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Risk assessment

NEW APPROACH IN THE PROCEDURES OF GAS FREEING AND INSPECTING CONFINED AND ENCLOSED SPACES IN MARITIME VESSELS

P. STAVRAKAKIS[a]*, M. CHALARIS[b], P. SARAFIS[c], G. DOURMAS[d]

[a]*Senior Naval Officer Aegean Staff – Hellenic Navy (C' Branch) Terma Propontidos, Palataki, 18 539 Piraeus, Greece*
E-mail: p.stavrakakis@gmail.com
[b]*Hellenic Fire Corps Headquarters, Direction Health and Safety, 31 Piraeus Street, 10 553 Athens, Greece*
E-mail: mchalaris@chem.uoa.gr
[c]*Athens Naval & Veterans Hospital-Infections Diseases & Tropical Medicine Department, LMU, Munich, Germany, 14 Ap. Ellinon, 15 343 Athens, Greece*
E-mail: psarafis@med.uoa.gr
[d]*Department of Shipping Trade and Transport, University of the Aegean, Korai 2a, 82 100 Chios, Greece*

Abstract. In naval vessels, air quality monitoring in general and specifically gas free-testing is an important and demanding task. Gas-free procedures include measurements of oxygen levels, explosive (% LEL) and toxic gases by qualified and experienced personnel through various handheld devices. However, confined spaces of warships (fuel tanks, CHT spaces, voids, etc.) along with other special features appeared in ships (low accessibility, poor lighting, moisture, lack of air movements, etc.) provide with more difficulties regarding air quality monitoring. A versatile handheld field device, originally developed for early location of entrapped people, specially modified and designed is tested for supporting the air quality monitoring procedure of naval spaces. The device developed enables chemical, visual and audio capabilities. Special performance characteristics such as robustness, corrosive resistant, easy decontamination, explosive proof and minimum electromagnetic signature are investigated for optimum performance. This all-in-one device will possibly provide on-line and on-site measurements offering to fleet crewmembers and shipyards personnel an easy-to-use reliable tool for performing air quality monitoring effectively, efficiently and quickly. Furthermore, the cost for maintenance and inspection of confined spaces will be probably reduced without risking personnel safety, while adding to air quality monitoring the abilities of audio and visual abilities for surveillance.

Keywords: gas-free, gas-free testing, confined spaces, air quality monitoring.

* For correspondence.

AIMS AND BACKGROUND

Entering or/and working in confined spaces aboard ships is a demanding task that one has to face many serious even life-threading hazards. Those risks include oxygen deficiency, exposure to toxic contaminants, fire and explosion, drowning, risk of engulfment by solid materials, risk of being trapped by small passage ways, and other hazards. The present paper is representing the need for gas-freeing confined and enclosed spaces, the hazards and risks associated with gas-free operations along with the current methods used in gas-free engineering. In addition, in Discussion, the paper presents a proposed method for eliminating the need for human presence in confined or enclosed spaces thus reducing significantly the risks to which the gas-free practitioners will be exposed to. Finally, it is summarised the main conclusion derived from the work presented in the present paper.

Undoubtedly, no routine hazard with the exception of ordnance is as dangerous as the presence of potentially lethal atmospheres in ships. In many instances, potentially harmful gases or vapours are present in such a low concentration (ppm or even ppb) that no adverse conditions are created. By design, a ship has many confined spaces (especially tanks and voids) in which a multitude both of toxic and non-toxic gas- and vapour-creating operations are used in the normal operation of the ship. Hazardous atmospheres may be created that can explode or cause asphyxiation and poisoning. Compounding the problem is that many gases or vapours are not detected by the human ability of smell and personnel attempting to save a fallen shipmate may themselves be overcome and killed by undetected vapours. It is for these reasons that every confined space must be gas-free tested. It is known as gas-free engineering. In fact, personnel entering or working in or on confined spaces may encounter hazards[1,2], including:

(a) lack of sufficient oxygen to support life;

(b) excessive levels of oxygen which increase the danger of fire or explosion;

(c) presence of flammables or explosive atmospheres or materials;

(d) presence of toxic atmospheres or materials.

Because they are not always readily apparent, not detectable by the human senses, it is imperative to test for hazardous conditions prior to entering confined spaces.

EXPERIMENTAL

SOURCES OF CONFINED SPACES HAZARDS

Many factors need to be evaluated before entry into, or work in or on confined spaces. Such evaluations shall include, at a minimum:

(a) whether present or previous contents have introduced flammables, toxicants or oxygen depletion or enrichment;

(b) whether the location and configuration of the space (including restricted access, obstructions or remoteness) may inhibit or interfere with movement, ventilation, escape, rescue, or firefighting;

(c) whether the types of operations to be conducted within the space can produce toxicants, flammables, oxygen depletion or enrichment or ignition sources;

(d) whether fixed equipment (for instance piping systems, conduits, ducts, machinery or pressurised lines) within the space are potentially hazardous;

(e) whether there are other hazards, such as slippery surfaces, restricted walkways or ladder, poor illumination or hazardous materials present;

(f) whether the contents or the nature of the boundary spaces may result in fires or explosions because of the work being done in the space;

(g) whether environmental conditions may contribute to confined space hazards (for example elevated ambient temperature may cause accelerated vaporisation, seepage or leakage of volatile solvents);

(h) whether additional hazards may be created by work interruptions, welding or cutting torches that have remained in the space or securing of the space ventilation during the interruption.

ENTRY AND WORK RESTRICTIONS FOR CONFINED SPACES

All confined spaces shall be considered hazardous. Entry into, or work in or on such spaces is restricted. Additionally, results of gas free tests may dictate further restrictions. Broadly the following[1] shall apply to confined spaces:

(a) entry by non gas-free engineering personnel or work in confined spaces must be prohibited until such spaces have been inspected, tested and certified safe for entry or work or both;

(b) entry into or hot work in or on fuel tanks, spaces in which fuel tanks vents terminate, piping or equipment servicing such spaces or other confined spaces known to contain flammable fuels should be permitted by the ship commanding officer;

(c) only approved intrinsically safe, spark-proof or explosive-proof equipment should be used when oxygen-enriched atmospheres or flammable or explosive vapor gases, or material are present;

(d) when materials and conditions within the space introduce flammables, toxicants or unsafe oxygen levels than the source of the contamination should be removed before entry or work.

WORKING ALONE

Personnel in any confined space shall always work with an observer or an outside attendant. It should be maintained communication between personnel outside the space and personnel entering or working inside.

PERSONNEL PROTECTIVE EQUIPMENT (PPE)

Personnel entering or working in confined spaces shall use certified and approved Personnel Protective Equipment appropriate to the operation, exposure and expected hazards.

ACCESS TO HAZARDOUS SPACES

Access with more than one means should be provided to a confined space having a hazardous atmosphere, or in which ongoing work may generate. This provision is very important in case of an accident where emergency and /or medical evacuation is needed.

TESTING PROCEDURES AND RESULTING RESTRICTIONS

The testing and examination of a confined space shall consist of certain routine steps as follows[1–10]:

(a) initial testing shall be performed from outside the space;

(b) first, testing for oxygen should be conducted using an approved and calibrated oxygen-meter. The normal oxygen level of ambient air at sea level is 20.9%. Oxygen levels less than 19.5% or greater than 22% shall be considered immediately dangerous to life or health (IDLH);

(c) second, testing for combustible vapours or gases should be conducted using an approved and calibrated combustible gas indicator. Concentrations of 10% or greater of the lower explosive limit (LEL) shall render the atmosphere IDLH. Many combustible indicators function by indicating a circuit imbalance. This imbalance is created by combustion within the meter and requires proper oxygen levels in the sample. Atmospheres that are oxygen-deficient or oxygen-enriched affect combustible indicators of this type. The oxygen requirement is a further reason for testing oxygen first;

(d) third, testing for toxicants should be conducted according to the nature of the space and its contents, use or operations. Common toxicants aboard ship include hydrocarbons, hydrogen sulphide, carbon monoxide and carbon dioxide;

(e) when initial tests indicate deviations from normal oxygen levels or the presence of flammables or toxicants, personnel entry must be prohibited.

All fuel tanks, chemical tanks, sewage system tanks (including all piping associated with these systems) or similar high hazard areas shall be treated as IDLH regardless of test readings until these spaces have been emptied, cleaned and ventilated to remove contaminants and certified by qualified and authorised personnel.

CONDITIONS FOR CLASSIFYING SPACES AS IMMEDIATELY DANGEROUS TO LIFE OR HEALTH (IDLH)

A confined space classified as IDLH is one in which the atmosphere meets one or more of the following conditions[1,9]:

(a) flammables vapours at a concentration of 10% or greater of the LEL;

(b) oxygen content less than 19.5% or greater than 22% by volume. The IDLH for submarines underway, due to the difference in the partial pressure of oxygen, is less than 16.5% by volume;

(c) presence of toxicants above IDLH limits.

Entry into IDLH spaces is authorised only under emergency conditions. Specific precautions must be observed for entry into IDLH spaces.

DISCUSSION

It is clear that when naval personnel work in or on confined spaces and maintain all current safety precautions they have to deal with certain difficulties that some of them are the following:

- entering into IDLH spaces demands specific preservation of strict rules;
- inspection of IDLH spaces is feasible only by entering or prior cleaning the space;
- accidentally exposure to extreme dangerous conditions. From the aforementioned problems it is derived that the current approach of gas-free engineering consumes valuable resources such as:
- time;
- protective equipment;
- extra manpower;
- special training.

OUR PROPOSED METHOD

It is clear that gas-freeing or entry into a confined space is a demanding task that involves significant risks. The idea is to develop a system capable of inspecting and collecting data from confined spaces without the need for human presence in it or the requirement for cleaning the space prior the inspection. One solution to the problem can come by modifying CHAVI-med[11], which is a versatile, low-cost, lightweight, autonomous device originally developed for early location of entrapped persons in collapsed buildings. The device combines field chemical analysis with visual and audio capabilities. What we are really trying to achieve is that, by dropping a suitable probe from a confined space opening, to collect all the necessary data concerning the confined space. The main parts of our device are the following:

(a) the head, which carries camera, microphone, sampling tube, servo-motor and light bulbs;

(b) the probe, which is a flexible tube combined with various rigid sleeves can move to any direction within a space. Also the probe internally carries the appropriate cabling and externally the sampling tube;

(c) the control unit. With this unit a single operator can have complete control of every function of this device. All data that collected by the probe head are been checking by the operator and stored for later analysis and evaluation. Furthermore, the operator can watch images from the space, displayed on the control unit screen. Also headphones are provided so the operator can listen to the sounds reaching the head microphone. Additionally there is the capability for cordless transmission of the collected data and remote control of all the functions of the device;

(d) a multi-gas analyser monitors the space atmosphere for oxygen levels, combustibles and toxicants. So the operator can be aware of the atmospheric conditions prevailed in the space. Furthermore a GC-IMS device analyses and monitors air quality within the space. In this way, it is possible to be detected even minors leaks or any unusual gas in the space. Allowing the responsible staff to take preventive measures or to make the appropriate repairs. Besides to that, it is also possible through the sampling tube the collection of air samples for further analysis or legal purposes.

SPECIAL PERFORMANCE CHARACTERISTICS

It is also our top priority to examine every parameter in order the developed device to operate with optimum performance. The environment in which this device will operate it is extremely hostile. That means our device should combine robustness, corrosion resistance, easy decontamination, explosive proof and minimum electromagnetic signature with the best way.

• First, robustness is a quality that every device aboard a ship should have. By its nature a naval vessel, especially warships, is a challenging field. In fact, the combination of narrow spaces, vibrations and lack of attention by the crew creates the demand for robustness for long-term use.

• Second, resistance against corrosion is a general principal for everything in a ship, due to the fact that the sea environment is itself aggressive. Besides, the confined spaces atmosphere might create intense corrosive conditions such as those in ballast or chemical tanks.

• Third, easy decontamination is a parameter of paramount importance for operators and crewmembers health. The environment in which the device will perform its operation may hide chemical and biological agents of high toxicity. For this reason the device exposed parts should be cleaned and decontaminated completely in a way that ensures simplicity and effectiveness.

• Fourth, it is basic that every kind of equipment that is used in confined spaces must be explosive-proof. This also applies for the developing device.

• Fifth, minimum electromagnetic signature is a capability that it does not stand as a requisite for operation within a confined space. But, we are examining this as an option for further applications.

ADVANTAGES

An easy-to-use reliable tool. Our primary goal is the final result to be a device that will combine reliability and effectiveness with easy operation and deployment. The reason for this is the fact that likely users of a device of this kind may be members of a ship crew with given training and technical background. On the other hand, the daily life has shown that the possibility of using a demanding and complex appliance discourages its use and probably the rate of errors might be high. If this applied in gas-free procedures, the outcome would turn out to be fatal.

Minimising risks. We also believe that the use of this device will minimise the entries required in confined spaces for inspection. In this way there will be a significant decrease of risks that the personnel will be exposed to. By using this device there is a strong alternative. The operator can gather data for a space without having someone inside holding test kits or a gas analyser. Otherwise, in order to obtain information about a confined space someone should get in and some others should stand-by outside the space as rescue personnel. Revising the history of fatal accidents in confined spaces we can see that in most cases the fatalities are rescuers who tried unsuccessfully to save a dying victim.

Reducing cost. By using this device the collected evidence can be stored for later or detailed processing. Allowing the engineering staff to evaluate the findings in due time. So there will be the ability to keep detailed records for every ship space. Having this in mind it is more than certain that ships crews can have accurate perception for the confined spaces condition thus they can better programmed the maintenance schedule, saving money and time.

CONCLUSIONS

There is no doubt that accidents occurred and there will be more in the future. When considering the causes for this sad reality, there are a lot of reasons that can be told about it. Actually, when crewmembers are exposed to a dangerous situation, like the entry into confined spaces, there are many things that can go wrong. However, we strongly believe that the implementation of the modified device can contribute in reducing the number of fatalities and injuries caused by unsafe conditions in confined spaces. Moreover, this device would allow those involved to operations associated to confined spaces to perform their duties with increased safety and efficiency.

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