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The following review was provided to the NFPA TC on September 26, 2003 by GSI's Tom Wysocki.

NFPA Technical Committee on Carbon Dioxide Fire Extinguishing Systems

Mr. Chairman and Fellow Committee members:

As a result of studying the August 8, 2003 report entitled "Review of the Use of Carbon Dioxide Total Flooding Fire Extinguishing Systems" submitted by Bob Wickham as part of his substantiation for logs 9, 10, and 11 of the ROP November 2004, I wish to share the following with you:

1. General Comment

The report contains a great deal of specific background information extracted from various sources on types of carbon dioxide systems and lists some of the common applications for these systems. The report goes on to compare various "halon alternative" agents to carbon dioxide. It also give some personal opinion survey results from IMO delegates and "system manufacturers" about their preferences for fire protection in marine and industrial hazards respectively. The conclusions in section 4, however, come before a thorough discussion of the risks and benefits of carbon dioxide. The recommendations in section 5 likewise come before a risk-benefit analysis is presented.

2. Risks and Benefits Must be Considered

Indeed, the lack of a risk-benefit analysis is the major shortcoming of this report. In the Preface to the report, the EPA representative attempts to justify this omission with the following assertions:

1. "In most risk benefit analyses, both the risk and the benefit accrue to the same party. . . the beneficiary of the risk has been the risk-taker him/herself. In the case of carbon dioxide systems, the beneficiary of the risk and the risk taker are nearly always different parties."

   My comment: In our personal lives we always are making "risk-benefit" considerations. The personal risks we choose to take rarely affect only "the risk-taker him/herself." Family, friends, society in general are affected by the actions of each individual. In the workplace, there are always risks for employees – which risks both directly and indirectly may accrue to the employer. In some cases, the employer is likewise a worker directly exposed to the risks in the workplace.

2. "The decision to employ carbon dioxide systems is never made by those who are ultimately exposed to the danger of death or injury."
3. "This is why it is a public safety issue. We have one segment of society (owners, owners' representatives, etc.) making decisions to use carbon dioxide systems in instances that needlessly expose an entirely different group of people. "

For a risk-benefit analysis to be a valid part of the decision making process, the person exposed to the risk and the beneficiary of the risk need not be the same. Generally, the "risk-taker" will get benefit from "taking the risk." Employees are always exposed to risks as part of the job. Employees always are deciding whether the risk of working is worth the benefit of the wages to be earned.

If one wishes to earn the wages of an electrician, one will accept the risk of exposure to potentially deadly electric shock. If one chooses to earn the wages of an iron worker, one accepts the risks of falls and other hazards which go along with the work.

When addressing public safety, regulators likewise need to make risk-benefit analyses. Before permitting or denying access to any type of device, the benefits from such access must be weighed against the risks inherent in that access. For example, regulators have the power to ground aircraft, deny access to roadways, and restrict the use of automobiles. In some instances, regulators have made just such restrictions. But only after considering whether the risk addressed by the restriction outweighs the benefit of unrestricted access.

Point number 3 (above) is telling. The EPA assumes that carbon dioxide systems are used that "needlessly expose" people to risk. This assertion should only be made after complete consideration of the benefit provided by the carbon dioxide system and likewise the alternatives to its use. It is telling because it exposes the underlying purpose of this report – which purpose appears to be justifying elimination of carbon dioxide from the arsenal of fire protection tools available for protection of total flood hazards. This "justification" is to be done without any consideration of the losses of life, property and livelihood that could occur if carbon dioxide systems were not permitted to be used. Indeed, the number of lives and livelihoods preserved and amount of property saved by these systems might very well justify the risks involved in their continued use.

Some Facts

Nearly all carbon dioxide systems are used in "work place" environments – the vast majority in either industrial or "marine" settings. There are tens, probably hundreds, of thousands of these systems in operation today. In most cases, these systems serve as the "first line of defense" against damage to property, loss of life, and loss of livelihood from fire. Their performance record in this regard, although not perfect, is enviable. It will take some work to quantify the lives and livelihoods that have been preserved because these systems are installed and operable. The successful extinguishment of fire using carbon dioxide systems is so commonplace that it is not newsworthy.

Every environment has risks associated with it. Industrial environments have more risks than the typical office environment. The marine industry has a higher level of risk than the typical land-based industrial environment.

- To illustrate, in the randomly selected month of December 2002, Countryman and McDaniel's database of marine accidents[1] shows

    1. 14 fire/explosion events killing 10 people,
    2. 10 piracies in which 12 crew men were murdered,
    3. 11 collisions resulting in 11 dead,
    4. 9 vessels grounded,
    5. 9 sinkings with 104 dead.

[1] Countryman and McDaniel, database of marine casualties, http://www.cargolaw.com

6. No deaths due to carbon dioxide discharge were reported in that time frame.

In this month alone, there are more fatalities in the marine industry, none due to carbon dioxide system discharges, than all the fatalities attributed by the report to carbon dioxide discharges in the last 50 years. (The report references an EPA report which collected data on injury and deaths attributed to carbon dioxide fire extinguishing systems. During the period from 1948 to 1999, 24 deaths attributed to carbon dioxide fire extinguishing systems in the marine sector are listed.[2]) Clearly there are considerable risks to personal safety inherent in working or traveling on ships – risk of injury or death from a carbon dioxide fire system discharge is extremely small.

Safety professionals seek to minimize the risks to workers and the general public while permitting operations to continue in an efficient, cost-effective manner.

We all make numerous risk-benefit analyses in the course of our lives – given that all human ventures involve risk of injury and death, we must regularly assess the benefit of a given activity versus the inherent risks.[3] Decisions to drive a car rather than use public transportation, live in a high rise building rather than a single level house, purchase and store various poison chemicals in the household, and who has not stored a can of gasoline in their attached garage for their lawnmower - all of these decisions have implicit “risk-benefit” considerations attached.

Risk-benefit analysis helps to uncover exposures to injury or death which are “unreasonable.”

> The Lloyds Casualty Archives for 1991 through 2001, referenced in the report section 6.2, includes 161 reports related to fire on ships over a 10 year period. Some of the reports are duplicates related to the same incident. No doubt there were fires not included in these archives. Still this is a substantial database of fire incidents on marine vessels.
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> Among the 161 Lloyds’ reports are carbon dioxide discharges which extinguished fire without injury to personnel. When there were no carbon dioxide systems available, the reports recount numerous reports of deaths and injuries due to fire and manual fire fighting operations. (A quick review of the incidents showed 41 dead from fires, 58 injured in fires and 11 vessels sank due to fire.)

This data could have been used as a starting point for a risk-benefit analysis related to fire and the use of carbon dioxide in the marine sector. The inclusion of a risk-benefit analysis in this report would have strengthened the report significantly. But the conclusions and recommendations drawn from a risk-benefit analysis might not be those which are currently being espoused in this report.

3. Fire fighting equivalency

A. The equivalency of performance of halon alternatives to carbon dioxide is alleged in the report. For example, section 4.2 states*, “Contrary to widely held beliefs within the industry that*

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[2] **Carbon Dioxide as a Fire Suppressant: Examining the Risks**, United States Air and Radiation EPA430-R-00-002 Environmental Protection (6205J) February 2000

[3] Examples of and statistics for everyday activities which cause injury or death are readily available from the National Safety Council.

4. **NFPA 12 Contributions to Safety – Perspective on Regulation** page 6 of this letter.

carbon dioxide systems are unique and cannot be replaced by other systems, the facts are that there are several extinguishing agent systems that perform as well as or better than carbon dioxide in the most frequent applications."

The desired conclusion is "why take any risk in using carbon dioxide when other agents will do the job as well or better." One must consider the facts regarding carbon dioxide compared to other agents before deciding if other agents are really available that "perform as well as or better than carbon dioxide . . ."

- The standard design criteria for total flood carbon dioxide systems protecting spaces where flammable liquids or gases are the fuel require that the system "inert" the atmosphere. Inerting the atmosphere precludes fire or explosion even if ideal mixtures of oxygen and fuel with an ignition source are present.

  Halon alternatives are typically designed to provide a flame extinguishing concentration – not an inerting concentration. Under ideal conditions of stochiometric mixture of fuel and oxygen with a persistent ignition source, the alternative agents in flame extinguishing concentrations may not extinguish the fire and prevent explosions. NFPA 2001 recognizes this.[4] It gives direction that under certain conditions (which conditions almost certainly exist in every ship machinery space and most other areas where flammable liquid fuels are the hazard), an inerting concentration of the alternative agent should be used. Nonetheless, very few authorities are even aware of the distinction between flame extinguishing concentrations and inerting concentrations – and designers routinely use flame extinguishing concentrations. The level of protection against fire and explosion is not equivalent to that provided by carbon dioxide systems – carbon dioxide systems are typically designed to provide a higher level of protection with greater fire safety factors.

  The inerting concentration of many of the halon alternative halocarbons for many flammable liquids is above the LOAEL concentration. This is probably the main reason designers avoid using inerting concentrations of halocarbon agents. Yet unless the inerting concentration is used, performance of halon alternative agents cannot equal the performance of the standard carbon dioxide total flood system for flammable liquids hazards.

B. There is another big difference between carbon dioxide and the halocarbon alternative agents: the halocarbon agents decompose in acid gases such as hydrogen fluoride in the process of extinguishing fire. These gases are corrosive and toxic. The subsequent presence of these gases in the atmosphere can present a hazard to personnel. They also can cause damage to equipment or instruments in the area.

Carbon dioxide and the inert gases do not decompose into hazardous acid gases during the process of extinguishing fire.

In this respect the "other agent" halocarbons cannot *"do the job as well as, if not better than, carbon dioxide."*

4. Report alleges "cost" eclipses all other considerations

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[4] NFPA 2001, 2000 Edition, 3-4.3.2* The inerting concentration shall be used in determining the agent design concentration where conditions for subsequent reflash or explosion could exist.

Report section 4.5 *"The choice of a fire suppression flooding system is based on several factors. In the case of carbon dioxide systems, cost apparently eclipses all other considerations to the detriment of sound safety and performance decisions."*

There are many concerns, in addition to cost, which should be acknowledged to give credibility to this report. The EPA sponsored report chooses to simply deny the validity of these concerns.

Among these concerns are

1. Performance of the Halon alternatives on fires is a concern. Early difficulties in extinguishing laboratory scale fires with "cup burner" concentrations of HFC227ea caused concern about the reliability of the agent as a fire extinguishing media. The fact that the required concentration of agent to extinguish a simple laboratory scale heptane fire is, in part, dependent on the thickness of the metal cup holding the burning heptane gives one cause for consternation.[5]

2. Carbon dioxide systems are designed to provide an "inert" atmosphere in spaces containing flammable liquids and gases. Although alternative agents designed per NFPA 2001 requirements should likewise provide for an inert concentration, in reality most systems are designed only for flame extinguishing. Many AHJ's do not understand this distinction but technically astute engineers do understand the potential difficulty.

3. The plethora of alternative agents gives potential purchasers concerns about which, if any, of the current alternatives will exist in 5 or 10 years.

4. Decomposition of halocarbon agents when exposed to large flame fronts as typical in flammable liquids fires was a concern for some when Halon 1301 was used – it remains a concern with the halocarbon alternative agents.

5. Although FM200 seems to have the greatest following among the halocarbon replacements, Kyoto raises a concern about the long term viability of any agent with a non-zero GWP.

6. Many users were "caught" world wide by the restrictions on Halon 1301. It is understandable that they will be concerned over new "chemical" replacements.

7. Timely availability of agent for system recharge on a world wide basis is a valid concern. A ship sitting in port waiting for a recharge is a big "cost item." This was one of the big concerns when Halon 1301 was considered for marine application. Carbon dioxide was and is available in virtually every shipping port in the world. During the 1970s, the E. I. DuPont de Nemours & Company put on a strong public relations campaign to assure naval architects, shipyards and owners that they would support recharge of Halon 1301 systems world-wide. This helped assuage the concern. No manufacturer of any of the new chemical agents has put a similar effort forth in the marine industry. Hence, the concerns expressed about availability of recharge should not be summarily dismissed.

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[5] For simple flammable liquid fires with the fuel burning in a small metal cup, the required concentration of HFC227ea to extinguish the flame was found to vary depending on the thickness of the metal forming the cup wall.

8. Space considerations and weight considerations are always important especially in the marine environment. Space consumed by fire protection equipment takes away from space available for cash cargo. Compared to carbon dioxide, some of the halocarbon agents take up about 40% less floor space and weigh about 40% less (per section 11.3 of the subject report). This is an advantage for these halocarbons directly related to the overall cost of ownership.
   Inert gas systems and water mist systems per the section 11 information consume 260% and 600% more floor space than carbon dioxide systems and weigh 2 to 3 times more than carbon dioxide systems. This is a definite deterrent to their use in the marine environment.

4. NFPA 12 contributions to safety – Perspective on regulation

Report Section 4.1 Bullet point 3: *"With the exception of the US EPA and the US Coast Guard, there is not another standards making organization or regulatory body, nationally or internationally, that has done anything of substance to reduce the incidents of death and injury caused by carbon dioxide systems."*

This statement is simply not true. From long personal experience since 1979, I can attest that the NFPA 12 Technical Committee on Carbon Dioxide systems has given constant and continuing attention to improving the safety features required for carbon dioxide systems. In fact, the overall safety record with the hundreds of thousands of installed carbon dioxide systems is a good one.

This report references the EPA report "Carbon Dioxide as a Fire Suppressant: Examining the Risks." This report cites 119 deaths and 152 injuries over the 80 some year history of carbon dioxide system use. For many of the incidents, there is little detail – only that a discharge occurred and someone was killed or injured. But for those instances where detail is available, one usually finds that the proper procedures set forth in NFPA 12 for installation, operation, or maintenance of the carbon dioxide were 1) not followed 2) in some cases purposely circumvented.

It is a constant source of frustration and concern for every regulator with an interest in safety and the common good, when people do not follow the guidelines. On the roadways, if people followed traffic laws, accidents and deaths would be considerably reduced. (Auto accidents account for nearly 50% of accidental deaths each year.) If people working at height would follow the standard safety rules, injury and death due to falls would be substantially reduced (National Safety Council reports over 13,000 deaths in the USA due to falls in 1999 alone). If the householder would follow prescribed procedures for storing and using household chemicals, injury and death due to poisoning could be substantially reduced. (Over 12,000 died in the USA during 1999 due to accidental poisoning per NSC Statistics.)

To claim that NFPA 12 has not "done anything of substance" in the area of reducing risk to life is simply false. The committee has done much in providing good guidance both in the way of fire protection and protection of personnel – and especially for those who follow the guidance, a good record of safety exists. The NFPA 12 technical committee is dedicated to ongoing improvement in the area of life safety.

5. Historical effectiveness of marine fire extinguishing systems

The report contains data on the effectiveness of marine fire extinguishing systems which illustrates the great effectiveness of carbon dioxide in extinguishing fire.

There were 52 fire situations listed in the report that involved carbon dioxide systems. Four fire situations involved Halon 1301 systems.

In five (5) of the situations with carbon dioxide, the systems were deployed and there is no comment on the outcome. These were likely successful in controlling the fires. If the systems failed, it is quite likely there would be further damage reported in the account.

The report lists eight (8) “unacceptable” results with marine carbon dioxide systems. In looking at the detail on the eight (8) “unacceptable” results, it is not clear which, if any, represented “failures” of the carbon dioxide system itself.

> In three (3) of the eight (8) “unacceptable” incidents, the total flood carbon dioxide did not fail – it was either inoperable or not operated or in one case a reflash occurred due to premature ventilation of the engine room. <u>These clearly are not related to the choice of agent.</u> (Suzane, Bolivar, Carter)
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> In two of the eight “unacceptable” incidents, it is not clear whether the system was discharged or whether strictly manual fire fighting with portable extinguishers was employed. (Billikin, Calvados)
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> In yet another instance, the fire was within an exhaust gas boiler stack. It is not clear whether the crew discharged a total flood engine room system or attempted fire fighting within the boiler with portable extinguishers. They followed up with boundary cooling using seawater and were able to keep the fire controlled and it eventually was extinguished. This appears to be a case where the total flood system, if activated, would not have been capable of getting the carbon dioxide to the fire within the boiler. (Berge Charlotte)
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> In another of the reported “unacceptable” results, the Commodore fire was initially reported under control using the total flood carbon dioxide system. The vessel made its way under its own power to port. The report indicates that the vessel when the vessel reached dockside it was opened up and fire began burning vigorously. Unclear from report whether reflash occurred in engine room or whether contents of cargo hold caught fire when the cargo hold was opened at dockside. (Norman Commodore)
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> The only reported “unacceptable” which may truly be “unacceptable” from a system performance viewpoint was the engine room fire on the tug Lawrence L. The system reportedly discharged into the engine room but failed to extinguish the fire. The tug maneuvered to dockside and the fire extinguished (report does not say how the fire was extinguished). Anything we say concerning this incident is speculation.

Several years ago I investigated a fire on a similar tug which was not extinguished by the installed total flood Halon system. I found that the reason for the failure was that the engine room was not sealed and ventilation was not shut down upon discharge. The Halon system never did built up a sufficient concentration. This was a poor design/operation – not a “halon” failure. One must be careful in attributing “failure” of a fire extinguishing system – since in most all cases, the systems do the intended job if properly designed, maintained and operated.

In summary, there may have been at most 5 “system failures” out of 52 fires. Even if this is true, it should not be considered an indictment against carbon dioxide. In all likelihood, the carbon dioxide systems extinguished better than 90% of the fires reported – with the remaining few percent able to be controlled by manual follow up. No deaths due to the carbon dioxide were reported. Nor were there deaths attributable to the follow up fire fighting efforts. No vessels were lost.

The Halon systems likewise performed well in the four reported instances. But it is noteworthy that in 2 of the 4 Halon system discharges, complete extinguishment was effected by using water spray and foam discharges after the Halon discharge.

It is rare that the agent "fails" or is "overcome" by the fire – failures are generally traced to human errors, failures to maintain, failures to correctly operate, design flaws – all failures which equally affect systems regardless of the agent employed. In summary, the performance record of the systems referenced in the report is excellent.

6. Report's Conclusions in Section 4

Comments on Specific Items

Report Section 4 Bullet point 4: *"It is technically indefensible that standards and regulatory organizations employ rigorous review standards to assure that the new halon alternatives (including halocarbons, inert gases and aerosols) are safely employed in normally occupied spaces while seemingly relegating a lower level of scrutiny to the use of carbon dioxide systems at lethal concentrations in spaces where personnel may be exposed."*

<u>The new Halon alternatives are held out to the public as having life safety characteristics similar to the Halon 1301 which they replace.</u> It is appropriate, even "essential," that use restrictions be applied to these alternatives to insure that they truly are equivalent in safety to Halon 1301.

<u>Carbon dioxide has not been held out as a "life safe" alternative to Halon 1301</u>. Knowledge of risks associated with carbon dioxide pre-date Halon 1301 systems. Halon 1301 was the alternative to carbon dioxide. Those who specify and use carbon dioxide do so for reasons of 1) superior fire fighting capability, proven reliability in actual field fire situations, 2) ability to extinguish fire even with stochiometric concentrations of fuel and oxygen present, 3) "three dimensional" fire fighting capability 4) electrically non-conductive, clean, dry agent which does not form corrosive by-products as it extinguishes fire, 5) ability to store large quantities in bulk delivery systems or ability to obtain re-charge quickly nearly anywhere in the world (thus providing for continuity of operations), 6) ability to pipe long distances and use centralized storage with selector valves, and 7) general cost-effectiveness.

The risks of carbon dioxide are well known and well understood. Halon alternatives are purported to provide equivalent life supporting properties and lack of carcinogenic effects, mutagenic effects, and disturbance of CNS function to Halon 1301 – carbon dioxide never has been held as a "life safe equivalent" to Halon 1301. Carbon dioxide has already undergone rigorous examination over its more than 70 years of use in systems – the risks are known – the performance as a fire fighting agent is proven.

Report Section 4.3 Training

Training is essential for safe use of any fire extinguishing system. It is extremely essential for safe use and maintenance of systems which contain quantities of pressurized gas.

An area where regulation is needed is the area of recurrent training. Spending for training should not be "discretionary," it should be mandatory – required by regulations and enforced by regulatory prescriptions.

Report 4.5 Bullet point 3: *"The review of the new alternatives incorporates the latest scientific knowledge and technological expertise on safe human exposure, environmental effects and system performance to determine appropriate applications and restrictions on applications of these systems. The same rigor has not been applied to carbon dioxide systems."*

> Carbon dioxide has been used for over 70 years and has extinguished safely, without incident, more fires than all of the Halons and "Halon alternatives" combined. The fire protection and scientific community has long recognized the risks of human exposure to carbon dioxide - no need for incorporation of any "new" scientific knowledge or technological expertise in considering carbon dioxide as a fire extinguishing agent.
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> It is clear that breathing the concentrations of carbon dioxide required for total flood fire extinguishing can be lethal.
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> Environmental effects of carbon dioxide are known - however, the use of carbon dioxide for a fire extinguishing agent actually has provided a sink, albeit a very minor one, for carbon dioxide which might otherwise have been discharged to the atmosphere.
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> The "rigor" has already been applied over decades of study and experience.

Final Comments

Some final overall comments – these are a personal opinions based on over 30 years of in-depth involvement in special hazards fire protection:

From the beginning, the fire protection community has recognized the inherent danger associated with total flood carbon dioxide systems. The fire protection community also recognized the many benefits afforded by this type of fire extinguishing system. Carbon dioxide systems have endured as the pre-eminent gaseous extinguishing system for over 70 years. They have extinguished more fire, saved more lives and preserved more livelihoods than any other gaseous agent system.

Over the years, other agent systems have gained popularity and become pre-eminent in various specific applications. In lieu of carbon dioxide, Halon 1301, Halon 1211, dry chemicals, wet chemicals and special water extinguishing systems have been pre-eminent in various applications.

In the United States for example, Halon 1301 was nearly the exclusive gaseous agent used in computer and telecommunication facilities from the mid 1970s through the early 1990s. It had taken considerable market share in the marine industry where space and weight are at a premium – but reliable fire extinguishing characteristics are essential. Halon 1301 earned these distinctions because it is a clean, dry agent with good fire fighting characteristics coupled with life safety, economy of storage space and weight, and acceptable cost. Halon 1301 systems achieved their status in spite of the fact that at least into the late 1970s, they were more costly to install and recharge than carbon dioxide systems.

The Halon alternatives have yet to approach an equivalent status to Halon 1301. The Halon alternatives have yet to approach an equivalent status to carbon dioxide. It is much more than simply cost. When and if an agent is developed with the combination of fire fighting capability, economy of storage, lack of secondary damage, and life safety - an agent which is pre-eminent among its competitors - the market will award it a place of pre-eminence. And one more factor will be required of the agent – it will have to be absolutely environmentally benign. The Halon experience was enough to keep purchasers from espousing on a widespread basis any agent with environmental "baggage."

Carbon dioxide should be permitted to continue as the agent of choice for its various industrial and marine applications – until either

1. a superior agent is marketed in a competitive manner or
2. valid risk-benefit analysis demonstrates that the benefits of carbon dioxide systems are outweighed by the risks.

Carbon dioxide is NOT a "halon alternative" in the sense that the new halon alternatives may become. Halon was a *carbon dioxide* alternative and with the essential removal of new Halon installations from the market place, it is natural that carbon dioxide would be used where Halon once supplanted it.

Respectfully yours,

Thomas Wysocki
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