

FIREPASS – A NEW TECHNOLOGY FOR TOTAL FLOODING APPLICATION

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INTRODUCTION

As the search for reliable and viable means of fire suppression progresses, engineers have learned that the science of fire prevention and suppression is one riddled with numerous variables and complexities. Present generation total flooding systems have proven to be a vast improvement over early water sprinkler systems but still face enormous drawbacks for protecting normally occupied facilities.

The technical drawbacks of current-generation systems are further complicated by health and environmental regulations. The applicable regulations make it very difficult for present systems to reliably accomplish the goal of total flooding fire suppression. Such problems have spurred the quest for new technologies and alternatives to present systems.

This presentation intends to note some of the major deficiencies with current systems as well as highlight a new alternative system. Using a new approach in total flooding, many problems facing present-generation systems are uniquely solved. Specifically, these problems are solved through the application of a fire-suppressive/preventative premixed nitrogen-based oxygen-reduced (hypoxic) total flooding agent. This new system maintains a precisely controlled oxygen level that is healthy for occupants. Such an agent can be produced in ample quantities at the site from the ambient air and can be stored for instant fire suppression and/or the creation of a permanent human-friendly breathable fire preventative environment. This technology dubbed FIREPASS (Fire Prevention and Suppression System) and described in U.S. Patents: 6,314,754; 6,334,315; 6,401,487; 6,418,752 and 6,502,421, contains multiple innovations that radically differentiate it from existing total flooding inert gas based systems.

Although the properties of IGS are widely known, the FIREPASS examined in this study utilizes nitrogen-enriched or hypoxic (low oxygen) air in such a manner that it dramatically reduces the risk that fire poses to normally occupied facilities. The FIREPASS system is a three-part system. It can be used in preventative, suppressive or a hybrid prevention/suppression system. This for the first time, can offer protection against fire ignition using healthy and breathable hypoxic air. Additionally pressurized vessels of hypoxic air can be used either alone or in a supplementary fashion as a total flooding inerting agent in the unlikely event that a fire actually does break out. Whether used independently or as a 2-part hybrid system, this FIREPASS offers unique fire protection benefits as well as an unparalleled safety level.

This system, while solving many of the problems facing current-generation systems, also allows for its implementation in facilities that may be considered practically impossible to evacuate such as air/spacecraft or submarines. Additionally it offers a higher level of protection to facilities such as Critical Operations Control Centers (COCC) where loss of functionality shall be considered wholly unacceptable.

DEFICIENCIES OF CURRENT TOTAL FLOODING SYSTEMS

1. All total flooding applications presume an inevitable disruption in the functioning of a protected facility, which can be unacceptable in case of a COCC or other vital military operations.
2. Extinguishing major fires in obstructed spaces cannot be reliably achieved with total flooding chemical suppressants.
3. The aggressive chemical agents released are toxic to humans. Present systems require evacuation upon system activation and cannot ensure the respiratory health of an individual that may be incapacitated in the protected environment.
4. Dry chemical extinguishing agents are also highly corrosive to electronics and may cause more harm than good in the event of activation.
5. Both chemical and inert gas total flooding systems for normally occupied spaces are capable of only a single, short-lived, use. Therefore, recovery operations must be performed under a significant risk of re-ignition.
6. In the event of accidental actuation, present-generation systems are rendered useless until costly and time consuming re-fills are complete. This may be unfeasible in such applications as ships and nuclear submarines that are away from port for long periods of time. Moreover, until then, the space is no longer protected from fire.
7. Total flooding is strictly limited to the enclosed structures that would contain the released suppression agent at design concentration. However, there is a significant risk of not achieving the prescribed design concentration. For instance, the structural integrity of a protected space could be damaged because of an explosion or by a mechanical deformation. This can cause an uncontrolled leakage of the flooding agent, preventing the creation of the appropriate fire-suppressive concentration. In the case of inert gas-based agents, fire can still propagate in atmospheres where the oxygen content has not been sufficiently reduced, thus producing higher levels of carbon monoxide which can cause inhalation poisoning in the occupants.
8. Conversely, when the design concentration of an inert gas-based agent becomes excessive, another hazardous situation in which occupants may suffer from severe hypoxia arises.

One of the primary concerns in present-generation total flooding technologies is achieving agent homogeneity in the protected space. If a fire exists in a region of lower agent concentration it will take longer to extinguish, meanwhile the flame is producing large amounts of toxins and causing further damage. Because inhomogeneities originate from insufficient mixing of inert gas with the ambient compartment air, inert gas diluting-based technology unfortunately has an inborn deficiency. In this regard, the inert gas systems for occupied spaces shall be more correctly referred to as oxygen-diluting rather than total flooding systems.

In order to achieve maximum dispersal, suppression agents are usually injected horizontally from an elevated position. Unfortunately, agent inhomogeneities become increasingly common and more difficult to control as one elevates the dispersion nozzles. Additionally, properly mixing the internal atmosphere in the protected compartment can be greatly complicated by the presence of common room obstructions such as equipment installed in the protected compartment. Present technology does not reliably accomplish the necessary homogenous mixture of extinguishing agents. This inability to reliably predict the time needed to extinguish a fire, toxic decomposition product output, and large temporal-spatial agent inhomogeneities underlines the need to simulate and test design concentrations in varying sized and configured compartments. However, these simulations and tests are usually focused on achieving appropriate design concentrations in closed unoccupied compartments where the evacuation of occupants is not accounted for.

According to NFPA 2001 Standard [1]:

“The requirement for pre-discharge alarms and time delays is intended to prevent human exposure to hazardous hypoxia”.

Additionally, the pertinent NFPA regulations meant to minimize casualties in the event of extinguishing agent dispersal are at odds with the methods necessary to reliably achieve the prescribed agent design concentration for occupied compartments.

NFPA requirements mandate personnel evacuation upon initiation of present-generation systems. Though well intentioned, these regulations ensure large obstacles in designing a reliable fire suppression system. Occupants quickly evacuating through doors in an emergency scenario are likely to leave uncontrollable openings that would prevent achieving design concentration and minimal hold time. These regulatory obstacles add to the already inconsistent nature of present-generation systems.

SUPPRESSION APPLICATION

The FIREPASS suppression agent is premixed hypoxic air consisting of 10-12% O₂. The agent itself is effective against the same threat regime and extinguishes in a fashion similar to 100% N₂ systems. It is important to note that the safety level and the simplification of the dispersal process differentiate the FIREPASS agent from 100% N₂ and other IGS systems.

FIREPASS' premixed agent is why this system cannot possibly saturate the space with a gas that has dangerously low levels of Oxygen; thus, it ensures the safety of the occupants. This advantage also eliminates the need for Oxygen monitoring systems meant to ensure the safety of the occupants.

Unlike Halon systems, the FIREPASS system can release its agent in the protected space at floor level. Having much colder temperatures and a higher density than normal air, the FIREPASS agent floods the protected space from the ground up in the same way water might flood a compartment. Therefore, the air of the protected compartment that is polluted with combustion products would be vented out through the top of the compartment and substituted with the agent. This advantage allows the FIREPASS system to be truly thought of as a total-flooding system.

In the suppression mode, FIREPASS is a total flood system and agent that fully complies with the NFPA Standard 2001, "Clean Agent Fire Extinguishing Systems." FIREPASS can prevent and/or extinguish fires in Class A, B and C hazards.

In the suppression mode, the effluent discharge of agent with 10-12% eliminates fire in a short time, while simultaneously evacuating toxic combustion gases and providing occupants with fresh breathable air. At 10-12% O₂ all combustion will cease (Fig. 1).

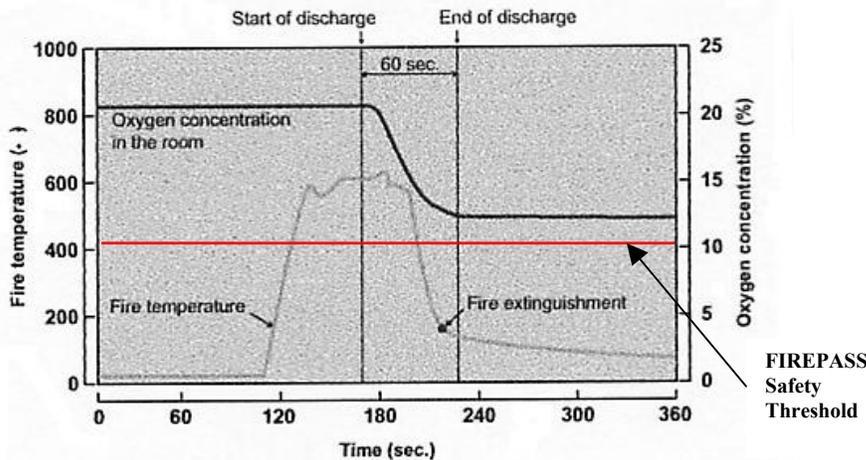


Fig. 1: Koatsu (Japan) 100% N₂ System Extinguishing Properties

The above modified diagram of Koatsu Nitrogen System discharge, illustrates the suppression offered by a typical N₂ suppression system. The red line on the graph illustrates the safety threshold of the FIREPASS system. The FIREPASS system with 10% O₂ agent will not allow the O₂ percentage to drop below 10% whereas typical N₂ systems cannot ensure proper mixture percentages due to inhomogeneity issues. In order to function properly, typical Inert Gas Systems must release the agent in its entirety within approximately 60 seconds. The problem being, at the end of the 60 seconds, if design concentration and/or suppression are not achieved, there is nothing more the system can do to protect against fire. The FIREPASS system, due to the nature of its agent, has the same ability to bring the O₂ environment to 12% within 60 seconds. Furthermore, it can continue to discharge the hypoxic agent for up to 20 minutes, or as long as needed, without allowing the O₂ environment to drop below safe levels. This ensures that all glowing will cease and recovery operations can operate without risk of reignition.

As the hypoxic air forces out the contaminated air through pressure vents, the space will be filled with a breathable fire-safe atmosphere. Unlike many common emergency ventilation systems meant to provide the occupants with breathable air, the FIREPASS system does not supply the fire with additional oxygen. Furthermore, the slightly positive pressure created and maintained in the protected space helps to eliminate fresh oxygen-rich air from flooding into the compartment and feeding the fire through any openings.

Fig. 2 illustrates the concept of FIREPASS in fire-suppression mode for a large volume hangar.

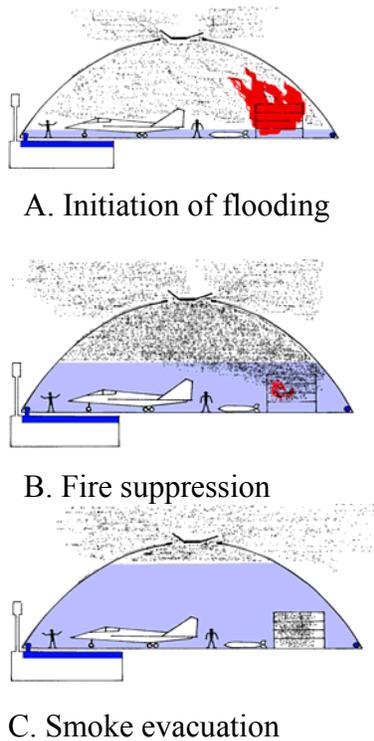


Fig. 2

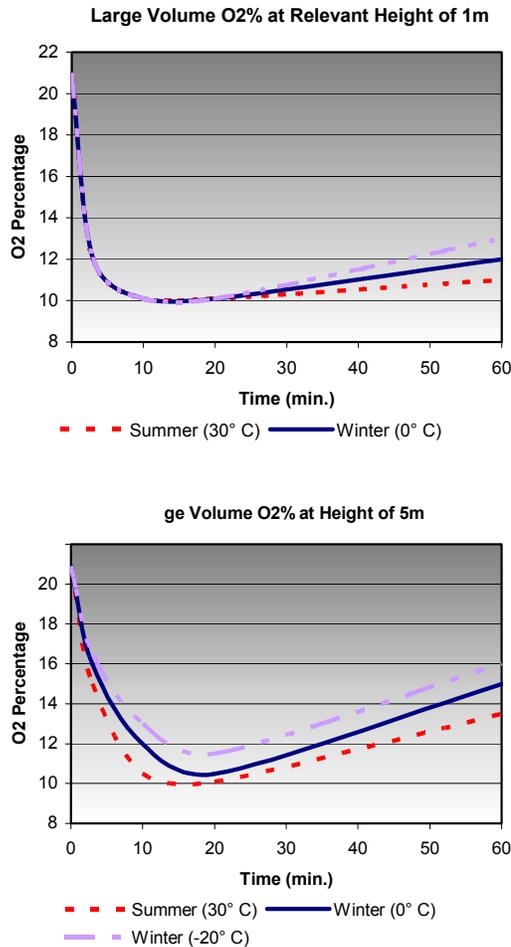


Fig. 3

Figure 3 illustrates a computer model for oxygen concentration and hold time for the scenario shown in Figure 2 within 60 minutes after agent released.

The above figures relate to FIREPASS in suppression mode being applied to an aircraft hangar with the volume of 40,000 m³. **Fig. 2** illustrates the manner in which the FIREPASS examined would flood the hangar with breathable hypoxic air whereby extinguishing the fire, ventilating the space and allowing for uninterrupted use of the facility. The fire-suppression system employed in this hangar consists of 40 high-pressure vessels each containing 2.5 m³ of the hypoxic agent having 10% O₂ at 300 bar pressure. Agent released from such a pressure will be much colder than the internal atmosphere. The discharge of the system will provide 30,000 m³ of the agent that will provide and sustain an environment having between 10% and 12% O₂ in the bottom portion of the structure for at least 30 minutes – time enough to eliminate fire and any

glowing and take appropriate measures. Warmer ambient air and smoke will be pushed upwards and will not affect considerably the oxygen content in the lower level.

Fig. 3 illustrates the O₂ percentages at various times at a relevant height of 1m and at a height of 5m when tested at three different outside temperatures. The chart shown on Fig. 3 is based on 7 years of data gathered on flooding environments with hypoxic air. The experimental data, which was gathered in tests involving different sized spaces, was run through a computer model to simulate the flooding of a 40,000m³ volume. The preliminary computer model is pending validation.

Note that, at a height of 1m at all outside temperatures, the FIREPASS system achieves a full suppression in 12% O₂ atmosphere in less than 3 minutes. During 20 minutes of the agent release, the O₂% will be reduced to 10% and can be maintain at a fire suppressive O₂ level for an extended period of time.

At a height of 5m the system is slightly slower, but still effective in achieving a flame suppressive environment. In the unlikely event that fire is initiated at a height of 5m, a full suppression can still be achieved within 10 minutes and maintained for 20-30 minutes. This is due to extraordinarily long discharge capabilities that the FIREPASS posses.

The hold times are dependent upon outside temperature; if it is very cold outside, the dense outside air has a tendency to penetrate the protected environment, thus decreasing hold time. Hold time degradation due to outside temperature is related to height; at 5m outside temperature plays a more significant role than at 1m.

The FIREPASS in suppression mode is suitable for scenarios from small to extremely large volumes where the FIREPASS in prevention mode may not prove to be cost effective.

FIREPASS technology is less sensitive to structural integrity damage because it relies on effluent continuous delivery of the self-propelled agent; therefore it provides reliable fire suppression in semi – enclosed structures and even in opened traffic tunnels [2].

PREVENTATIVE APPLICATION

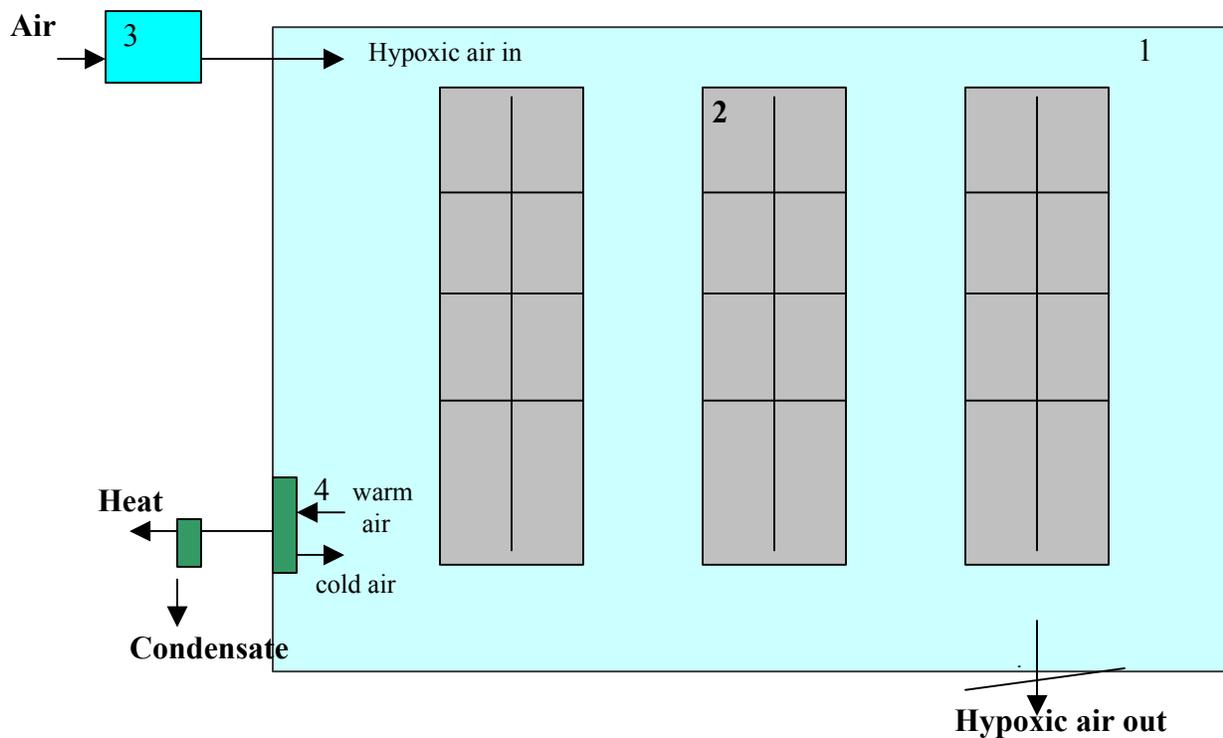
As aforementioned, the FIREPASS has the unique capability to create a breathable environment which prevents flame ignition. FIREPASS' fire preventative normobaric hypoxic environment can provide a truly unique solution for the fire safety problem in COCCs and other important applications. In preventative mode, the environment in the normally occupied facility is perpetually maintained at 15-16% oxygen, which is healthy for human occupants. (15-16% O₂ at sea level corresponds to an altitude of 2600-2100 meters in terms of O₂ partial pressure.) This preventative environment significantly reduces the possibility of ignition of a majority of common flammable materials.

The occupants of a FIREPASS protected COCC would regularly work in an artificial normobaric oxygen-controlled atmosphere. Since the facility must be capable of functioning autonomic for extensive periods the general principles of maintaining the atmosphere in a habitat enclosure should be applied.

An important advantage of preventative FirePASS is that it creates and constantly maintains a slightly positive barometric pressure inside a protected facility, which prevents warfare aerosolized agents from permeating. At the same time, the intake-air shall be decontaminated and filtered from aerosolized biological, chemical and radionuclide agents.

Alternatively, the preventative mode can be introduced when attack risk is increased; therefore, COCC can operate in enhanced safety mode. In the case of an explosion or fire eruption the addition suppression mode aforementioned can be immediately activated.

Surprisingly, in most applications, implementation of the FIREPASS in a preventative mode does not require costly re-engineering of the protected space to achieve a drastic improvement in the current level of fire safety. Moreover, if needed the technology allows for combining of various fire suppressive approaches, which can provide a significant synergistic effect. Conveniently, the preventative environment can be used not as an alternative, but as a supplementary option, thus drastically enhancing the conventional fire-safety mechanisms without interfering with their performance. For instance, there is no need to remove or deactivate an existing sprinkler system simply because it will not be activated in the preventative environment. Physically preventing the ignition process, this environment reduces risk of fire (as well as fire-extinguishments related risks such as water damage) virtually to zero. For these reasons, FirePASS in preventative mode would be ideal for COCC as well as other important facilities such as data storage rooms.



1 – Computer room, 2-Equipment racks, 3-Hypoxic generator, 4-Split a/c unit

Fig. 4. Schematic design and performance characteristics of a preventative system.

The preventative system illustrated above works as follows:

- a. Ambient air is drawn into the hypoxic generator where it is purified and made hypoxic.
- b. The air ventilates the entire room inhibiting any common ignition sources.
- c. Hypoxic air leaks from the room thus completing the flow and ventilating the facility.
- d. Heating/ Air-Conditioning units must be split-type closed dedicated systems.

The FIREPASS, when executed in an environment such as a data storage facility, would ensure that ignition would simply not occur. In order to install the system in such a data storage facility, the primary concern would be to minimize leakage of ambient air. This can be accomplished through inexpensive measures such as door alterations (i.e. airlock).

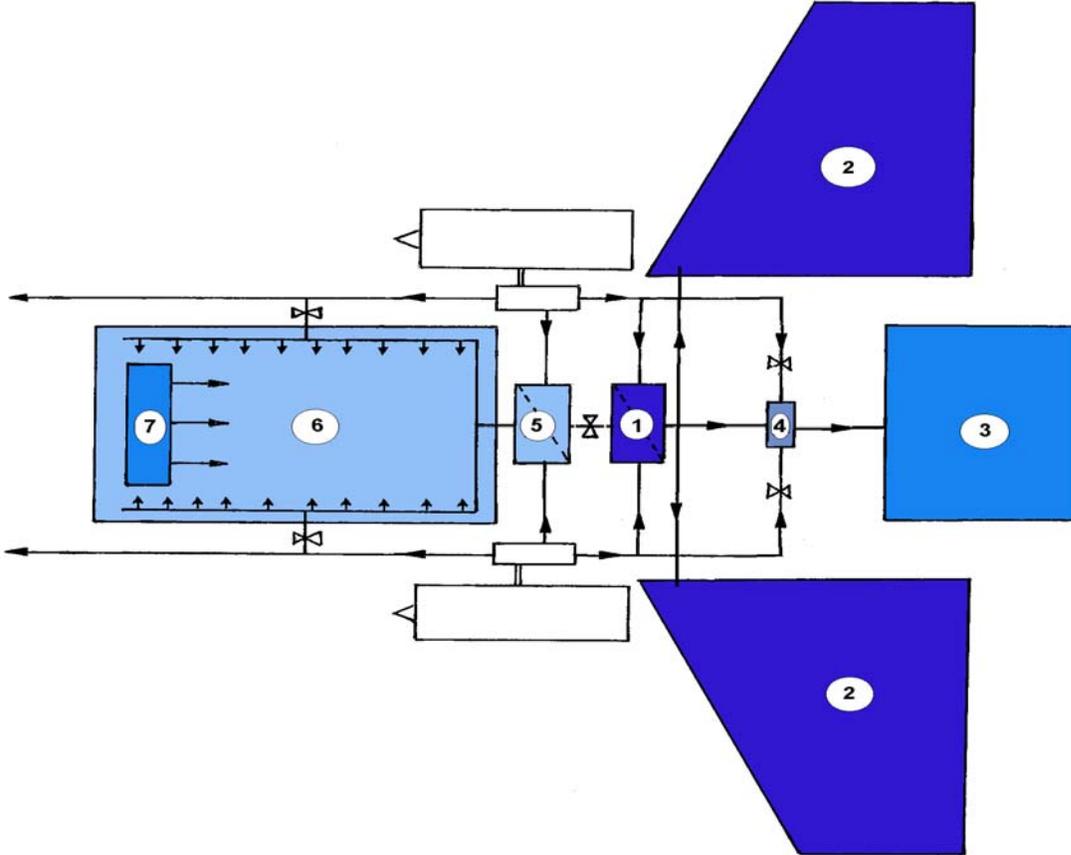
As long as the protected environment is isolated from any greater ventilation system that supplies the room with non-hypoxic outside air, it will be suitable for preventative FIREPASS. In most room applications, this is simply done by closing ventilation outlets and installing an air-conditioning/heating unit dedicated to the protected environment.

Installation of FIREPASS in any given facility requires minimal calculations and room alteration to ensure that flow is sufficient to maintain the hypoxic environment at a slightly positive pressure.

AIRCRAFT APPLICATION

After the TWA Flight 800 tragedy, a National Transportation Safety Board recommended the research of NEA [hypoxic] technology to inert fuel tanks to prevent explosion. Airplanes are an ideal application for hypoxic technology. The FAA's test of the preventative portion of the technology yielded promising results. According to the FAA's latest safety newsletter, "The design incorporated a clever and relatively simple dual-flow design for generating NEA [hypoxic air] during ascent and cruise and lower-purity and high-flow NEA during descent...the industry was impressed by the simplicity of the design and positive modeling results." [20, 21, 22]

FIREPASS technology can be applied to fuel tanks, the cargo compartment, and in the event of a fire, the passenger cabin can also be protected.



1- hypoxic module; 2- fuel tanks; 3- cargo compartment; 4- bleed air mixer; 5- hypoxic module; 6- cabin; 7- storage container

Fig. 5 shows a schematic diagram for the implementation of the FIREPASS in an airplane.

In the system illustrated in Fig. 5, two hypoxic modules (1 and 5) are utilized. Both modules are fed bleed air from the engines, yielding hypoxic air with 10% oxygen content or lower, if needed. That air is then sent into different compartments. The first stream goes directly to inert the cargo fuel tanks (2). The second stream goes to bleed air mixer (4) that brings the hypoxic air to a breathable O_2 level that prevents ignition (15-16%). This breathable air is used to inert the cargo compartment (3). In the event of a fire, the mixer (4) can be adjusted to provide a fire suppressive atmosphere at 10-12% O_2 in the cargo compartment (3). Both modules must produce adequate amounts of hypoxic product, in order to cover the leakage flow from the compartments (2) and (3).

In the event of a cabin fire, the primary module (5) provides fire-suppressive breathable atmosphere that will ventilate cabin (6) and protect occupants from fire and inhalation poisoning. In this case, the module (5) is switched off from the system (1-2-3) automatically and its product, diluted by the bleed air gradually to 12-15% O_2 , is delivered into cabin (6) ventilation system.

In order to instantly establish a fire-extinguishing atmosphere in the large volume of the cabin (6) a necessary amount of the hypoxic agent is released from a pressurized storage container (7). Suitable low-pressure flexible containers are described in U.S. Patents: 6, 401,487 and 6,418,752. In this application the hypoxic agent should contain and provide 3-4% of carbon dioxide in the inspired hypoxic air, which improves tolerance to even severe degrees of hypoxia [11, 13].

The use of the FIREPASS in an aircraft as diagramed in figure 5 is an example of effectively combining prevention with suppression strategies.

ONGOING AND FUTURE WORK

FirePASS Corporation is currently working with International Aero Inc's. (FAA Repair Station IQNR108K) Fire Protection Laboratory on the Cargo Compartment fire suppression system within the FAA minimum performance standards for aircraft cargo compartment built-in fire suppression systems [20]. Using their Low Pressure Dual Fluid water mist system and ventilation with FIREPASS hypoxic air, IAI is looking at a systems approach that also includes Cargo, fuel tank explosion protection and fire protection in hidden areas of the aircraft [21, 22, 23, 24, 25]. Full scale aircraft fuselage and cargo test devices are instrumented and working at IAI's facility. These development tests are ongoing and will be reported to The Task Group on Halon Options of the International Aircraft Systems Fire Protection, later this summer.

The combination of Hypoxic Air and Water Mist is the only sensible and environmentally friendly system that will meet all the new terrorist threats to commercial airliners. With an abundance of bleed air and hundred of gallons of water available, the oxygen depletion combined with fine water mist is an economical solution to cabin and cargo fires.

HEALTH AND SAFETY CONSIDERATIONS

The primary goal of inert gas systems is to reduce the oxygen content of the protected environment to a level that no longer supports combustion. Consequently, present-generation inert gas systems also significantly risk the lives of occupants who may be in the protected environment upon system activation. Specifically, the occupants are at risk of suffering from acute hypoxia (lack of oxygen). Much research and regulatory efforts has been focused in this area.

According to current EPA guidelines, healthy young individuals can remain in a 10-12% oxygen atmosphere for 30 to 40 minutes without impairment. The EPA, as well as the NFPA, assumes that in an emergency where present-generation inert gas flooding systems are employed, the oxygen level may drop dangerously below safety limits. The likelihood of hypoxia combined with the toxic effects of combustion products lead the EPA to require the occupants in such a fire emergency to wear a Self Contained Breathing Apparatus (SCBA) as prescribed by OSHA.

Nevertheless, the advance of biomedical research opens a new window of opportunity for the application of FirePASS as a reliable total flooding system for normally occupied facilities with an unprecedented safety level. The strategy of maintaining a gaseous environment in a human occupied space is based mainly on the common sense presumption that any artificial breathing

mixture should simulate Earth's atmosphere as closely as possible. It is commonly believed that any significant alteration in the proportion of constituent gases would be potentially hazardous for humans. But what if that paradigm is not completely true?

In 1996, this question was addressed during the development of Hypoxic Room System, designed for athletic and fitness training and to simulate adaptation to hypoxia. The numerous health benefits of hypoxia adaptation are broadly recognized today in the field of athletic and fitness training. Additionally, such health benefits are increasingly used in preventive and curative medicine applications [3, 4, 6, 9, 10,].

The use of hypoxic atmospheres for fire prevention in closed spaces such as submarines, computer rooms, storage facilities, archives, etc. has been previously suggested and has undergone extensive research [5, 7, 8]. Human physiology and performance in normobaric oxygen reduced atmospheres has been extensively studied in the last decades. One technical report [7] expounded the effects of a fifteen day exposure to different levels of normobaric hypoxia (17 and 13% O₂). The authors concluded that there will be little or no decrement in cognitive functions at 17 and 13% O₂ and that acute effects of hypoxia and fine motor control seem to dissipate rapidly upon increasing oxygen to 17%. Another study [8] investigated the effects of normobaric hypoxic exposure (from 16 to 12.7 % O₂) on visual and motor performance at prolonged (up to 14 days) confinement. The study concluded that, under the conditions tested, visual and motor performance decrements could not be observed even when at oxygen content of 13 kPa (corresponds to 12.7% O₂ in normobaric air). In these experiments, the effects of hypoxia did not seem to be any greater than the effects of motivation, change of environment, fatigue, or similar factors. Not only has a normobaric moderately hypoxic environment proven to be safe, it has in fact been proven to be healthy.

A number of studies elucidate the beneficial health effects provided by intermittent exposure to hypoxia. Schobersberger et al. [4] concluded that after a 3-week exposure to moderate altitude, corresponding in oxygen partial pressure to 17% normobaric O₂, patients with metabolic syndrome: a) tolerated their sojourn without any physical problems, b) exhibited short-term favorable effects on the cardiovascular system and c) had significant improvements in glycemic parameters that were paralleled by a beneficial significant increase in high-density-lipoprotein-cholesterol. Another study by Heinicke et al. [9] investigated whether the acclimatization to long-term intermittent hypoxic exposure in members of the Chilean Army who frequently move from sea level to 3,550 m altitude (corresponds to 13,5% O₂ in normobaric air) is correlated with acute acclimatization or chronic adaptation to hypoxia. They have found that the acclimatization to long-term intermittent hypoxia resembles the adaptation to chronic hypoxia and its beneficial effects. Such beneficial effects due to intermittent exposure to hypoxia have been again supported by Bailey et al [3, 10].

As numerous researchers confirm, intermittent exposure to moderately hypoxic environments can yield amazing health benefits. The FIREPASS with its ability to precisely control the oxygen environment will not only be an invaluable tool in fire protection but it may in fact prove to be overly healthy.

BENEFITS OF ADDED CARBON DIOXIDE

CO₂ can be added to a breathable fire-suppressive agent in extreme conditions such as high altitude flame suppression. Research has shown that CO₂ mixed with inert gas- extinguishing agents can prolong human exposure to hypoxia. The advantages of increased CO₂ in a diluting inert gas agent were described by Lambertsen et al [11]. It is proven that over the range of oxygen reduction to be encountered in fire extinguishment, the tolerance of normal individuals to hypoxia is improved by simultaneous exposure to increased carbon dioxide levels. A significant body of scientific and medical data exists concerning the concomitant exposure to lowered inspired levels of oxygen and increased inspired levels of carbon dioxide. All of the referenced data is based on direct measurements in human subjects. The period of relevant research and analysis covers more than 60 years dating back to 1943. Low degrees of combined hypoxia and hypercapnia (high carbon dioxide) can be tolerated for several days without detectable adverse effect [12]. Extremely low levels of oxygen or extremely high levels of carbon dioxide can be tolerated for less than a minute. Between these extremes there are degrees of combined hypoxia and hypercapnia which are advantageous to the safety of occupants for durations necessary in fire protection applications. Carbon dioxide in the concentrations of 3 – 4 % in the inspired hypoxic air promptly improves tolerance to even severe degrees of hypoxia [11].

This is the result of the combined effects of three normal physiologic control mechanisms. They are: (a) stimulation of respiration, which increases arterial blood oxygen content and partial pressure, (b) dilation of brain blood vessels, which increases brain blood and oxygen flow, (c) a shift in the hemoglobin dissociation curve, which aids unloading of oxygen in all tissues.

A substantial body of clinical research demonstrates direct health benefits of moderate hypercapnia [13, 14]. The underlying molecular-biological mechanism is related to improved antioxidative defense because CO₂ supposedly works as a systemic mitochondrial antioxidant [15, 16].

The beneficial effects of added carbon dioxide in fire-suppressive applications may be accompanied with minimal respiratory discomfort, but will not prevent purposeful mental or physical activity and is readily reversible without residual effect [11, 17].

The volumes of evidence pertaining to the health benefits of intermittent hypoxia exposure and the added hypoxia safety, provided by the optional addition of CO₂ to the FIREPASS suppressive agent, present the foundation for the first truly human-friendly fire prevention and suppression system.

RELIABILITY

The environment of nitrogen-enriched air found in a FIREPASS protected volume provides increased thermal absorption and heat dissipation. Such a fire-preventative atmosphere, being HEPA-filtered and conditioned at optimal temperature and humidity, would significantly increase the operational reliability of computers and other continuously energized equipment.

The system perpetually maintains the protected facility at a moderately hypoxic atmosphere (at a slightly increased barometric pressure) that resembles in oxygen partial pressure the air of altitude resorts. Intermittent exposure to such an environment is proven to be not only safe, but induces a variety of health beneficial adaptations in humans that may significantly increase their operational reliability [6].

In addition to the reliability concerns pertaining to the protected space, the reliability of the system itself must be addressed. The inspection, maintenance, and testing of inert gas based systems is vitally important to ensure their reliability. NFPA 2001 standards recognize that these systems only remain effective when they are properly maintained. The standard details the intervals at which these systems shall be inspected and the required maintenance and testing procedures that must be followed. This includes a thorough inspection of the enclosure to determine if new penetrations or other changes have been made that would cause excessive leakage or affect the design volume. It also details the requirements for approval of the newly installed systems. These include, but are not limited to: the piping system installation, testing, agent quantity verification, flow tests, and electrical component review procedures. Regarding these requirements, the FirePASS system has the advantage of being less sensitive to excessive leakage. Moreover, it is a self-restituting system, which requires only electric energy supply for cylinder refilling. Therefore, it can be tested and exercised on a regular basis. This joint advantage allows for more frequent testing and mitigates many of the obstacles common to present-generation systems.

The hypoxic generator itself has an impressive record of accomplishment as far as technical reliability is concerned. Some of the FIREPASS generators have been operating at full capacity without maintenance upwards of 29,000 hrs.

COST / EFFICIENCY CHARACTERISTICS

In a study by Wickham [18], the evaluation of cost for shipboard inert gas fire-extinguishing system was given for a 500 m³ test enclosure, as specified by the International Maritime Organization for gaseous extinguishing agent systems [19]. According to this study, the hardware consists of nineteen 80 liter cylinders, piping, actuators and nozzles at total cost of \$22,897. This cost is based on the cost of the system hardware and extinguishing agent and does not include the labor, materials, or other costs related to the actual installation of the system.

FIREPASS for the same 500 m³ enclosure would require the same number of cylinders at 300 bar pressure or 25 cylinders at 200 bar. However, to provide guaranteed fire extinguishing by supplying agent within 10-20 min after the initial fire knock-down would require 2 or 3 more cylinders accordingly. This could increase the cost of the system by 5% to 30%, but dramatically raise the system's reliability level.

Today, the total cost of FIREPASS manufacturing and installation is higher than that of current CO₂ systems or chemical agent systems. Therefore, its current application probably can be best justified in critically important facilities where loss of content and/or interruption of function are fully unacceptable. Such places as military installations, combat vessels, airplanes, COCCs, munitions storage facilities, and similar facilities could be reliably protected in preventive or suppressive mode or by a combination of both.

CONCLUSIONS

Current generation suppression systems, due to their inborn deficiencies, cannot reliably extinguish fires and prevent reignition. Perhaps more importantly, they cannot provide sustainable fire prevention.

Many of the deficiencies can be solved or mitigated with the employment of the FIREPASS hypoxic technology. The FIREPASS, due to its premixed agent can provide a breathable flame prevention environment as well as reliable fire suppression. The safety level that the FIREPASS agent provides, allows for extended discharge times that serve to prevent reignition. And, once the entire agent in the suppression system is discharged, it can recharge itself on-site. FIREPASS' safety advantages over systems using Halon ensure flame suppression as well as the continued functionality of important facilities such as COCCs.

In prevention mode, occupants can safely work in an environment that does not support common forms of ignition. The prevention mode is particularly appealing because in high risk applications it can easily be coupled with a suppression system.

The list of possible applications is endless. However; the current cost of the system does limit the list of probable applications. The system should be primarily considered for facilities that absolutely cannot afford a fire. Applications where fire may result in loss of critical functionality, priceless data, or life should consider the system as promising option. Non-critical applications should consider cost effectiveness before employing the system. But it is important to note that the price of such a hypoxic system may quickly drop due to technological advances.

Overall, the FIREPASS and its unique use of a hypoxic fire-suppressive agent, mitigates or otherwise solves the problems facing current generation suppression technology.

*** Footnote: "FIREPASS" is used here solely as abbreviation of Fire Prevention And Suppression System, developed by FirePASS Corporation.**

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