TEER ENERGY APPROACH

Ansul Fire Protection
J.S. Nicholas

"Halon Alternatives Technical Working Conference 1993"
Hay 11-13, 1993
INTRODUCTION
The health and environmental concerns of today's consumers have led manufacturers to pursue evermore environmentally friendly products. It is no longer acceptable for globally conscious corporations to produce products which exhibit questionable environmental impact. Although many products are sold on the merits of "what they will do," more and more products are attracting customers because of "what they will not do," to people or the environment.

The fire protection industry has also increased its environmental awareness with its search for a replacement for Halon 1301, the gaseous fire extinguishing agent widely used to protect data processing centers and other normally occupied areas where equipment is either sensitive or irreplaceable. Although Halon 1301 was considered safe for people or high value equipment, it is now considered a threat to the environment due to its ozone depleting characteristics.

The goal of the fire protection industry has been to find agents with the advantages of Halon 1301 while eliminating the environmentally destructive characteristics. That goal has been realized with the development of INERGEN. INERGEN agent will extinguish class A and B fires and has demonstrated inerting capacity. Because INERGEN is derived from atmospheric gases it has no impact on the environment. It has no ozone depletion potential or greenhouse warming potential. Similarly, when properly installed, INERGEN will not harm sensitive or irreplaceable equipment. It forms no toxic or corrosive decomposition products.
The gas mixture comprising INERGEN is 52% nitrogen, 40% argon and eight percent carbon dioxide. INERGEN behaves much as carbon dioxide in the extinguishment of fire. Both gases act in lowering the oxygen content below that which supports combustion. However, INERGEN acts to stimulate respiration and oxygen transfer within the human body. This principle is important in distinguishing INERGEN from other inerting gases. The addition of argon to the mixture creates a density gradient for INERGEN which works to promote air/INERGEN mixing.

**INERGEN CLASS A FIRE CAPABILITY**

Initial evaluations of the class A capability of INERGEN were carried out using the following test protocol.

The class A fire test consisted of a modification of a UL fire test. The fuel load consisted of a cubical wooden crib eight inches on a side. The 32 members were comprised of pine one inch by one inch by eight inches long. The total surface area of the crib was 846 in’ resulting in a surface area to volume ratio 3.4:1. The crib was soaked in charcoal lighter fluid for thirty minutes prior to ignition, then placed on a load cell and lighted with a propane torch. Computerized data acquisition gave rapid readings of all parameters, including oxygen and CO, levels from a Nova gas analyzer.

After establishing the burning rate of the fuel it was determined that a minimum of 25% to 35% weight loss was sufficient and reproducible in establishing a condition of “flaming” combustion when using a wooden crib. The success of extinguishment was measured when a steady-state was achieved on the weight loss
What Is INERGEN™

INERT GAS + NITROGEN

COMPOSITION

- Nitrogen .................. 52%
- Argon ..................... 40%
- Carbon Dioxide ...... 8%
How Does INERGEN™ Work

- **NORMAL ATMOSPHERE**
  - O₂: 21%
  - CO₂: < 1%

- **INERGEN™ ATMOSPHERE**
  - O₂: 12.5%
  - CO₂: 4%

15% O₂ LEVEL REQUIRED FOR COMBUSTION (FIRE)

CO₂ LEVEL INCREASED TO ACCELERATE RESPIRATION
Class ‘A’ Fire Protocol

- 32 Member Crib
  - 1 inch x 1 inch x 8 inch Pieces
- 256 Cubic Feet Lexan Test Enclosure
- Labtech Notebook Data Acquisition
- NOVA Analytical
  - O₂ - CO₂ Gas Analyzer
- Hanging Load Cell
- Omega Thermocouples
Why INERGEN™

ADVANTAGES

• Contains Only Naturally Occurring Gases
  ➤ Zero Ozone Depletion Potential
  ➤ No Global Warming Potential
  ➤ No Hazardous Decomposition Products
  ➤ Non-Toxic, No Cardiac Sensitization

• Clean, Dry, Electrically Non-Conductive
• Effective On All Common Types Of Fires
• Simplified Flow Calculations
curve. This could be verified by observing the temperature curve over the same period. Successful extinguishment would result in a negative sloping temperature profile. A positive slope at the end of the soak period indicated deep-seated burning and would correlate to a continued weight loss.

The test chamber was constructed to form a volume of 256 cubic feet (8HX8WX4D). Construction was such that three vertical walls were made of Lexan with the back, top and bottom made of 3/4 inch plywood. Centered at floor level of the side opposite the entry is a circular air inlet (4" diameter). Diagonally opposite is a 4" exhaust vent capable of 800 cfm. A load cell is suspended in the center of the box. This cell is capable of measuring weight loss to one ounce. A wire mesh basket is supported from the load cell and used to contain all fuels. This basket has dimensions of 12" diameter by 12" height. Located in the ceiling of the test chamber is one three-eighths inch INERGEN nozzle.

The vent and blower were left on during the pre-burn period. At the desired weight loss fan power was stopped and the inlet vent was closed to simulate fire detection. The agent was discharged, fire out time was noted, and the soak time measured. The soak period began from the point in time when the box achieved a 15% O2 concentration. At the end of the soak period the blower was again powered up and the inlet vent opened. Temperature and weight loss were monitored for the duration of the soak time and for an additional ten minutes during the power up period.

Test results from a 30% weight loss test are shown in this slide. Measured parameters included weight loss, O2, CO2 and CO concentration, fuel temperature and extinguishment time. Typical results for some of these parameters are shown in the following graphs.
Class 'A' Fire Results
Weight Loss Profile

TIME (SECONDS)

WEIGHT OUNCES

34% INERGEN™ - 30% BURN - 8 INCH CRIB
Class 'A' Fire Results
Oxygen & Carbon Dioxide Levels

34% INERGEN™ - 30% BURN - 8 INCH CRIB
Class ‘A’ Fire Results
Carbon Monoxide Profile

34% INERGEN™ - 30% BURN - 8 INCH CRIB
The results demonstrate that INERGEN is capable of extinguishing class A fires at an injected concentration of 34%, equivalent to a received concentration of 28-29%. In testing to this protocol, extinguishment has been achieved on average within 90 seconds of the start of discharge with a total discharge occurring over two minutes. The concentration of carbon dioxide increased to 4.5% with the oxygen concentration stabilizing at 11%. Carbon monoxide reached an average maximum of 380 ppm.

By setting the preburn time as a function of weight loss, a more controlled experiment was established for evaluating class A effectiveness. The burning rate over twenty-five to thirty-five percent weight loss was found to be linear and very reproducible during this testing. The results of this testing indicate that INERGEN demonstrates good class A fire extinguishing capacity for normal class A loading, at a concentration of 29%, equivalent to a design concentration of 34%.

**INERGEN CLASS B FIRE CAPABILITY**

The extinguishing concentration of INERGEN can be determined using the Cup-Burner method as developed by Imperial Chemical Industries in the mid 70's. Cup-burner evaluations have been used since that time for the purpose of establishing extinction concentrations for Halon fire extinguishing agents. With the banning of Halons because of their contribution to ozone depletion, the use of the cup-burner has again been employed to evaluate alternative clean agents. National Fire Protection Association proposed standard 2001, Clean Agent Fire Extinguishing Systems, expressly calls out the use of the cup-burner for demonstrating the class B effectiveness of candidate agents and for establishing minimum extinguishing concentrations.
Class ‘A’ Fire - Summary
Crib Fire Test Results

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Extinguishment Concentration</td>
<td>29.0%</td>
</tr>
<tr>
<td>Design Concentration</td>
<td>34.0%</td>
</tr>
<tr>
<td>Final Carbon Dioxide</td>
<td></td>
</tr>
<tr>
<td>Concentration</td>
<td>4.5%</td>
</tr>
<tr>
<td>Final Oxygen Concentration</td>
<td>11.0%</td>
</tr>
<tr>
<td>Final Carbon Monoxide</td>
<td></td>
</tr>
<tr>
<td>Concentration</td>
<td>380 ppm</td>
</tr>
</tbody>
</table>
The basic components to the cup-burner consist of the cup, burner support block, chimney, and flow meters. The apparatus was set-up as described in Appendix A Section 3-4.2.2 of draft NFPA standard 2001. To the inlet of the cup-burner is attached Tygon tubing of sufficient length and diameter to allow convenient location of a 500 ml separatory funnel. This funnel is used as the fuel reservoir and fuel leveling mechanism. The funnel is fixed with a side-mounted-teflon-micrometer valve for fuel flow adjustment. The funnel sits in an adjustable ring stand for ease in maintaining a constant fuel level.

Brooks flow meters were used to measure the flow of air and INERGEN. Line regulators were used to reduce the house pressure of air and tank pressure of INERGEN. Air flow was measured at 10-12 psi while INERGEN pressure was regulated at 40 psi. A volumetric flow curve for air was developed using the bubble burette technique. A similar curve for INERGEN was developed. Volumetric gas flows for test purposes are then set using the flow curves.

Reagent grade heptane was used as the fuel source. INERGEN was supplied to the manufacturing specification of 52% N\textsubscript{2}; 40% Ar; 8% CO\textsubscript{2}.

The test for extinguishing concentration is as follows. After assembling the burner apparatus, charge fuel to the reservoir. Set the rotameter to a flow of 30 l/min. Center the cup-burner in the block and allow fuel to fill the cup to within 3 mm of the lip. Avoid spillage of fuel as any spillage will contaminate the air flow. Light the fuel in the cup-burner and place the chimney on the apparatus. Begin to increase the flow of the extinguishing agent to the point of extinguishment. Allow ten seconds between each successive flow increase. Back the extinguishing concentration down and repeat the test three times. Record the extinguishing concentration.
Class 'B' Fires - Cup Burner

- Fuel
- Cup
- Air
- Agent
- Glass Beads
- Flame
The determination of extinguishing concentration is computed as follows:

\[ \text{IT Conc.} = \frac{F_1}{F_1 + F_2} \times 100 \]

where:

- \( F_1 \) is the agent flow rate in L/min;
- \( F_2 \) is the air flow rate in L/min.

Because the inerting volume of INERGEN is higher than that of alternative agents the total flow through the cup-burner was balanced so that 40 L/min was maintained. As an example, if the INERGEN flow for an extinguishing concentration was determined to be 11.5 L/min, the air flow was reduced to 28.5 L/min thus maintaining a total flow of 40 L/min through the system. It was the opinion of those skilled in the use of the cup-burner that flows exceeding 40 L/min could result in blow-out of the cup-burner rather than extinguishment. However, tests up to a total flow rate of 50 L/min gave similar results. All other aspects of the cup-burner test remained consistent with earlier work.

The cup-burner results for the extinguishing capacity of INERGEN, for heptane at 25°C, was found to be 29.1 Vol.%. Extinguishment occurred within 5 seconds of exposure to this atmosphere.

**T88 INERGEN SYSTEM**

The efficacy of the agent can be demonstrated within the laboratory through Class A and Class B fire testing. As with all new clean agents the question of application must then be addressed. The INERGEN fire suppression system is an engineered system utilizing a fixed nozzle distribution network. Standard DOT cylinders and a special version of Ansul's CV-90 valve are used. The flow is single phase and typically lasts 1-3 minutes.
Class 'B' Fires
Cup Burner Calculation


dd

\[
\text{EXTINGUISHING CONCENTRATIONS} = \frac{F_1}{F_1 + F_2} \times 100
\]

\[F_1 = \text{agent Flow Rate}\]
\[F_2 = \text{air Flow Rate}\]
Class 'B' Fires
Cup Burner Results

Fuel .................. Heptane

Temperature ............ 25 °C

Time to Extinguish ...... 5 Sec. Max.

INERGEN™
Concentration ........... 29.1%
The system can be actuated by detection and control equipment for automatic system operation along with providing local and remote manual operation as needed. Accessories are used to provide alarms, ventilation control, door closures or other auxiliary shutdown or functions.

The basic system consists of extinguishing agent stored in high strength steel alloy cylinders. Various types of actuators, either manual or automatic, are available for release of the agent into the hazard area. Both pilot and slave valves are available. The agent is distributed and discharged into the hazard area through a network of piping and nozzles. The piping is schedule 80 for the manifold and schedule 40 for distribution. Typical pressure drops are as shown. The cylinders are connected to the distribution piping or the manifold by means of a flexible discharge bend and check valve assembly. Each nozzle is drilled with a fixed orifice designed to deliver a uniform discharge to the protected area.

A hydraulic flow program has been written to calculate system design parameters. Single phase flow provides a relatively straight-forward basis for this program. A system installation and maintenance manual is available containing information on system components and procedures concerning design, operation, inspection, maintenance and recharge. The system is installed and serviced by authorized distributors that are trained by the manufacturer.

The INERGEN system is particularly useful for suppressing fires in hazards where an electrically non-conductive medium is essential or desirable; where clean-up of other agents presents a problem; or where the hazard is normally occupied and requires a non-toxic agent.
## INERGEN™ Systems

<table>
<thead>
<tr>
<th>Design Type:</th>
<th>Modular / Engineered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder Assembly:</td>
<td>3A/3AA DOT 2015+ Minimum</td>
</tr>
<tr>
<td>Cylinder Valves:</td>
<td>ANSUL CV90 (With Gauge)</td>
</tr>
<tr>
<td>Discharge Nozzles:</td>
<td>New, Similar To Halon Types</td>
</tr>
<tr>
<td>Distribution Piping:</td>
<td>Schedule 80-Manifold, Union Orifice Plate Schedule 40-Branch Pipe Network</td>
</tr>
<tr>
<td>Detection / Control:</td>
<td>Standard Detection / AutoPulse™</td>
</tr>
<tr>
<td>Flow Calculation:</td>
<td>Single Phase Flow</td>
</tr>
<tr>
<td>Discharge Time:</td>
<td>1 - 3 Minutes</td>
</tr>
</tbody>
</table>
Engineered Systems Design
APPLICATIONS

The following are typical hazards protected by INERGEN systems:

- Computer Rooms
- Subfloors
- Tape Storage
- Telecommunication/Switchgear
- Essential Electronics
- Banks/Vaults
- Oil/Gas Facilities
- Process Equipment

Total flooding is currently the only recommended application method for INERGEN systems. The design flooding concentration of an INERGEN system will typically be from 44-50%. This will result in a room concentration falling within the design window of 11% to 14% oxygen and 2.5% to 4.5% CO₂. A typical set of curves for oxygen and CO₂ concentrations and the pressure drop for a typical system discharge is as shown.

NOISE

During the initial testing of INERGEN systems in August 1992, it was thought that the relative noise level of the INERGEN discharge was louder than that for Halon 1301. This led Ansul to investigate ways of reducing the sound pressure associated with the system design. Initial pressure waves were recorded in the range of 122 dB to 126 dB using the A scale of measurement. Subsequent design changes have reduced the noise level significantly.

A typical noise level curve for an INERGEN discharge is as shown, dropping quickly, from a peak of 117 dB to levels below 90 dB.
Where Will NERGEN™ Be Used

- EDP / Computer Facilities
- Telecommunications
- Essential Electronics
- Oil / Gas Facilities
- Banks / Records Storage
- Historical Sites
Room Concentrations \( \% \)
of Oxygen and Carbon Dioxide.

![Graph showing the change in oxygen and carbon dioxide concentrations over time.](image)
INERGEN™ Discharge.
Manifold, After Orifice Plate, Nozzle...
For a comparison to Halon, refer to the following:

### Noise Monitoring of INERGEN Discharge (dБ)

<table>
<thead>
<tr>
<th></th>
<th>INERGEN</th>
<th>Halon 1301</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK L</td>
<td>117.9</td>
<td>130.0</td>
</tr>
<tr>
<td>Max L</td>
<td>103.4</td>
<td>113.4</td>
</tr>
<tr>
<td>Min L</td>
<td>46.7</td>
<td>46.8</td>
</tr>
<tr>
<td>LAvg</td>
<td>90.0</td>
<td>101.4</td>
</tr>
</tbody>
</table>

The discharge of INERGEN developed a peak sound pressure of 117.9 dБ while the Halon test developed a peak of 130 dБ. The INERGEN discharge noise level decrease quickly, while a Halon discharge is relatively unchanged throughout.

The Occupational Safety and Health Standard for Occupational Noise Exposure, 1910.59, defines permissible noise exposure for the workplace. The allowable limits can be found in Table G-16 and G-16A of the standard. OSHA recommends a 90 dБ TVA with a peak dБ of 140.

Although both INERGEN and Halon would comply with this requirement, comparatively halon displays a peak sound pressure 24 times the intensity of INERGEN for a period seven times longer.

**PHYSIOLOGY SUMMARY OF INERGEN**

As with all total flooding fire extinguishing agents, it is recommended that personnel evacuate the space as soon as a fire is detected. In addition rapid response detectors, warning alarms, sirens, and horns are used to prompt rapid evacuation, and a short time delay prior to system release provides sufficient evacuation time. With these standard precautions, exposure to the hypoxic atmosphere created by INERGEN will not normally occur. However, consideration must be given to situations in which an individual cannot or chooses not to evacuate.
INERGEN™ Discharge - Sound Pressure Level
# Noise Comparison

<table>
<thead>
<tr>
<th>Inergen</th>
<th>HALON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Level (db)</td>
<td>117.9</td>
</tr>
<tr>
<td>Allowable Exp (Hrs.)</td>
<td>0.19</td>
</tr>
<tr>
<td>Peak Sound Pressure Duration (Seconds)</td>
<td>3.0</td>
</tr>
<tr>
<td>Peak Sound Pressure As % of Discharge Time</td>
<td>1.1%</td>
</tr>
</tbody>
</table>
The components of INERGEX are non-toxic. The carbon dioxide content of the atmosphere created by INERGEN has a well documented beneficial physiological effect, stimulating respiration and enhancing the efficiency of oxygen transfer from the atmosphere to the blood stream and to the brain. Nitrogen and argon are physiologically inert at normal atmospheric pressures. The sustained breathability of the extinguishing atmosphere created by INERGEN is directly related to the degree of hypoxia (decreased oxygen) and hypercapnia (increased carbon dioxide).

A distinction should be made between the physiologic effects of INERGEN use and the effects of fire, heat, or toxins in smoke produced by combustion. The duration of safe tolerance to the toxic products of combustion will be much less than the physiologic tolerance to the non-toxic component gases of INERGEN. In the event of unavoidable delay in evacuation, the physiologic tolerance to INERGEN extinguishing atmospheres greatly enhances the prospects of human survival without residual effect.

With this background, it is appropriate to examine the following:

+ The physiologic effect of the INERGEN extinguishing atmosphere on "normal" individuals.
+ The physiologic effect of the INERGEN extinguishing atmosphere on individuals with cardiovascular or pulmonary impairments.


- **Hypoxia** - Low Oxygen

- **Hypercapnia** - High $CO_2$
Effects On
"Normal" Individuals

Effects On
"Impaired" Individuals
TEE INERGEN EXTINGUISHING ATMOSPHERE

The concentration of oxygen necessary to support combustion is dependent on the fuel. Data is available on a wide range of Class B fuels. With the exception of those fuels which provide their own oxygen, extinguishment typically occurs below 14-15% oxygen. This has been the basis for the successful use of carbon dioxide systems for many years. Class A and Class B testing with INERGEN has shown the typical INERGEN design extinguishing atmosphere to be 12.5-14.0% oxygen and corresponding carbon dioxide levels of 3.5-4.0%.

PHYSIOLOGIC EFFECT ON "NORMAL" INDIVIDUALS

A significant body of scientific study exists concerning the concurrent 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.

Small degrees of hypoxia (low oxygen) and hypercapnia (high carbon dioxide) can be tolerated for several days without detectable adverse effect. Extremely low levels of oxygen or extremely high levels of carbon dioxide can be tolerated for less than a minute. In between these extremes are degrees of combined hypoxia and hypercapnia which are advantageous to the safety of occupants for durations necessary in fire protection applications.
INERGEN™ Atmosphere

Oxygen ..................... 12.5 - 14.0%

Carbon Dioxide ..... 3.5 - 4.0%
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. Carbon dioxide increases brain blood flow and oxygenation at all levels of inspired oxygen. The rate of oxygen consumption by the brain at 12% oxygen and 4% carbon dioxide is the same as the consumption in normal air containing 21% oxygen. Because of the constant ratio of carbon dioxide to inert gases in INERGEN, there tends to be an automatic adjustment toward increased levels of carbon dioxide as oxygen levels are reduced through the application of increasing amounts of INERGEN. This is clearly physiologically appropriate.

PEXSIOLIGIC EFFECTS ON INDIVIDUALS WITH IMPAIRMENTS

Specific experiments have not been conducted concerning tolerance of individuals having heart or lung abnormalities to INERGEN or to any other extinguishing agent, nor are they likely to be performed. It is therefore necessary to obtain practical clinical judgement concerning situations of risk for such impaired individuals in the workplace. Such an evaluation has been conducted by clinical and research specialists at the University of Pennsylvania Medical Center, and has been peer reviewed for the EPA by specialists at the University of Rochester Medical Center, the National Institute of Health, and Temple University Medical Center. All of the reviews have been favorable.
INERGEN™ Health Effects

Relations of brain metabolism to brain oxygenation. Effects of hypoxia without CO₂ in breathing atmosphere and with CO₂ in breathing atmosphere.
For individuals with abnormalities of heart, circulation or lung, only their prompt exit from space involved in fire and extinguishment is considered rational. If assistance is not normally required, it is unlikely to be needed as a specific consequence of INERGEN flooding. The time course for changes of oxygen and carbon dioxide levels within the individual are in the order of several minutes. The full degree and effect of long duration exposure to hypoxia will not occur within the first several minutes after the first breath of a low oxygen atmosphere. Therefore, physiologic changes should not interfere with an exit procedure, even for an individual with circulatory or pulmonary impairment.

Specific relevant clinical abnormalities considered include:

- Coronary vascular disease.
- Cardiac decompensation.
- Cardiac arrhythmia.
- Prior stroke.
- Pulmonary emphysema.

For the above conditions, review by scientists of the Environmental Biomedical Research Data Center at the University of Pennsylvania concludes that persons handicapped by degrees of cardiac or pulmonary abnormality not limiting capability for normal entry and exit should be able to exit during INERGEN flooding, with any transient exposure completely reversing itself on exposure to the external atmosphere.

**U.S. EPA SNAPS PROGRAM**

Based on the physiologic data presented for INERGEN and the resulting peer review, EPA has accepted INERGEN for use in occupied and non-occupied spaces, and for inerting.
CONCLUSION

**INERGEN** is a unique extinguishing agent that is completely environmentally friendly. It has effectiveness on both Class A and Class B fires, it does not form toxic or corrosive decomposition products, it does not create obscuration and it leaves no residue. **INERGEN** can be used in an engineered system with readily available equipment, and is accepted for occupied spaces by the U.S. EPA.