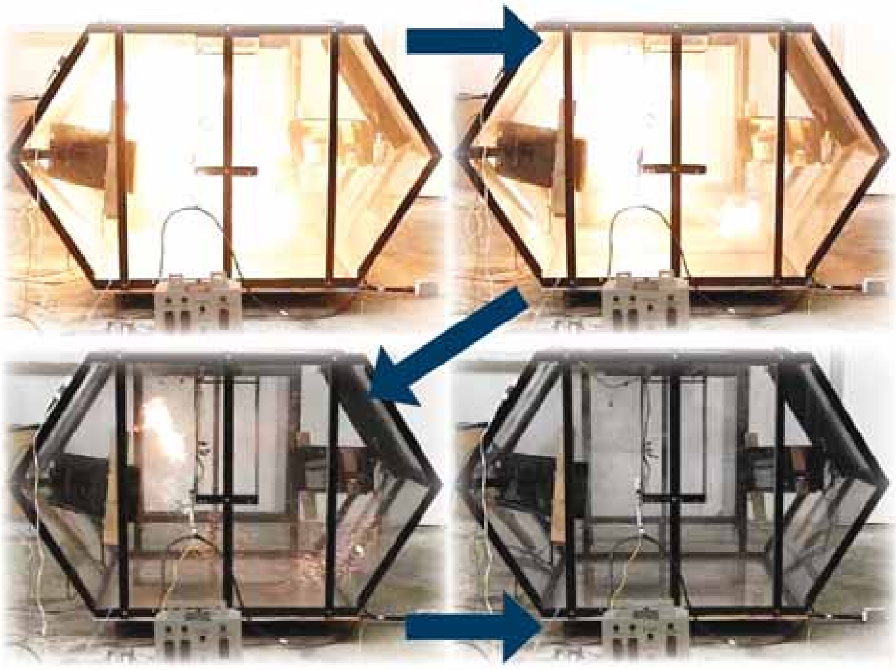
FIRE PROTECTION SOLUTION MEETS ENVIRONMENTAL CHALLENGE

N_2 EXPLOSION AND FIRE SUPPRESSION SYSTEMS

By Adam Richardson

Adam Richardson *is the President of N_2 Towers Inc. ("N_2"). Mr. Richardson has been a key participant in the clean agent fire suppression business for over 29 years, and is a former board member of the Halon Alternative Research Corporation (HARC). While president and owner of a Canadian-based total flood fire protection system supplier, he designed the first Underwriters Laboratory Canada (ULC)-approved Halon reclamation system, sold and installed the first UL/ULC-listed FM-200 fire protection system in Canada in 1993, and oversaw the UL/ULC listing of the first approved argon inert gas fire system for North America in 2000.*



A revolutionary breakthrough in clean agent, total flood fire protection is underway that completely changes the way occupied spaces normally serviced by traditional total flood systems will be protected in the future. This breakthrough is facilitated by the exploitation of advanced technology, adapted from other high-tech industries and customized and enhanced for fire protection use. It exhibits features and capabilities that, when coupled with novel packaging, delivery concepts and designs, provides opportunities for radical new approaches in total flood protection. This confluence of new technology and design, in re-writing the rules of total flood clean agent fire protection engineering, provides enhancements in size and weight efficiency, affordability and life cycle cost, toxicity and safety, while providing total compliance with the most stringent environmental climate change regulations worldwide, as an ideal heir to the market previously served by Halon-based systems.

BACKGROUND

The total flood clean agent fire protection system industry provides asset protection for high value applications, such as computer rooms, telecommunications facilities, and other high value assets such as power generation equipment, and even museums and records storage areas. This multi-billion dollar industry provides "total flood" protection

Figure 1. *N_2 Tower fire suppression system*

in such applications by automatically filling the protected compartment completely at a uniform concentration that assures that the fire will be extinguished, no matter where it might be located. The extinguishing medium used in such systems is expected to be “clean” – that is, leave no residue behind after discharge that must be cleaned up due to corrosivity or other concerns. Current state-of-the-art total flood fire protection systems typically comprise a bank of multiple pressurized bottles (commonly tens of bottles of more) that hold the extinguishant, stored at high pressure using special thick-walled metal bottles to permit liquefication of the extinguishant, or increase the total mass stored if non-liquefied gases (such as nitrogen or argon) are used. They are released by high-strength, special purpose valves on the bottle when activated either manually or via an alarm control panel. A complex plumbing network has to be designed to transmit the extinguishant at masses required to meet precise extinguishing concentrations within a tight tolerance band of room concentration required to meet both the extinguishing and inhalation toxicity requirements, with independent capacities required for individual rooms in a typical multi-room protection scenario (such as a factory or high-rise building) using the same distribution network. This requires considerable effort and expense up front in the development of flow calculation methodologies to support the safe engineering of systems for such complex flow configurations. It should be noted that the adequacy of this approach is predicated upon an accurate knowledge of the "free volume" (room volume minus space for equipment and furniture, etc.) anticipated over the operational life of the protected compartments, given changes in its contents, etc.; increased equipment placed in the room can easily result in an increase in discharge concentration beyond that which is safe for human exposure. The expense of using such a distribution network is also experienced when a system is installed at a customer site; complicated piping networks must be designed and installed on site with a notable labor expense; if the system is retrofitted into an existing building, significantly higher costs are incurred in tearing out existing drywall and other infrastructure. Such high-pressure bottles are prone to leak, thereby requiring frequent inspection. If a leak is noted, the high pressure bottles may need to be sent to a central re-filling installation, resulting in protection down time at the customer site. A system can be similarly disabled by a man-made or natural disaster, such as a gas leak explosion, tornado or earthquake, which can damage a piping network, including water sprinkler mains, thereby rendering a system virtually useless.

The fluorocarbon known as Halon 1301 has been the extinguishant of choice for decades for this use, being clean, relatively non-toxic and highly efficient. However, scientific findings of its contribution to ozone depletion resulted in the discontinuation of its U.S. manufacture in 1994 (and eventually by the rest of the world), with existing systems relying on recycled Halon until regulations invoked in various parts of the world require their imminent decommissioning. Research over the last fifteen years has resulted in a myriad of "first generation" Halon replacements, including "clean" hydrofluorocarbons, which have been deployed in recent years. These chemicals behave in a similar manner to Halon 1301, except their greatly reduced effectiveness in comparison (since they typically do not have the flame chemistry inhibition of Halon 1301) results in systems requiring from two to ten times the extinguishant mass and storage space, and being

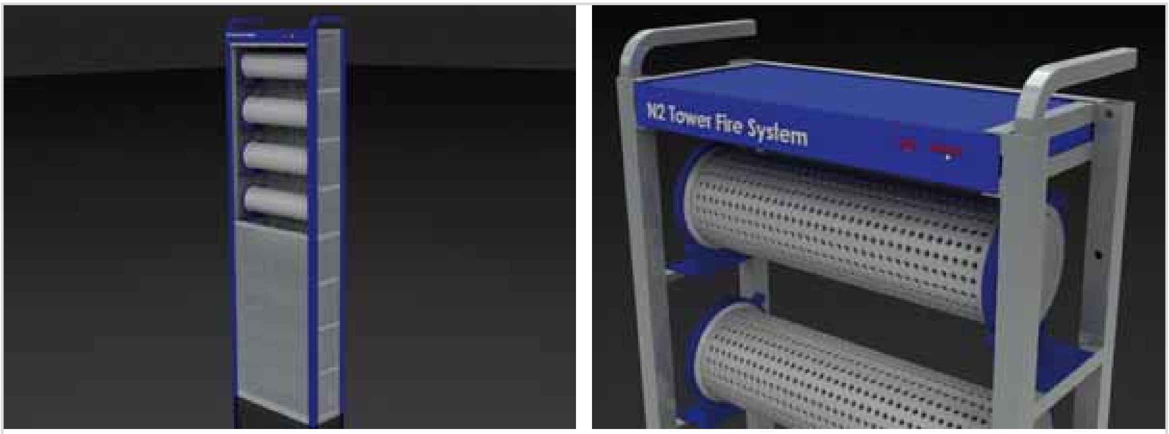


Figure 2. *The N_2 Tower fire suppression system top section and full frontal view complete with the new adjustable ceiling support struts, armed and disarmed N_2 Tower LED indictor lights*

generally more expensive results in a more costly alternative from both an extinguishant and hardware perspective. In addition, the increased storage space requirement for a large increase in extinguishant bottles poses a difficult placement problem for facility engineers, and a considerable obstacle for those wishing to retrofit an existing Halon installation with a bottle "farm" many times bigger than its Halon predecessor in a limited storage space. Most of these hydrofluorocarbons have human exposure toxicity limits very close to their required extinguishing design concentrations; therefore, they are more sensitive to changes in room storage filling capacity in terms of posing a risk to occupants. These exposure limits are typically restricted to five minute or less exposure times; occupants with reduced evacuation capability, such as those injured, aged, disabled or even medical patients may find this evacuation time challenging, and the increased cardiotoxicity risk with many of these new extinguishants makes limited exposure scenarios even more critical. Once discharged into a room, these hydrofluorocarbons have a propensity to decompose into large quantities of hydrogen fluoride, a gas that can produce a caustic acid when exposed to moisture that can pose a real health hazard to occupants or rescue personnel, or even equipment, when exposed to fires bigger than a small circuit board, particularly if it takes some time to detect the fire. For this reason, the U.S. Navy uses water mist to wash out hydrofluoric acid after hydrofluorocarbon discharge into a machinery space fire, in addition to cooling the compartments, to protect firefighter personnel. Finally, most of these chemicals have been determined to have long atmospheric lifetimes, thereby making them subject to subsequent global warming legislation worldwide in line with the Kyoto Protocol over the next few years.

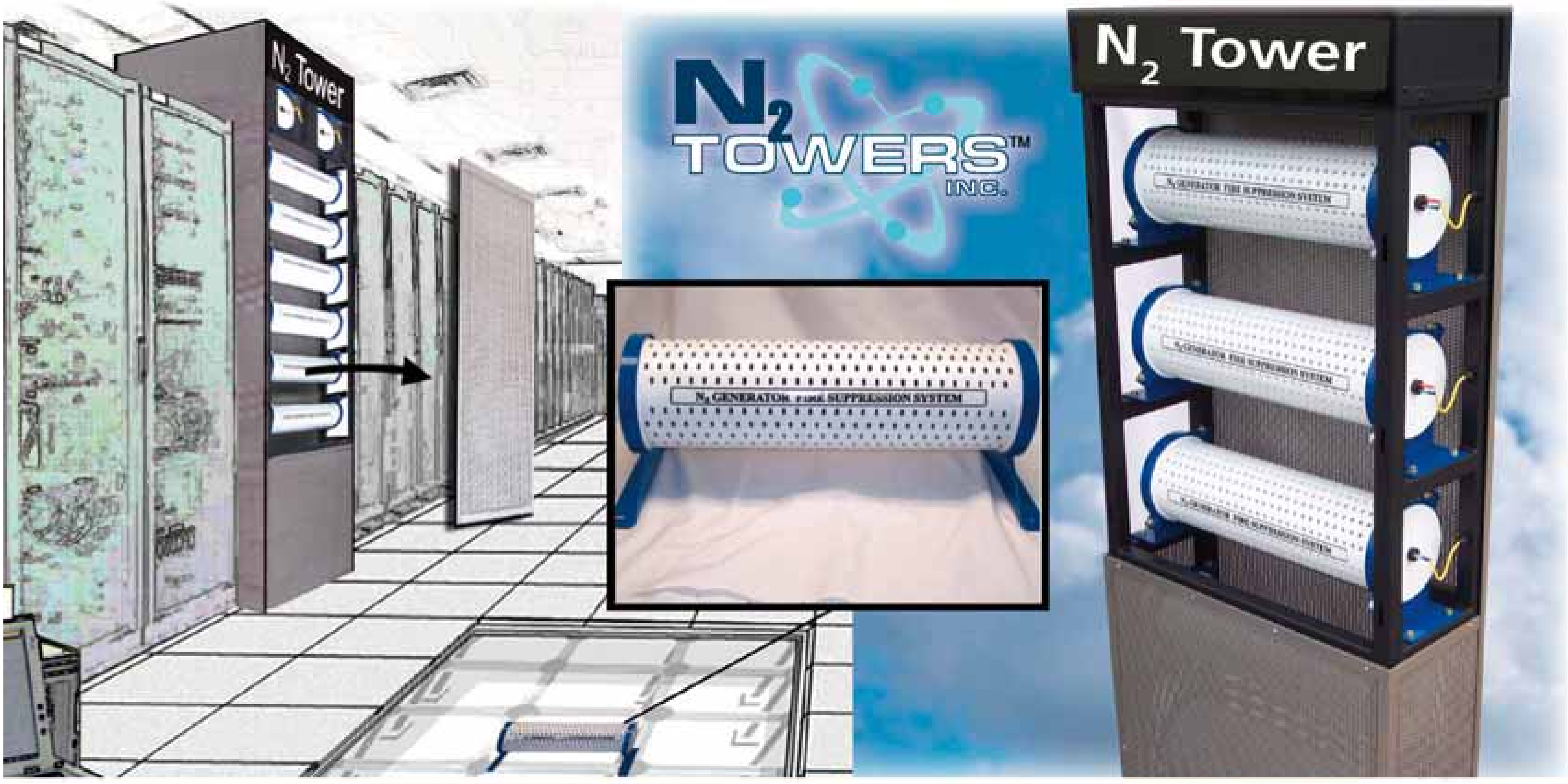
Figure 3. *Two N_2 Generators with two un-mounted N_2 military diffusers*

"Environmentally friendly" alternatives to the hydrofluorocarbons have been proposed and even fielded to a limited degree, but also suffer from their own design and operational limitations. Water mist systems were devised to use less water than sprinkler systems, and hence less water-related damage, although such damage is only reduced, not eliminated. Even with considerable research and engineering expertise applied internationally, it has proven very difficult to design mists to flow around obstacles like gases, and reach shielded fire areas such as under tables, and the efficiency of suppression is largely influenced by the size and nature of the fire. Inert gas systems, such as those using nitrogen or argon, require up to ten times the number of bottles of their Halon predecessor (due to their inefficiency and inability to be liquefied under pressure in a practical manner), requiring not only considerable additional storage space, but often larger diameter plumbing that would need to replace Halon-suitable pipes. The very high pressure bottles used in inert gas systems can also pose an additional safety hazard if damaged or otherwise compromised, including the thicker-walled distribution plumbing that might be vulnerable at any joint connections. It is readily apparent that the current replacements for Halon 1301 for total flood applications suffer from a number of design limitations that results in systems that are costlier, more cumbersome or even more hazardous than their Halon predecessor, and the search continues for the ultimate, "permanent" solution. Many of these difficulties are exacerbated by the design and economic challenges posed by the current design approach for total flood systems.

Figure 4. *Two N_2 Generators complete with mounted N_2 military diffusers*

SOLID PROPELLANT INERT GAS GENERATORS FOR FIRE EXTINGUISHING

The new N_2 technology developed herein addresses each of these concerns in a novel way by exploiting a technology capable of storing nitrogen in a solid propellant form, thereby eliminating its primary design difficulty of storage efficiency, while also eliminating the need for costly and complicated distribution plumbing. This is achieved by the proper use of solid propellant materials specifically engineered to decompose into 100% clean nitrogen gas upon activation, in the manner desired for a commercial total flood system. This mature N_2 Generator technology has been used exten-



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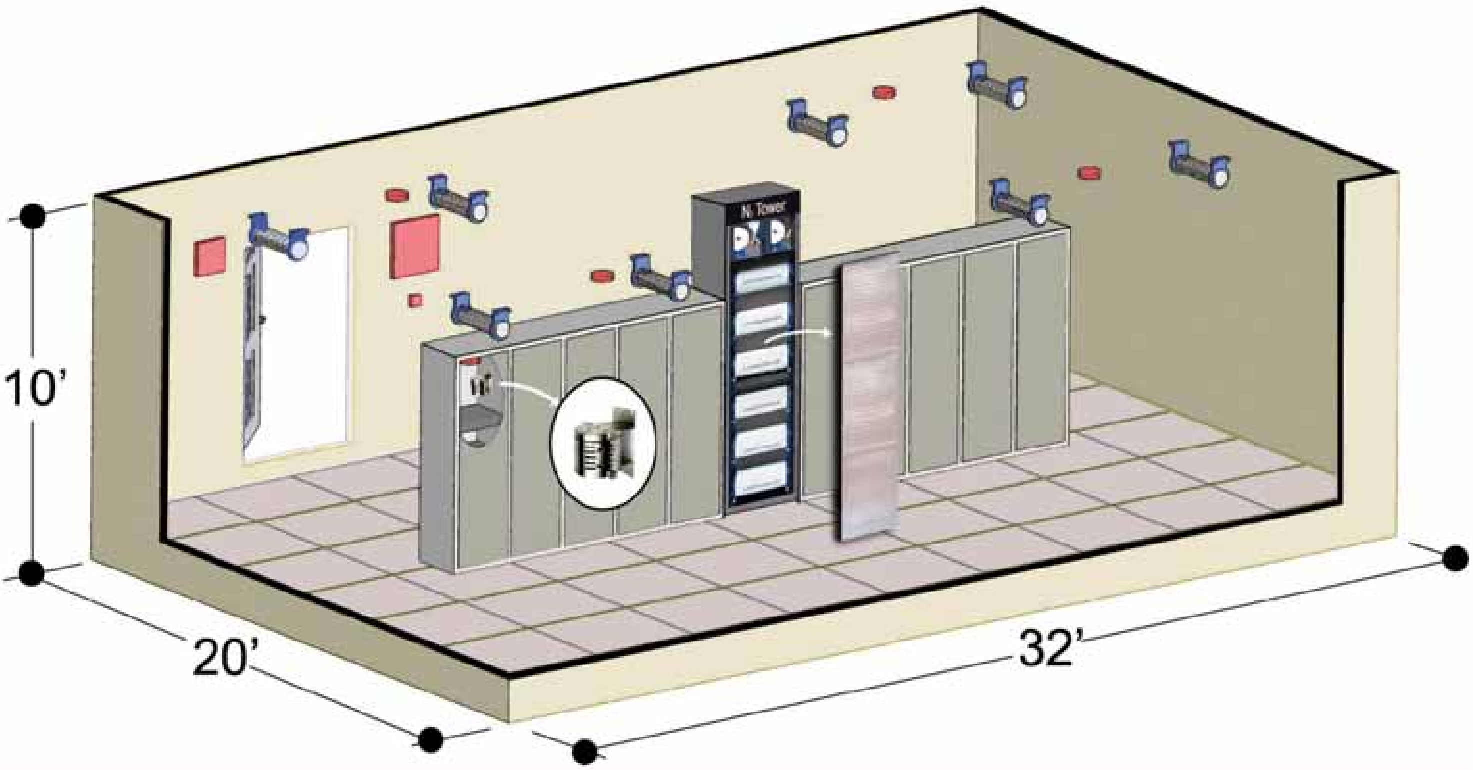

One 24 inch long N_2 Generator protects a 400 cubic feet "ft3" space (11.327 meter3). Therefore the above 6,400 ft3 (181.227 meter3) computer room requires a total of 16 x N_2 Generators either mounted to the ceiling, dispensed from an N_2 Tower or both, in an occupied space.

Fire Suppression System Design made Easy.

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SIMPLE DESIGN ADVANTAGES OF THE "N_2 TOWER" APPROACH

The N_2 Tower technology has a number of significant advantages over the current state of the art, of which the following are examples:

(1) Compact System. Since the extinguishant can be packaged in a dense, solid propellant form, rather than a compressed liquid (with required vapor space above to propel it) or compressed gas, it is inherently more space efficient, which is sorely needed for the practical installation of Halon substitutes. Since research has shown (and in fact is little known) that 100% nitrogen is competitive with Halon 1301 and HFC's in extinguishing performance on a mass basis, packaging then in a solid form results in a package that is near-optimal in its efficiency, while meeting current and future environmental restrictions.

(2) High Efficiency of Warm, Moist Inert-Rich Atmosphere. The technique of the N_2 Tower, dispensing the N_2 Generator's warm nitrogen inert gas into the compartment atmosphere permits the unique capability of providing an ultra-high heat capacity (the key property of suppression) atmosphere that still retains its gas-like flow and filling behavior. This is achieved by temporarily raising the room temperature for a few seconds by up to 10 to 15 degrees, which dramatically increases the mass of generated nitrogen gas that can be retained in air, suppress and extinguish a fire.

(3) Leak-Proof System. Since the active extinguishant is stored as a solid propellant form, the system cannot leak.

(4) Rechargeable On Site. N_2 Generators have a 30 year service free shelf life, their replacement after discharge is made simple by the removal and re-insertions of "fresh" N_2 Generators, which can be performed by authorized worldwide N_2 fire system Distributor service personnel on site without the need to ship units for refurbishment; thereby reducing system down time and further exponential costs of ownership.

(5) No Plumbing, Nozzles or High-Pressure Cylinders Needed. The time and expense of designing and installing networks of plumbing and nozzles throughout a building are eliminated, as well as their testing and maintenance and inspection, since the system is in effect "pre-engineered", with only the need to know the compartment size to be protected.

(6) No Hydrogen Fluoride Generation. The 100% clean nitrogen gas discharge will not decompose into the caustic acid by-products that can pose a threat to humans and machinery, even in large fires.

(7) Safe Oxygen Levels and Overall Toxicity. Inert gas systems are permitted to drop oxygen levels as low as 12% to extinguish fires, yet permit occupants five minutes to evacuate; N_2 Tower tests to date have shown room extinguishment at levels no lower than 15%. This provides extra safety for occupants in poorer health or with less mobility; it also provides a design margin that many hydrofluorocarbon fire system products do not in being flexible in its safe protection over wide changes in the room free volume as stored equipment capacities change over the life of a protected compartment. Inert gas solutions like N_2 Towers also do not pose the special cardiotoxicity issues that are present with many hydrofluorcarbon-based products.

(8) Simple Retrofit in Existing Facilities or Replacing Halon Systems. Since the N_2 Towers are mounted in the protected room, cramped bottle storage spaces are not necessary, including those that previously housed a small number of Halon bottles. N_2 Towers have a smaller foot print than comparable inert gas high pressurize bottle systems, thus the N_2 Towers save floor space in the protected area.

(9) 100% Environmental Friendly - No Ozone Depletion or Global Warming. N_2 Tower fire systems are all-natural and comply with all existing or future national or international environmental legislation. These systems can be specified for use anywhere in the world with no restrictions or complications, and once installed, one can be confident they will be compliant for the rest of the application's intended use period as a sound investment.

(10) A "Clean" Product, With No Residue Cleanup Required. The extinguishant is truly 100% nitrogen "clean", with no cleanup required, unlike other pyrotechnic, solid particulate-based "aerosol" generator products now in the marketplace.

(11) Mixes and Flows Throughout Compartment Like a Gas. The elevated temperature and significant momentum of the discharged nitrogen gas as its exits the N_2 Tower promotes excellent mixing in a compartment, including behind obstructions and around corners, and its gas density being comparable to air inhibits stratification that might otherwise deter its ability to extinguish fires at higher elevations.

(12) Highest Reliability. Gas generator devices are designed to the highest levels of reliability of any industry, due to their propensity for use in critical life-safety applications such as automotive airbags, and such extreme levels of reliability are standard for this mature industry, coupled with the very simplicity of the design and invulnerability to other disruptions such as piping damage due to manmade or natural disasters or mishaps, with each compartment being independently protected.

(13) Works Well Under Temperature Extremes. Gas generator devices are less influenced in their discharge rates and performance than pressurized containers when exposed to temperature extremes, and by elevating the discharge temperature, it prevents the extinguishant from immediately freezing after discharge under extremely cold conditions, unlike many other fire protection approaches.

(14) An Ideal, Cost-Effective Solution. The up-front cost of the tower units, negligible design and installation costs (compared to current approaches), labor requirements, and minimal inspection and maintenance support needed results in a system that provides superior up-front and overall 30 year service free life-cycle costs, compared to its competitors. The standardization of the N_2 Tower and N_2 Generator designs (which the airbag industry has mastered in exploiting economies of scale) also promote a very budget-friendly solution that meets all other performance and operational requirements. The simplicity of the installation and maintenance approach provides opportunities for distributors that do not currently have deployed teams of pressurized equipment-experienced field personnel to offer N_2 Tower products to their customers using their current personnel support infrastructure.

Figure 5. *Computer room N_2 Tower fire suppression system*

sively in the public sector through its widespread use as the primary component of automobile airbag inflators, which reliably convert solid propellants to gaseous by-products almost instantly. Solid propellant inflators also are used in a myriad of other applications, including aircraft engineering escape slides, life rafts and other aerospace and military uses. The military began to first look at modern versions of these devices in the early 1990s as a Halon replacement for aircraft engine nacelle and dry bay applications, resulting in their eventual use on the U.S. Navy V-22 tilt rotor and F-18 E/F aircraft. Other versions of these devices are used as part of an extinguishing system now offered by Ford on their Crown Victoria police interceptors. However, these devices to date have only been approved for use in unoccupied spaces as stand-alone systems, due to the high concentrations of carbon dioxide produced by current systems and formulations, and their expense has made them an economic challenge for large-scale fire protection applications.

THE "N_2 TOWER" BREAKTHROUGH

A patented breakthrough in the overall design of systems employing inert gas generator technology for commercial, total flood applications, in concert with new formulations that produce 100 % nitrogen gas are ideal for occupied areas, has resulted in the advent of a new type of total flood fire protection system poised to revolutionize the industry. This new type of total flood system comprises the incorporation of multiple, uniformly-sized solid propellant N_2 Generator cartridges into a single "tower" design, which is actually installed in the room or compartment to be protected. Each N_2 Tower is designed to protect a given number of cubic feet of free compartment volume; multiple towers are used for larger areas, and fractional volume coverage can be achieved by simply reducing the number of N_2 Generator cartridges in a given tower – thus, clean agent fire suppression systems engineering made easy (in effect, a “pre-engineered” solution for all total flood applications). These normally non-pressurized N_2 Towers, when activated either manually or by use of a fire suppression system releasing panel which then puts the N_2 Generator programmable sequence panel into alarm, which will activate the N_2 Generators either in series or all at once, as pre-programmed by the N_2 technician. This design eliminates the need for remote bottle installation and a network of distribution plumbing otherwise required to be designed, installed and maintained. A key feature of the design is the use of a unique propellant formulation and cartridge design devised specifically for this fire protection application. The propellant chemists and engineers have identified a propellant formula that converts, upon activation, into a clean 100 % nitrogen gas. By being uniquely able to generate 100 % nitrogen gas at a slightly elevated temperature (but still compliant with NFPA 2010 standards for human exposure limits to exhaust gas temperatures of analogous devices), the large mass of nitrogen gas can be held in gaseous state with slight, temporary increases in temperature results in its discharge in a total gaseous state into the protected compartment. A picture of a representative production design N_2 Tower (as it is being marketed commercially) is shown in Figure 1, and an illustration of a preliminary N_2 Tower mockup and N_2 Generators as manufactured by N_2 in Belleville, ON, Canada. with adjustable extended ceiling support struts, armed and disarmed LED lights is shown in Figure 2. Figure 3 is a picture of two N_2 Generators complete with two dismounted N_2 military diffusers.

Figure 6. *Art Gallery N_2 Tower fire suppression system*

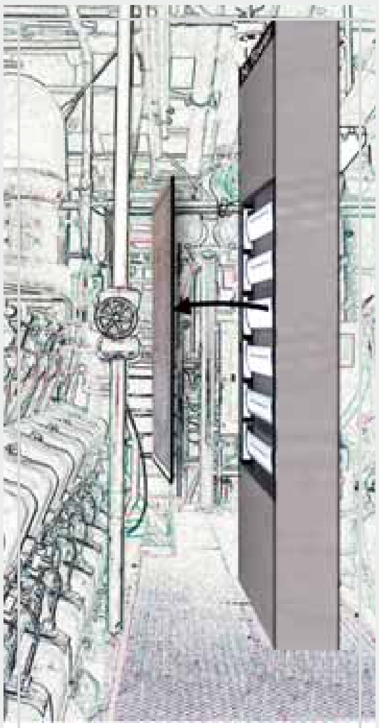

Figure 7. *Shipboard N_2 Tower fire suppression system*

RECENT TEST RESULTS

The latest automatic detection and N_2 Generator explosion suppression tests were conducted at UTeC Labs in Kansas as witnessed by US Army (TARDEC) and UL & ULC representatives on May 25 and 26, 2010.

During four of the N_2 explosion suppression tests conducted on May 26, three times we used two 6" long by 6" diameter N_2 Generators inside the 130 cubic foot lexan fire test booth which was built as a replica of a test booth constructed by the National Research Council of Canada ("NRC") 2007 study of "Explosion protection in a small compartment, using HFC explosion suppression systems".

On May 26, the N_2 Generators extinguish the explosive fire faster than the HFC counterparts used within the NRC 2007 test report. As well, when the two N_2 Generators were discharged within 100 milliseconds of each there was no re-ignition of the three test fires, during our military specified 2.2 second pressurized fuel spray and three second continued electrical ignition source.

The explosive test fires were extinguished and kept suppressed at a 15.2% oxygen per volume level and noise level maximums of 139.5 decibels by the N_2 Generators which were each mounted with a N_2 military diffuser. There was zero HF generation during the tests because the N_2 propellant formulation contains no fluorine. The NRC 2007 study recorded levels of up to 11,000 ppm of HF generation during their explosion suppression tests; these levels of HF can easily kill a man. They also used HFC concentration levels of 7% in an empty space whereby if the space was congested with equipment and men like inside the crew compartment of an armor vehicle, then the concentration of the HFC fire agent could conceivably rise to a 10% per volume level of gaseous HFC fire agents which has caused heart attacks in laboratory test dogs in the past. We also discharge our N_2 Generators inside crew compartments using an N_2 military diffuser which has two single lines of discharge ports to direct the nitrogen gas down along the inside walls of the armor vehicle and not directly into the faces of the soldiers inside the armor vehicle, such as many existing HFC systems do presently installed inside armor vehicles.

Two 6" long by 6" diameter N_2 Generators were mounted in the opposite left and right corners of the 130 cubic foot lexan test booth. The left N_2 Generator was activated 44 milliseconds after the explosive fire was detected and the second N_2 Generator was activated 100 milliseconds after the first N_2 Generator.

To the left hand side of the booth we installed a 100 psi supplied air to gasoline fuel mix spray nozzle (re: NRC 2007) which blows across an electrical ignition sparker to ignite an explosive fire ball inside the test booth with the spray nozzle supply valve being left open for 2.2 seconds and the sparker igniter left on for 3 full seconds.

The explosive test fire was detected in approximately 2 milliseconds, a delay of 44 milliseconds was programmed into the N_2 releasing panel and using two 6" long N_2 Generators for each of three tests on May 26, we extinguished the fire in 160 to 185 milliseconds which is faster than the NRC 2007 HFC test fire systems.

The ideal N_2 Generator explosion suppression system consists of more than one generator inside a crew compartment and is fired in series immediately after the first generator has discharged.

The third 100 millisecond delayed, multi 6" N_2 Generator test on May 26 included two obstacles placed within the test chamber; the two 6" N_2 Generators extinguished this fire in 160 milliseconds. The NRC - HFC explosion suppression systems could not extinguish the obstacle test fires in their 2007 test report.

During the fourth test on May 26 we used a 10" long by 6" diameter N_2 Generator mounted to discharge its N_2 agent down along the ceiling towards the fuel spray nozzle directly across on the other side of the booth. We also left the two obstructions inside the test booth during this test; the explosive fire was again extinguished in record time and there was no re-ignition of the flame.

EXAMPLES OF COMMERCIAL STRUCTURAL APPLICATIONS

Telecommunications and Computer Facilities

Figure 5 is an illustration of an N_2 Tower

TABLE 1. TEST PARAMETERS FOR MAY 26th, 2010 TESTING

Test No.	Description	Delay for 1st Generator	Delay for 2nd Generator	Time of Extinguishment	Re-ignition?
1	2-6 inch Generators	44 ms	100 ms	185 ms	No
2	2-6 inch Generators	44 ms	100 ms	150 ms	No
3	2-6 inch Generators, with obstruction	44 ms	100 ms	160 ms	No
4	1-10 inch Generator, with obstruction	44 ms	n/a	215 ms	No

TABLE 2. TEST RESULTS FROM MAY 26th, 2010 TESTING

Test No.	Description	Noise Level	Booth Pressure	Minimum O_2 Content	Minimum CO Content
1	2-6 inch Generators, 100ms delay	139.5 dB	1.4 psi	15.6 %	840 ppm
2	2-6 inch Generators, 100ms delay	139.4 dB	n/a	15.3 %	910 ppm
3	2-6 inch Generators, with obstruction	139.6 dB	n/a	15.3 %	691 ppm
4	1-10 inch Generator, with obstruction	139.7 dB	1.5 psi	15.4 %	712 ppm

device in a computer room, an ideal application of its clean extinguishing traits, while posing no harm to valuable electronics. Note its design seamlessly blending into the bank of computer data processing equipment, permitting its installation in the most inconspicuous manner possible.

Industrial Power Equipment and Machinery Space

N_2 Towers can be installed in unobtrusive locations in such spaces, including individual N_2 Generators installed on ceilings or in smaller compartments, and provide protection against Class B fuel fires and well as Class A, with no frustrating post-discharge cleanup required.

Museums and Records Storage Areas

Figure 6 shows an illustration of a decorative, disguised application in a modern museum setting, utilizing a "stacked", double N_2 Tower fire protection system configuration, protecting valuable works of art while not detracting from the artistic motif of the room setting.

EXAMPLES OF TRANSPORTATION APPLICATIONS

Shipboard

Figure 7 is an illustration of a N_2 Tower in a shipboard machinery space, providing reliable, efficient Class A and B fire protection with no residual hazards for inspection personnel, and ease of maintenance. Notice the ability to efficiently stack multiple N_2 Generators if desired, to both reduce the system footprint and further promote mixing at a range of room elevations.

Aircraft

N_2 Generators provide unique capabilities for many aviation applications, including cargo bays, hidden areas, other dry bays and engine nacelles.

Military Armored Vehicles

Figure 8 is a photograph of a typical N_2 Generator installed inside an armor vehicle crew compartment. The automatic detection and N_2 Generator explosion suppression system is suitable as a retrofit-type assembly to replace existing halon 1301 or HFC armored vehicle crew compartment explosion suppression systems, or used as a new supplemental system for sustained protection. For these latter applications, two or more generators (sequenced for either longer suppression and higher capacity, or for a "back-up" second shot) are wired to activate in series as programmed into the N_2 sequence control panel. The N_2 sequence panel can be put into alarm by any existing commercially available explosion detection and releasing system.

CURRENT STATUS AND FUTURE PLANS

N_2 Generators received their DoT approval number EX2010030506 on July 16, 2010 along with its U.N. proper shipping name as a flammable solid, inorganic, n.o.s., shipping number UN3178 and U.N. Classification Code 4.1. N_2 has submitted its US SNAP List application for use in occupied spaces as a halon alternative and N_2 will be full scale production capable by the fourth quarter of 2010 in Belleville, ON, Canada.

SUMMARY

Through our numerous N_2 explosion suppression tests at UTeC Labs over the last six months we have been able to extinguish the explosive fire and keep it from re-igniting by discharging our N_2 Generators from all various locations from within the NRC style test booth.

The synergy of the new N_2 fire system technology derived from other high-performance industries, mated with new N_2 Tower design approaches for total flood systems in general are now possible with their N_2 Generators, which provide the 100 % environmentally friendly, total flood, clean agent fire suppression system solution that end users have been waiting for. ■

Figure 8. *N_2 Generator (c/w no N_2 military diffuser) mounted vertically inside an actual armour vehicle crew compartment*