity of greater than 50 (pS/m) [5] will relax quickly because it transmits the charge to the steel hull, which is grounded in the water. Accumulator oils are defined as having a conductivity of less than 50 pS/m [5]; these oils relax (dissipate charge) slowly.

When an accumulator oil is loaded, charges of similar sign repel from each other toward the liquid's outer surfaces, including that in contact with air. The latter is called the "surface charge" and is usually of most concern. [3]

ISGOTT states that, in general, black oils do not accumulate static charge and clean oils (distillates) do. It classifies several oils as follows:

Non-accumulator oils

Crude oils
Residual fuel oils*
Black diesel oils
Asphalts

Accumulator oils

Natural gasolines
Kerosenes
White spirits
Motor and aviation gasolines
Jet fuels
Naphthas
Heating oils
Clean diesel oils
Lubricating oils

* The May 1991 addendum extends static electric precautions to residual fuel oils.

Texaco's operating instructions [13] state that loading rate precautions are not necessary for gasolines and some aviation fuels because of their low viscosity and low friction. "Avjet JP 4" and middle distillates require loading precautions to prevent static accumulation.

Hoses, wands, pipes, etc. Equipment introduced into cargo tanks for routine operations, most often, hoses, wands, and other piping components, has been blamed for several accidents. Static charge can accumulate on non-conducting material such as plastics or on insulated conducting material.

Polyvinyl chloride (PVC) wands used for overhead stripping of tank barges were blamed for a barge explosion which killed two men [12]. The plastic or polyethylene sleeves used for gas freeing can accumulate charge. Such a sleeve was partly to blame for the explosion on the AMERICAN EAGLE [10].

Fixed plastic pipe in cargo tanks has also been found to be potentially hazardous, since charge can build up outside the pipe during tank cleaning or inert gas operations or inside when fluid is flowing through the pipe [14].

Carbon dioxide Solid particles of carbon dioxide become charged during discharge from the nozzle and can lead to incendive sparks in a flammable atmosphere [3, 5].

Weather During periods of normal humidity, a film of water provides a leakage path over most solid insulators. In the dry climates of places such as deserts and arctic regions, humidity leakage may not be expected [6].

Synthetic clothing Industry experience shows that synthetic clothing does not give rise to significant electrostatic hazard under normal operating conditions; such clothing is not recommended because of its behavior when exposed to flames and heat [3, 5].

4.2.3 Spark discharge The cause and prevention of spark discharge has drawn the most attention in the efforts to address this problem. Incendive sparks are those which release adequate energy to ignite flammable vapors. Spark energy may be reduced by physical factors such as electrode resistance, spark gap distance, and large gap areas. Discharges are sometimes in the form of a "corona", an ionization of gas which is not incendive but may precede an incendive spark.

Known causes of incendive sparks are identified below.

· Insulated conductors Unbonded, conductive objects in a cargo tank can accumulate available static charge and generate incendive sparks when discharging to another conductor, such as hull structure. They may be either trash or equipment unknowingly left in the tank or equipment introduced to do work in the tank [3, 5].

· Cargo measuring devices (ullage tapes, thermometers, gas sensors, etc.) present a particular hazard since they are often used during and immediately after cargo loading when some risk factors are at their highest. Use of these devices within a sounding tube is acceptable; electrical potential there is low because of its small volume and the shielding it affords from the rest of the tank.

· Falling water slugs The VLCC explosions in 1969 were blamed on washing water slugs accumulating charge as they fell through charged mists generated by the washing operation and discharging as they approached hull structure. Tank atmosphere control during water washing was recommended by ISGOTT (1984). Other investigations established that slugs from smaller portable cleaning guns do not cause incendive sparks. The use of these machines in uncontrolled atmospheres is allowed by ISGOTT [15].

4.2.4 Flammable vapor Oils give off hydrocarbon vapors whose flammable properties are described, in part, by the lower and upper flammable limits (LFL and UFL). LFL and UFL are the lowest and highest concentrations of the vapor in air that will ignite in the presence of an ignition source, otherwise known as the flammable range. Concentrations below LFL are too lean to burn and those above UFL too rich. Tank atmosphere control measures aim either to make the air/vapor mixture too lean or too rich [3, 5].

Tank atmosphere is a constant concern regardless of the loading condition. Several factors can give rise to hazardous conditions, particularly as regards electrostatic discharge.

· Steam cleaning Steam cleaning of tanks is necessary between some product loads and can release hydrocarbon gas in tanks thought to be gas free (5). This is due to the heat introduced by the process and the disturbance of sludge, clingage, rust particles, etc. on the surfaces of the tank. The released vapors are dangerous with the electrostatic charge caused by the steam and the contaminants in the wash byproduct.

· Switch loading The practice of using a cargo tank for different products in consecutive loads is called switch loading. Conditions for ignition may arise when a low-vapor- pressure static accumulator is loaded into a tank which previously held a volatile, high pressure cargo, even if no standing liquid from the previous load is present. Volatile gases may also be introduced if product piping lines were inadequately flushed between loads or if bypass piping arrangements allow inadvertent mixing.

· Temperature fluctuations Hot/cold temperature extremes can result in locally hazardous conditions, e.g., when some cargo is heated by piping exposed to the sun. In such a case, much lower Reid vapor pressures result, with a possible increased risk of vapors within flammable limits [3, 5].

Section 5 Corrective and Preventative Measures

This section is organized in parallel with Section 4, that is, the safety measures are categorized by the four conditions contributing to electrostatic ignition. The safety standards which follow have been previously published for public use or developed for the benefit of a particular company. Each citation is accompanied by its source. The documents are abbreviated as follows:

ISGOTT- International Safety Guide for Oil Tankers and Terminals and the May 1991 addendum extending anti-static precautions to residual fuel oils and other oils.

API 2003- API Recommended Practice 2003, 'Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents'.

API 2015- API Publication 2015, "Safe Entry and Cleaning of Petroleum Tanks".

NFPA 77- "Static Electricity".

AWSC- American Waterways Shipyard Conference, "Safety Guidelines for Tank Vessel Cleaning Facilities".

Dixie- Dixie Carriers, Inc. training video, "Safe Overhead Stripping"

Sun- Sun Oil Co. Safety Manual.

Texaco- Texaco Inc. Research, Environment and Safety Department, "Static Electricity Code".

5.1 Mitigation of static charge generation

The generation of static electricity cannot be prevented absolutely, but may be minimized or eliminated through the application of certain precautions.

5.1.1 Loading Precautions The following are essential only when loading static accumulator oils (conductivity < 50 pS/m):

- Restrict initial loading rates, when splashing and surface turbulence occur, to flow rates less than 1 meter/second (volume flow rate conversions available). Adequate inlet coverage's are: side or horizontal entrance- 0.6 meter; downward pointing inlet- twice the inlet diameter. **ISGOTT**
- Loading rate conversions appear both in **ISGOTT** and **Texaco**.
- Restrict initial unloading rates to shore installations also, as long as inlets in the shore tank are not covered with liquid. The inlet fill pipe should discharge near the bottom of the tank. **NFPA 77**
- Keep water and other impurities out of the incoming cargo stream as much as possible. Extra care with loading and unloading rates when presence of impurities (e.g., water, sulfur, metals) is suspected is essential. **ISGOTT, NFPA 77**
- Avoid pumping entrained gases with cargo. **NFPA 77**
- Degassing (to <20% of LFL at tank bottom) or inerting a ship's tank eliminates loading rate restrictions due to static electricity. **Texaco**
- Reduced pumping speeds are used for discharge of slops and other "mixed-phase flow" (some ballast) to shore tanks. **Texaco**

5.1.2 Displacing of lines Clearing of cargo piping prevents cargo contamination (a suspected cause in the TT 103 explosion) and requires care. **Texaco** employs the following precautions:

- Asphalts and heavy fuels only may be cleared with air or inert gas.
- Heavy fuels and crude oils may be cleared with water, which must thereafter be debottomed.
- When necessary to use inert gas to displace clean products, a minimum amount must be used, particularly for aviation fuels.
- Clean product lines should never be blown with air.
- To clear water from a product line, pump twice the line fill volume of product at 3 ft/sec (fast enough to prevent water persisting at low points and at the correct speed to minimize static generation).

5.1.3 Protection against mist and steam Steam must not be injected into the tank, particularly in an undefined atmosphere. Steam cleaning should be avoided unless absolutely required because of cargoes in tank. **ISGOTT**

When required, steam cleaning is only allowed in a gas free atmosphere. No conductor, even if bonded, is allowed in the tank during cleaning or while steam remains as a cloud. **Texaco**

Industry standards allow the use of steam driven blowers; this practice is now in question because of the AMERICAN EAGLE accident [10].

5.1. 4 Precaution for crude oil washing (COW) The use of "dry"· crude oil for COW is important in order to avoid electrically, charged mists sometimes produced by a crude oil and water mixture. Before washing begins, any tank which is to be used as a source of crude washing fluid should be partly "debottomed" to remove settled water. The discharge of a layer at least one meter thick (from the bottom) is necessary for this purpose. **ISGOTT** and [16]

5.1.5 Precaution for overall loading Non-volatile petroleum at a temperature less than its flashpoint minus 10oC may be loaded overall if the tank is gas free and there is no contamination by

volatile petroleum. Volatile petroleum or non-volatile petroleum which exceeds the aforementioned temperature must never be loaded in this manner. **ISGOTT**

Texaco allows loading from the top only for crude oil and cutback asphalts. For all other products, temporary hoses must extend to the bottom of the tank with free ends secured against movement.

5.1.6 Air injection precaution Precautions should be taken to minimize the amount of air or inert gas being blown into the bottom of a tank containing a static accumulating oil. **ISGOTT, NFPA 77**

5.1.7 Precaution for combination carriers Oil/bulk ore carriers are broad-beamed, often with single cargo holds extending the full breadth of the ship. These holds should be pressed full when carrying oil since the large sloshing effects of a slack tank can generate electrostatically charged mists. **ISGOTT**

5.2 Prevention of charge accumulation

The following safety precautions have been developed to prevent the accumulation of static charge.

5.2.1 Antistatic additives These additives raise the conductivity of a static accumulator; one specification calls for a minimum of 100 pS/m. **ISGOTT**

Treatment is required for these fuels in Canada. The Canadian General Standards Board specifies minimum conductivity of 50 pS/m for static accumulating fuels, especially aviation fuels [17, 18].

API 2003 recommends that these additives be introduced at the beginning of the "distribution train", and notes that their positive effect may be reduced by repeated shipments or passage through clay filters.

Safety precautions for the handling of static accumulating oils have historically been waived for those treated with antistatic additives. These precautions have, however, recently been extended to residual oils and oils treated with anti-static additive to raise conductivity above 50 pS/m (May 1991 amendment to **ISGOTT**). The document is silent as to treated oils at or above 100 pS/m.

5.2.2 Relaxation of static accumulators The charge which accumulates in a poorly conducting liquid will slowly dissipate after loading is completed and the cargo is still. Relaxation time of 30 minutes is recommended after loading of static accumulating oils before introduction of cargo sensors into the tank. **ISGOTT**

Texaco specifies a 15 minute relaxation time for tanks smaller than 80, 000 barrels (about 10, 900 tons) and 30 minutes for larger tanks.

5.2.3 Non-accumulating piping wands, etc. Several accidents have focussed attention on the static accumulating properties of nonmetallic piping materials. The Coast Guard has recommended that all pipes, hoses, and fittings be conductive, electrically continuous, and bonded to ship's structure [19]. The following precautions have been adopted for stripping and cleaning "wands":

- Wands must be non-corrosive, nonmagnetic, non-sparking, and conductive. Dixie uses stainless steel wands.
- Aluminum wands with brass tips may be used. **AWSC**
- The Coast Guard has recommended against wands made of certain conductive materials such as aluminum -and magnesium since they can spark in contact with rusty hull steel.

Electrical continuity (bonding) of this equipment is critical; this is discussed in a subsequent portion of the report.

The recommended use of conductive materials for fixed piping also addresses this problem. The Coast Guard has specified that plastic pipes (such as post-chlorinated polyvinyl chloride (CPVC)) in tanks containing combustible and flammable fluids have a maximum resistance to ground of 1 megohm (10^6 ohms). 200 kilohms is specified in tanks which are adjacent to pump rooms and which contain static accumulating cargoes (conductivity > 100 pS/m) [20].

The International Maritime Organization (IMO) is considering a similar standard: the resistance of plastic piping would not exceed 100 kilohms/meter, and nowhere should exceed 106 ohms [21].

5.2.4 Tank washing Prevention of static accumulation is critical during all tank washing operations because of the vigorous agitation of liquids involved. Detailed precautions for all tank atmosphere conditions are given in **ISGOTT** and will not be reproduced in full here. The most important are included.

Water wash Mixing of immiscible liquids is inevitable during water wash and is a source of static electricity. The following precautions apply, particularly in undefined or too lean atmospheres:

- The tank should be kept drained during washing and washing stopped in case of water buildup.

ISGOTT

- Recirculated wash water should not be used for tank cleaning. **ISGOTT**
- Chemical additives in wash water must not be used in an undefined atmosphere. **ISGOTT**
- The last cargo carried must be determined by examination of the Material Safety Data Sheet (MSDS).

AWSC, Dixie

- Prior to washing, tank bottoms, cargo piping, and cargo pumps must be stripped to the greatest extent possible.

AWSC

- Ground or bond the tank vessel to the facility prior to opening cargo tanks (further discussion follows). **AWSC**

5.2.5 Filters Loading rates should be adjusted to ensure that 30 seconds elapse between the time the cargo leaves the filter and the time it enters the cargo tank. This restriction applies primarily to micropore or clay filters. Coarse filters (less than 50 mesh per inch, if kept clean, do not generate significant charge. **ISGOTT, API 2003**

5.2.6 Mopping After stripping, barge operators often remove residue from tank bottoms by mopping. The mop head must be 100% cotton (non-accumulating and non-conductive), attached to a stainless steel wand. Both the mop bucket and the wand are bonded to the hull. Dixie

5.2.7 Carbon dioxide The use of carbon dioxide as a fire extinguisher or for inerting must be avoided unless the formation of solid particles is prevented.

5.3 Prevention of spark discharge

5.3.1 Bonding and grounding The most important measure to prevent electrostatic hazard is to bond all metal objects together, eliminating risk of discharge between objects, and to assure that all components in the cargo handling system are at the same electrical potential. Grounding to earth is not necessarily desirable for all forms of transport; airplanes and tank trucks are insulated from ground by their tires and may be at a vastly different potential. In the case of tank vessels, grounding (or earthing) is effectively accomplished by bonding to the hull, which is naturally earthed through the water. Equipment should be designed to facilitate bonding and, in particular, to avoid the insulation of any conducting metal.

- Bonding of cargo transfer piping Hoses used in terminal transfer operations must be continuously bonded, and grounded to the hull.

It is important to note that cargo transfer piping must be insulated from the land-side terminal since electrical potential may differ from that of the vessel due to stray current or cathodic protection of the pier. Insulating flanges, joints, or sleeves are sometimes used to divide the cargo hoses into electrically isolated halves - onboard and shore side. Each half is bonded and grounded to its respective base potential.

Texaco does not allow ship-to-shore bonding except where required by statute. In such a case, insulating flanges are still required in cargo lines, and numerous other precautions are specified regarding the bonding wire.

Texaco adds the following precautions:

- De-energizing the pier's cathodic protection system is not reason to waive precautions.
- Non-conductive hose can become conductive with use and is not an acceptable substitute for an insulating flange.
- Flange location is separately specified for all flexible, all metal, and combination connections.
- Insulating device is periodically tested for resistance of at least 1000 ohms.
- Cargo hoses must be tested for conductivity when new, and periodically thereafter.
- Insulating flanges must be used when connected to submarine pipelines which have cathodic protection.

Bonding of portable tank washing machines Bonding wires should be incorporated within all water hoses and bonding established between water hoses, the tank washing machine and the cleaning water supply line. Hoses must be indelibly marked to show identification, and a record of continuity testing kept. All hose connections must be made up and tested for electrical continuity · before the machine is introduced into the tank and not broken until after the machine has been removed. **ISGOTT, Sun, Texaco**

When suspended in a tank, portable washing machines must be supported by a natural fiber rope and not by means of the water supply hose. **ISGOTT, Texaco**

Bonding of overhead stripping and cleaning systems

Portable or "overhead" systems are often used for cleaning and stripping tank barges in the absence of fixed piping. The following is the most thorough treatment of the safe procedure for the overhead stripping operation:

- Each length of hose is tested for continuity and visually inspected for damage.
- Hose is bonded to pump.
- Pump has permanently attached bonding wire, which is attached to hull by a C-clamp. One jaw of the clamp has a sharp conical point to assure penetration of painted or rusted surfaces.
- Final electrical continuity check on assembled stripping system is required, from end of conductive wands (see discussion below) to hull, and from pump to hull.
- Personnel do not wear insulating gloves while bonding equipment, but do while stripping.
- Falling liquid in tank must be avoided.
- Wands (of approved construction) must be extended to the bottom of the tank while in use to prevent possible discharge in the middle.
- Bond is maintained until operation is finished and wand is completely withdrawn from tank.
- After stripping, pump is run to clear hoses.
- Checklist maintained throughout operation. **Dixie**

In addition, **AWSC** states that the tank must not be ventilated prior to or during stripping of flammable liquids.-

5.3.2 Dipping and ullaging When loading static accumulator oils, metallic dipping, ullaging, or sampling equipment must not be introduced or remain in the tank during loading, and for 30 minutes after completion of loading, to allow for relaxation of accumulated static charge. Bonded equipment which is grounded to hull structure may be used after the 30 minute stand down. Ropes used must be made of natural, not synthetic, fiber. **ISGOTT**

Texaco specifies a 15 minute relaxation time for tanks smaller than 80,000 barrels (about 10,900 tons) and 30 minutes for larger tanks.

The foregoing precautions also apply during water washing of tanks in uncontrolled atmospheres and for five hours thereafter, which period may be reduced to one hour if the tank is continuously vented after washing. **ISGOTT, Sun**

Operations carried out in sounding pipes are permissible at any time. **ISGOTT**

Permanently fitted float level gauges do not present a hazard if they are properly grounded and the guide wires are intact. **ISGOTT**

5.3.3 Tank cleaning Vacuum trucks should be located at least 50 feet away from the tank and upwind. Exhaust vapor from the truck should be downwind from the truck. Suction and discharge hoses must be electrically bonded and grounded. **API 2015.**

5.3.1 Loose objects Every effort must also be made to ensure removing all loose objects from a tank and to prevent loose metal or objects from falling into a tank. **ISGOTT, others**

5.3.5 Free fall of liquid It is essential to avoid the free fall of water or slops in the cargo tank or a tank used for receiving slops. **ISGOTT**

5.3.6 Gas freeing Portable fans or blowers should only be used if they are hydraulically, pneumatically, or steam driven. Their construction materials should be such that no hazard of incendiary sparking arises if the impeller touches the casing. **ISGOTT**

It should be noted that the U.S. Navy, as well as some operators, is considering discontinuation of use of steam driven blowers (such a machine was the suspected cause of the AMERICAN EAGLE casualty). Portable fans should be bonded to the deck. Air suction and discharge hoses should be bonded for electrical continuity to the or the hull. **ISGOTT**

5.3.7 Inert gas precaution If the inert gas plant breaks down during discharge, operations should be suspended. If air enters the tank, no dipping, ullaging, or sampling equipment should be introduced into the tank for at least 30 minutes, after which securely earthed equipment may be used; this restriction should be applied for five hours. **ISGOTT**

5.3.8 Carbon dioxide Carbon dioxide should not be injected into tanks which may contain flammable gas mixtures. **ISGOTT, NFPA 77**

5.4 Control of vapor composition

Control of tank atmospheres has historically been used to control fire hazards, particularly since inert gas systems (IGS) was mandated following the VLCC explosions of 1969. A number of different approaches are used to prevent flammable gas mixtures.

5.4.1 Definition of tank atmospheres Crew members should always check the Material Safety Data Sheet(s) (MSDS) prior to any operation, for cargo previously in the tank as well as that to be handled at that time. **Dixie, API 2015**. The MSDS is prepared in accordance with the OSHA Hazard Communication Standard (29 CFR 1910.1200) and includes the important physical properties of the material and all pertinent safety warnings. This knowledge is critical to tank atmosphere control.

The flammable constituents of a tank atmosphere are defined by ISGOTT as follows:

- Inerted An atmosphere made incapable of burning by the introduction of inert gas and the reduction of oxygen content below 8% by volume.
- Too lean An atmosphere made incapable of burning by the deliberate reduction of the hydrocarbon content to below the lower flammable limit.
- Undefined An atmosphere which may be above, below, or within the flammable range.
- Over rich An atmosphere made incapable of burning by deliberately maintaining the hydrocarbon content of the tank over the upper flammable limit (usually 15%). **ISGOTT**

5.4.2 Water washing Water washing of tanks may be carried out in any of these atmospheres □ provided specific precautions for each tank condition are complied with. These are specifically identified by both **ISGOTT** and **AWSC**.

Some companies exceed particulars of **ISGOTT** safety measures. In washing of inerted tanks, for example, **Sun** specifies the following:

- Oxygen levels below 5%, vice 8%
- Measurements required in each section of a tank divided by swash bulkheads
- Continuous monitoring of pressure and oxygen content during washing.

5.4.3 Gas freeing Gas freeing is one of the most hazardous operations on a tanker, since the tank atmosphere is likely to pass through the flammable range as fresh air replaces tank gases. All electrostatic precautions should be observed at this time. All cargo piping lines should be discharged and flushed with water, and the tank stripped afterward. Valves should be closed and secured. **ISGOTT**

Portable fans should be bonded to the deck. Final gas measurements should be done 10 minutes after completion of ventilation at several levels in the tank, and, in large tanks, at widely separate locations. **ISGOTT** Periodic checks of the atmosphere should be made, particularly when cleaning disturbs residual product in the tank.

5.4.4 Steam cleaning of tanks After carriage of certain products, some tanks require cleaning by steam. This should only be done in tanks which have been inerted or water washed and gas freed. The concentration of flammable gas should not exceed 10% of the LFL prior to steaming. Steaming should be avoided when there is any risk of a flammable atmosphere in the tank. **ISGOTT, AWSC**

5.4.5 Switch loading Switch loading is defined by Texaco as loading a low vapor pressure (high flash point) product, such as AVJET A, into a compartment in which the previous load was a high vapor pressure (low flash point) product, such as gasoline". Merely changing product is called "cross loading".

Care must be shown to avoid contamination of static accumulators, such as middle distillates, with low flash point products. Thorough flushing of cargo lines, stripping, and gas freeing are obvious precautions, which may not suffice to prevent disturbing liquids and gases absorbed by rust and sludge in the tank.

Certain products such as lube oils are not allowed to precede high static fuels such as "Avjet JP 4" as the last cargo. **Texaco** requires management approval for certain types of switch loading.

Tankermen should check the MSDS for the previous cargo as well as that to be loaded and proceed with extra caution (with regard to loading rates, hand dipping, etc.) if a static accumulating oil is being loaded where a highly volatile cargo was previously carried, or vice versa.

5.4.6 Securing of covers Stripping or cleaning of cargo tanks should proceed one at a time. All others must be closed and dogged in order to keep their atmospheres above the UFL and to prevent migration of hydrocarbon gases across the deck.

5.5 Exceptions

No antistatic precautions are necessary while the tank is maintained in an inert condition or if the non-volatile static accumulator oils are being handled in a gas free tank at a temperature of less than their flashpoint minus 10°C. **ISGOTT**

ISGOTT presents tables indicating necessary precautions and exceptions for all loading situations.

5.6 General

A clear chain of command and clearly spelled out responsibilities are a must for every routine cargo tank operation. **Dixie** has done so, designating duties for the operations supervisor, wheelman, and tankerman.

Management must strive to maintain consistently high levels of safety through training and proper placing of the priority on safety.

Section 6 Conclusions and Recommendations

6.1 Conclusions and Recommendations

- A large body of safety guidance against the static electricity hazard is available to industry, but has not eradicated the problem, as indicated by a number of serious accidents in recent years.
- Knowledge of static discharge safety by operators, tankermen, tank cleaning personnel, and others is often deficient, as errors leading to recent accidents show.
- Safety guidelines among existing safety publications are, for the most part, consistent, but significant differences were found on many points.
- A concise, readable guide (or guides) bearing the imprimatur of the Coast Guard will likely improve industry's safety record with regard to static electricity.

6.2 Recommendations

- Existing industry publications should be thoroughly checked against recommendations made following accidents by investigative bodies.
- The Coast Guard should proceed with Phase 2 of this project, the development of a safety guidance field manual for use by industry. The Coast Guard should consider making the manual an enclosure to a NVIC which spells out broader issues such as personnel training and management commitment to safety issues.
- The Coast Guard should consider preparing specific guidance targeted sectors of the oil shipping industry (e.g., large product carriers, barge operators, tank cleaners) with separate dedicated volumes of the field manual.
- A roundtable of experts from industry, government, and standards organizations should consider the scope, technical content, and manner of presentation of a Coast Guard field manual.

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