PERFLUOROHEXANE CLEAN EXTINGUISHING AGENT FOR STREAMING AND LOCAL APPLICATION SYSTEMS

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ABSTRACT

This paper will deal with the recent work done with the clean extinguishing agent perfluorohexane, known as CEA-614 as produced by the 3M Co. The paper will cover the chemistry, mechanisms, properties, toxicology, decomposition products, handling and recovery, fire performance, compatibility and environmental properties of perfluorohexane. Previous work by the New Mexico Engineering Research Institute (NMERI), the USAF and the U.S. Navy demonstrated that the perfluorohexane was an excellent fire extinguishing agent when used in the military flightline fire scenarios. Perfluorohexane demonstrated the best combination of properties of any of the proposed clean extinguishing agents for the replacement of Halon 1211 in flightline applications. In addition, the fire fighting capabilities of perfluorohexane have now been demonstrated in Underwriters Laboratory type fire scenarios with a high degree of success. This paper will discuss these recent developments with perfluorohexane and possible future work in the development process of this new cleaning extinguishing agent.

INTRODUCTION

It has been known since 1948 that perfluorocarbons have the ability to extinguish Class A, Class B and Class C type fires and at the same time meet the definition of a clean extinguishing agent (CEA), in that they are electrically non-conductive and leave no residue after extinguishment of the fire. These perfluorocarbons have now been commercially developed by the 3M Company as replacement agents for the previously used Halons in clean extinguishing agent applications. Slide 1. These perfluorocarbons include perfluoropropane, perfluorobutane and perfluorohexane in the homologous pertluoroalkane series. Pertluoropropane is intended for low temperature applications in total flooding and explosion inertion and perfluorobutane *is* intended for total flooding applications in normal industrial hazards. Perfluorohexane(PFH) is intended as a streaming and local application agent due to its special physical characteristics and high boiling point. This paper will deal with PFH known as FC-5-1-14 or commercially as CEA-614. CEA-614 is liquid at room temperature and as such offers some unique characteristics to the fue fighting community in the areas of streaming type portable fire extinguishers and directional spray nozzle designs for local application systems. The liquid nature of the agent also contributes to PFH's excellent handling characteristics and ease of charging portable extinguishers. The recovery and recycle of the PFH is also greatly simplified when portable extinguishers are serviced or maintained. Additionally, the PFH exhibits some of the most desirable qualities of any of the proposed new clean extinguishing agents being introduced into the marketplace. As for all perfluorocarbons, CEA-614 shows a high degree of compatibility with materials of construction, a very low toxicity level and acceptable environmental characteristics. This material is available at the present time for development and testing purposes plus quantities are available for commercial introduction of CEA-614 as the approvals and listings are granted.

HISTORY

Specialty perfluorocarbons have been produced by the 3M Company for over 40 years. Slide 2. These pertluorocarbons have been used extensively in the electronics industry because of their high degree of compatibility with the sensitive materials of construction related to this industry. Also, the low residue left on electronic components after they have undergone testing and evaluation in the perfluorocarbon liquids makes these fluids ideal for various electronic test procedures. Perfluorocarbons have been used in electronic reliability testing, vapor phase soldering, thermal management and now as chlorfluorocarbon alternatives and halon replacements.

Perfluorocarbons have a long list of physical characteristics that make them very desirable from a standpoint of using them as clean extinguishing agents. Slide 3. Among this list of physical characteristics are: chemically inert, non-corrosive, electrically non-conductive, compatible with all common materials of construction, leave no residue, essentially non-toxic, not ozone depleting, and not a VOC at ground level.

Many of these physical properties can be demonstrated by an electrically energized television submerged in the liquid PFH. A human hand immersed in the liquid perfluorocarbon demonstrates the electrical non-conductivity of this material and its essentially non-toxic nature. The liquid is also shown to be colorless and compatible with many materials of construction. These physical characteristics are common to all of the perfluorocarbons that are being introduced as replacements for halon in the clean extinguishing agent fire protection application arena.

In translating the general physical characteristics of perfluorocarbons to those required by a candidate clean extinguishing agent, it is noted that the new clean extinguishing agent must be effective in extinguishing fues, have a high degree of equipment compatibility, show low toxicity and minimal thermal decomposition products, be environmentally acceptable, be cost effective and be available in quantity. Slide 4 These additional requirements for clean extinguishing agent are met very nicely by CEA-614 when used in streaming applications with portable extinguishers and local application with directional spray nozzles.

CHEMISTRY / EXTINGUISHING MECHANISM

CEA-614 is also known as FC-5-1-14 in the ASHRAE designation system. This ASHRAE designation will be found in the NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, in the appropriate UL and FMRC documentation and EPA SNAP Rule.

The CEA-614 designation represents the same material as the generic perfluorohexane, with the "6" standing for six carbons and the "14" standing for the fourteen fluorine atoms on the molecule. Slide 5. CEA-614 is manufactured by 3M Company using a process called electrochemical fluorination. This process essentially turns a flammable material, hexane, into a non-flammable, fire extinguishing agent, perfluorohexane, by replacing all of the hydrogen atoms on the carbon chain backbone with fluorine atoms. The fact that all sites are taken up by fluorine indicates that it is a perfluorochemical.

Pertluorohexane has certain physical properties which make it definitely different from Halon 1211. Slide 6. Perfluorobexane has about twice the molecular weight of Halon 1211. The boiling point of perfluorohexane is 56° C, indicating that it is a liquid at room temperature. This is a very important physical characteristic of this agent as it leads to enhanced fue extinguishing ability and very desirable handling and recycling characteristics. The vapor pressure is much lower than Halon 1211, so it is delivered as a liquid rather than a gas to the fue area. The liquid densities of the two agents are essentially the same.

In a streaming agent application, CEA-614 has shown effectiveness on Class A, B and C type fues when tested by various military and industrial testing organizations throughout the world. The agent can be applied to a fire either with portable, hand held extinguishers or wheeled portable extinguishers as demonstrated by the thorough testing done by the USAF and the U.S. Navy in fligbtline fue scenarios.

CEA-614 differs from Halon 1211 in that it is essentially a physical agent and depends on its physical cooling ability and generation of an inert atmosphere to extinguish the fire. Slide 7. Approximately 90% of the extinguishing mechanism for CEA-614 involves physical action, while at maximum, 10% involves chemical action of free radical formation. In contrast, the halons are 90% chemical acting in nature as they supply bromine and chlorine radicals that interfere with the chain reaction of combustion. CEA-614's physical cooling nature comes in the form of the heat of vaporization, heat capacity of the agent and heat removal through decomposition of the agent in the flame front. All of these mechanisms remove heat from the tire, reduce the flame temperature below the ignition point and cause extinguishment.

HANDLING / RECOVERY / RECYCLE

As with all of the new clean extinguishing agents proposed to be marketed in the near future, it is recommended that PFH be recovered, recycled and reused whenever possible. Due to its liquid nature, this becomes an extremely easy operation with CEA-614. As a liquid, CEA-614 is supplied by 3M Company in normal liquid handling containers such as 5-gallon pails and 55 gallon drums. Bulk shipments are also possible for this liquid agent. The recovery process and recycle process, when needed, simply involves venting the nitrogen from a tire protection system or the portable extinguisher and returning the liquid agent to the shipping containers for reuse in the future or for return to the 3M Company for proper disposal.

When maintenance is required, the liquid nature of the CEA-614 makes recovery, recycling and reuse of the agent extremely simple. The major losses of agent in Halon 1211 extinguishers were seen when the O-ring seal in the portable extinguisher valve failed, venting not only the nitrogen gas, but also the Halon 1211 into the atmosphere. With CEA-614 being a liquid, the loss of the nitrogen pressurization charge through a faulty O-ring seal would not result in a loss of the CEA-614 charge. This liquid charge would remain in the extinguisher until an inspection showed the extinguisher to be faulty and maintenance procedures were instituted to recover the agent.

Recovery of the agent from a partially vented extinguisher is also quite easy. Simply inverting the extinguisher and venting the nitrogen charge through the dip pipe and valve assembly allows recycle of the liquid agent. In addition to recycling, the handling aspects of the liquid CEA-614 over the gaseous Halon 1211 are remarkably improved. Normal pumps, siphons and pouring techniques can be used to transfer the agent from the shipping containers to the system containers or the portable extinguishers as needed. No special materials of construction or recovery apparatus are required for CEA-614.

Common portable extinguishers and wheeled extinguishers can be used with CEA-614 with very little change in their components. For use in military flightline applications, typical Amerex military model; ***20*** pound, hand-held extinguishers and 150 pound, wheeled extinguishers were used with CEA-614 with no changes in the valve, dip pipe assembly, o-ring seals, hoses or nozzle. The change from Halon 1211 from CEA-614 was essentially a drop-in replacement. Some degradation of the fire performance, of course, was seen with CEA-614 in comparison with the previously used Halon 1211. For use in nonmilitary flightline applications where Underwriters Laboratory types fire scenarios are required, some modification of the current Halon 1211 extinguisher nozzles will be required to maximize the effect of the agent on both Class **A** and Class B fires.

FIRE PERFORMANCE

Perfluorohexane has been tested extensively by the U.S. Air Force, the U.S. Navy and the U.S. Army in various test scenarios. Slide 8. The U.S. Air Force testing was done as part of its replacement program for Halon 1211 in flightline applications, The fue testing was done at Tyndall Air Force Base and at the New Mexico Engineering Research Institute. Slide 9. In these studies, the 150 pound flightline extinguisher and the **20** pound portable extinguisher were evaluated for use in ground based, flightline extinguishing applications. In addition, the 20 pound extinguishers could be used in critical computer control facilities throughout the U.S.A.F. System. In this test program, the culmination of testing several hundred compounds, CEA-614 was ultimately judged as the agent best suited for the replacement of Halon 1211 in flightline applications.

In running the tests for the U.S. Air Force, the New Mexico Engineering Research Institute used a mock-up consisting of a 75 square foot circular pan in which JP-4 jet fuel was floated on top of a water base. Slide 10. A 55 gallon drum nacelle mock-up with a 3 GPM jet fuel spill into the 75 foot pan was used to simulate a 3-dimensional spill fue onto the flightlime runway.

Some typical tests, which compared pertluorohexane with Halon 1211, showed that in the 75 square foot 3-dimensional fue previously discussed and in separate fues of 250 square foot fuel spills on bare concrete, the fues using pertluorohexane were extinguished in essentially the same time as those using Halon 1211. Slide 11. In all of the cases, however, the use of perfluorohexane required 25-30% more agent to estinguish the same fue. These tests and others run by NMERI and the Tyndall Air Force Base led the U.S. Air Force staff to conclude that the pertluorohexane could extinguish overall average fires at approximately 80% of the efficiency of Halon 1211. Considering all of the desirable characteristics exhibited by CEA-614, the Tyndall staff concluded that PFH was the "agent of choice" when compared to the other proposed clean extinguishing agent replacements for Halon 1211.

In addition to the **U.S.A.F.** testing done by NMERI, testing was also done by the U.S. Navy at the Beaufort, S.C., Marine Corps Air Station. Slide 12. In these tests, 20 pound, hand-held extinguishers and 150 pound wheeled extinguishers made by the Amerex Corp. were used essentially unchanged with CEA-614. In these tests, a pooled fuel fue, an engine nacelle fire, a 3-dimensional spill fue, and a large pit fue were used to evaluate the CEA-614 performance. In all cases JP-8 was the jet fuel used in these evaluations.

The pan spill fire consisted of a 6-foot by 12-foot steel pan with baftles and a 1/4" layer of JP-8 fuel floated on a water base. This fire was extinguished by a professional firefighter, using the agent for the fust time, in 7.2 seconds.

The engine nacelle mock-up fue consisted of 2 sets Of two-55 gallon drums welded together with internal baftles to restrict agent flow from the front 55-gallon drums to the rear 55-gallon drums. A 5-gallon charge of JP-8 jet fuel was placed into each of the 55 gallon sets and allowed to burn for 30 seconds. The fue was extinguished with CEA-614 with a 20 pound, hand-held extinguisher in 2.5 seconds.

The 3-dimensional spill fire set-up consisted of the 72 square foot pan previously discussed for the pool fire with a 55-gallon engine nacelle mock-up positioned above it. JP-8 fuel spilled from the engine mock-up onto *an* inclined step and then into the 72-square foot pool fire. This combination pool and 3-D fire was attacked with a 20-pound, hand-held extinguisher. This fire represents the practical limit of the 20 pound extinguisher and was extinguished with CEA-614 in 16.1 seconds.

The last fue run at the Beaufort Marine Corps Air Station was an 810 square foot pit fire which was attacked with 150 pound wheeled unit. This fire again used JP-8 fuel, 1/4" deep, on a water surface. This fue was the practical limit for the 150 pound wheeled unit with CEA-614 and was extinguished in 22.9 seconds.

The previous fues described for the U.S. military are fire scenarios developed by the Air Force and the Navy to duplicate their fire hazards on the flightline. In the development and approval of portable extinguishers, it will be necessary to demonstrate a performance rating for the portable extinguishers with CEA-614 that matches the Underwriters Laboratory test scenarios. These types of tests, involving heptane fuels indepth and various Class A fuels, have been run in the development programs for portable extinguishers and CEA-614 in the recent months. During these test programs, it has been demonstrated that CEA-614 will have equal or better Class A performance than Halon 1211. Slide 13. This is due to PFH's liquid cooling nature on the Class A materials. This enhancement of Class A performance in a clean extinguishing agent will he of great benefit to those using these extinguishers in a normal industrial computer room or switch gear environment. In addition to Class A performance, CEA-614 has demonstrated approximately 75% of the previously demonstrated effectiveness of Halon 1211 on Class B fues. This combination of enhanced Class A ability and effective Class B fue fighting abilities, makes CEA-614 an excellent candidate to replace Halon 1211 in UL listed and Factory Mutual approved portable applications.

MATERIAL OF COMPATIBILITY

Like all other perfluorocarbons, CEA-614 shows extremely good Compatibility with all common materials of construction in the fire protection industry. No discoloration or degradation of the metal or agent was seen in the 10 day accelerated corrosion studies done with aluminum, stainless steel, carbon steel, copper, brass or electrical soldering materials. Slide 14 In addition to low corrosivity on the metals, CEA-614 does not exhibit the tendency to hydrolyze in the presence of water to form acids which can accelerate corrosion in the various common metals used in the portable extinguisher industry.

CEA-614 **as** with **all** other perfluorocarbon compounds, shows good compatibility with various elastomers. Slide **15.** Materials similar to the PFC compounds, such as fluorinated elastomers, will show some swelling and changes in tensile strength due to the similarities of the materials involved.

Additionally, CEA-614 shows excellent compatibility with most plastic construction materials. Slide 16. Fluorinated plastics are similar in molecular make up to perfluorocarbons and again show volume change and tensile strength change over that normally seen with the air control. The plastics and elastomers were evaluated with exposure times of 6 months at 75°C.

The general recommendations for materials of construction used with CEA-6 14 and portable extinguishers or directional spray nozzle systems are **as** listed **as** follows. Slide 17. For piping, tanks and fittings; stainless steel or carbon steel are the recommended materials of construction. For pipe sealants; PTFE tape, RTV silicone, anaerobic sealants and colloidal copper suspensions are recommended. For hoses, gaskets and O-rings; simple Buna-N or nitrile rubber materials of construction are recommended. Minimal amounts of plastizers should be used in the compounding of the above elastomers. For painted surfaces, epoxy paints are recommended **as** is any good grade of enamel paint. The preparation of the surface and a scratch free condition of the paint coating will, of course, add to the durability of the painted surface.

The above general recommendations are borne out by the fact that a perflurorcarbon much like CEA-614 is used in the Cray *2* computer as a direct contact coolant. **In** the Cray 2 computer, the liquid pertluorocarbon is circulated directly across the computing and power modules of the computer in order to remove approximately 200 kilowatts of power continuously from the operating computer. The wide variety of materials of construction in this **$18** million dollar computing system are protected by the excellent materials compatibility of the perfluorocarbon liquid used.

TOXICOLOGICAL PROPERTIES

CEA-614 is rated as practically non-toxic in **all** toxicity testing done to date. Slide 18. The highly stable chemical nature of CEA-614 and its essentially inert compatibility with biological systems has shown it to he an extremely desirable agent from the standpoint of toxicology.

Toxicity testing to date has shown that the CEA-614 **is** practically non-toxic when taken orally at acute dosages greater than 5 grams per kilogram of body weight of the subject rats. Acute inhalation studies have shown that CEA-614 shows no deaths or adverse effects over a 1 hour period up to 300,000 parts per million concentration. Mutagenicity tests using the Ames protocol have shown CEA-614 to be non-mutagenic. 90 day inhalation tests have shown no observed adverse effects up to the level of 50,000 parts per million. Cardiac sensitization tests with dogs have shown no potential for cardiac sensitization up to the saturation level of 17% per volume in air with CEA-6 14. These studies and others have shown that perfluorocarbons in general and CEA-614 in particular are practically non-toxic.

In addition to the toxicity of clean extinguishing agent candidates, another characteristic of interest is the thermal decomposition products produced when the agent comes in contact with the flame front. In the case of CEA-614, the main decomposition product is HF or hydrogen fluoride. It can he stated in general terms that the thermal decomposition products of perfluorocarbons are generally lower than any other clean, physically acting,

extinguishing agent candidate. This is due to the high bond strength of the carbon-fluorine bond which is the only bond in the pertluorocarbon's makeup. It has been demonstrated in total flooding applications, the perfluorocarbon perfluorobutane, (CEA-410) has shown lower overall decomposition products than those generated by typical HFCs, HCFCs or blended type clean extinguishing agent candidates.

In addition to the total flooding experimentation on thermal decomposition products, a thermal decomposition study was run for the U.S. Air Force comparing perfluorohexane to Halon 1211 and other candidate streaming agents. Using the typical 75-square foot, 3-D running fuel fire scenario, the U.S. Air Force collected data on the thermal decomposition products under actual fire extinguishing conditions. This study concluded that the PFH demonstrated the lowest total acid gas generation of any of the agents tested. Slide 19. In the case of Halon 1211, 260 parts per million average total acid gases were generated while 120 parts per million average total acid gases were produced with PFH.

ENVIRONMENTAL

The environmental characteristics of any clean extinguishing agent are exhibited within the fust three zones of the earth's atmosphere. The first zone is the troposphere in which VOC characteristics are a concern. The next zone is the stratosphere where the ozone depletion potential becomes an important characteristic of the agent. Lastly is the mesosphere in which products possessing long atmospheric lifetimes become a factor. Perfluorocarbons are stable molecules that do not react or degrade in the troposphere or the stratosphere, therefore they are not listed as volatile organic compounds and are exempt from Federal VOC regulations. Slide 20. Additionally, 3M's CEAs are not ozone depleting chemicals, as they do not possess either chlorine, bromine or iodine in their structure. Because of this, CEA-614 has a zero ozone depleting potential.

As has been pointed out previously, CEA-614 has exceptional molecular stability. This exceptional molecular stability leads to its safe, non-toxic, chemically stable and compatible nature. However, it also leads to a long atmospheric lifetime. PFC's do not degrade until they have had time to diffuse into the mesosphere. This results from their long atmospheric lifetime, which is reflected in the global warming potential of the molecule. However, a calculated global warming potential does not equate to the global warming concern of atmospheric scientists. Slide 21. The concern is a change in atmospheric temperature. Global warming potential does not equal atmospheric temperature change. Atmospheric temperature change however, is related to the global warming potential and the quantity of the product emitted into the atmosphere. It has been concluded by many prominent atmospheric scientists and organizations that, under no reasonable emission scenario can CEA-614 reach the level of emissions that will contribute to significant changes in the atmospheric temperature.

Therefore, it has been concluded by the U.S. Environmental Protection Agency that the principal environmental characteristic of concern for perfluorocarbon products is that of long atmospheric lifetime. Long atmospheric lifetime results in the potential for high global warming. However, the actual contribution to global warming depends on the quantities of pertluorocarbons emitted.

Therefore, for the replacement of Halon 1211 and in some cases Halon 1301, the EPA has approved the use of CEA-614 in applications requiring the high level of safety or performance which make other alternatives unacceptable due to the physical or chemical properties of CEA-614 or where exposure of the other alternative agent may approach its toxic limits or result in other unacceptable health effects.

APPROVALS AND LISTINGS

At the present time, there are no completed Underwriters Laboratory listings or Factory Mutual approvals for CEA-614 in portable or local application systems. The test work for these listings and approvals is underway at the present time and listings and/or approvals are expected by the end of this year.

MANUFACTURINC

CEA-614 is produced in existing production facilities in at least two locations in the world. Slide **22.** Testing and commercial quantities are now available for the CEA-614 product and adequate capacity exists in 3M facilities to meet **the** future market needs for CEA-614.

SUMMARY

In summary, it can **be** stated that due to the CEA-614's unique physical properties, **fire** performance, toxicological characteristics, materials compatibility, ease of handling and recovery, low thermal decomposition values, and its environmental acceptability; CEA-614 warrants serious consideration **as** a streaming and local application replacement for Halon 1211. Slide **23.**

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Replacement Applications

Total Flooding -
Halon 1301 ----> Perfluorobutane

Streaming -
Halon 1211 ----> Perfluorohexane

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Perfluorocarbons

3M has manufactured PFC's for over forty years -
PFC's are used In the electronics industry for:
- Electronic Reliability Testing
- Vapor Phase Soldering
- Direct Contact Cooling and Heating
- CFC Alternatives
- Halon Replacements

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Perfluorocarbon Properties

Colorless. Odorless	**Non-conductive**
Chemically Inert	Low Viscosity
Non-corrosive	Leaves No Residue
Materials Compatible	Non-flammable
Essentially non-toxic	Non-VOC
Low Surface Tension	Non-ozone Depleting
Low Heat of Vaporization	**35 Year Use History**

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Clean Agent Requirements

Effective In Extinguishing Fires
Equipment Compatibility
Non -Toric (People Compatibility)
Environmentally Acceptable
Cost Effective
Available In Quantity

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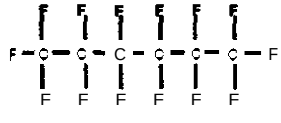
Streaming Agent: Perfluorohexane



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Physical Properties Halon 1211 & Perfluorohexane

	Halon 1211	Perfluoro-Hexane
Molecular Weight	165.4	338
Boiling Point (°C)	-4	56
Vapor Pressure @ 25°C (bar)	2.76	0.31
Liquid Density @ 25°C (kg/l)	1.567	1.517

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Effective in Extinguishing Fires

PERFLUOROCARBONS	HALONS
90 % Physical (cooling)	90 % Chemical (Radical)
Remove heat by vaporization (liquid)	Halon -1301, Br-
	Halon -1211, Br-, Cl-
Remove heat by decomposition	
Increase room heat capacity	
10 % Chemical	10 % Physical

Physical agents are generally less effective than Halons.

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Perfluorohexane as Replacement for Halon 1211

'Testing Completed by USAF

* NAW / Marine Verification
  (Primary Application Aircraft Flight Lines)
* Preliminary UL and FM Testing Completed

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USAF Halon Replacement Program

Perfluorohexane was tested at NMERI and Tyndall AFB as a replacement for Halon 1211 in;

- 150 lb. flightline extinguishers
- 20 lb. portable extinguishers
- Critical facility portable extinguishers

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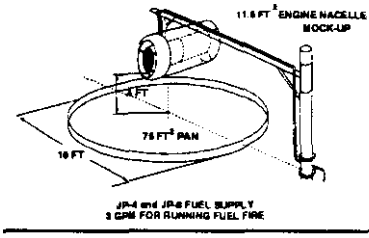
3-D Running Fuel Test Apparatus



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Halon 1211 vs. PF-Hexane Typical Performance by USAF

Agent	Fire Size (Sq. ft.)	Extinguishing Time (sec.)	Agent Used (pounds)	Flow Rate (lb/sec)
PF-H	75 -3D	2.6	28	9.7
H-1211	75 -3D	2.4	20.3	8.4
PF-H	~250*	6	38	6.3
H-1211	~250*	6	30	5

Tests with JP-4 (jet fuel) using a 150 lb wheeled extinguisher .
* On bare concrete

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Typical Perfluorohexane Performance at Beaufort MCAS

Extinguisher Size	Fire Size(sq ft)	Exting. Time (sec)	Average Flow Rate (lb./sec)
20# handheld	72(w/ baffles)	7.2	1.30
20# handheld	Engine Nacelle	2.5	1.64
20# handheld	72(3D running)	16.1	1.19
150# wheeled	B10 pit	22.9	4.80

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Streaming Agent Performance Comparisons, UL Type A & B

CEA-614 Will Have Equal Or Better Class "A" Performance Than Halon 1211

CEA-614 Will Be Approximately 75 % As Effective As Halon 1211 On Class "B" Fires

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CEA-614 Compatibility Various Metals

Metal	10 Day Min. Agent Exp.
Aluminum	No Discoloration or degradation of metal or agent
Magnesium	
Stainless Steel	
Carbon Steel	
Beryllium Copper	
Brass	
Solder	

CEA-614 Does Not Hydrolyze To Form Acids Which Accelerate Corrosion.

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PFC Compatibility With Various Elastomers

		Typical Exposure, 6 mo. @ 75 C			
		Butyl	Chloroprene	Fluorinated	Silicone
Property	Medium				
% Δ Tensil Strength	Air	-28	-11	+1	0
	PFC	-38	-15	-20	6
Δ Shore A Hardness	Air	+3	-3	-3	+3
	PFC	+3	-3	-3	+6
% Δ Volume	Air	-1.2	-0.8	-0.7	–
	PFC	-0.3	-1.0	+0.4	–

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PFC Compatibility With Various Plastics

		Typical Exposure, 6 mo. @ 75 C			
		PP	Nylon	PCTFE	PTFE
Property	Medium				
% Δ Tensil Strength	Air	Brittle	–	-12	-4
	PFC	Brittle	-1	-12	-20
ΔShore D Hardness	Air	0	+3	+2	0
	PFC	0	+3	+2	0
% Δ Volume	Air	+9.1	.a*	+1.1	.If
	PFC	+11.4	+9.2	+1.1	+3.0

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Materials of Construction General Recommendations

Piping, Tanks, Fittings	304 Stainless Steel Carbon Steel
Sealants	PTFE Tape RTV Silicone Anaerobics Colloidal Copper
Hose, Gaskets, O-rings	Buna N (Minimize Plasticizers)
Paint	Epoxy

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Toxicity Testing CEA-614 (Perfluorohexane)

Toxicity Test	Test Results
Acute Oral	Practically Non-toxic >5 g / kg Rat
Acute Inhalation (Rats)	1 hr LC50 >300,000 PPM
Mutagenicity (Ames)	Not Mutagenic
90 Day Inhalation (Rats)	No Observed Adverse Effects, >30,000 PPM
Cardiac Sensitization (Dogs)	No Potential For Sensitization Up To Saturation, >17 % v/v In Air

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Thermal Decomposition Results*

Agent	Total Acid Gases
CEA-614	120 PPM
Halon 1211	260 PPM

* USAF typical 3D running fuel fire scenario
(75 ft2 pit with 3 GPM running fuel spill)

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Environmentally Acceptable

Perfluorocarbons are exempt from Federal Volatile Organic Compound (VOC) regulations.

Perfluorocarbons are not Ozone Depleting Chemicals (ODC's)

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Environmental Effect

Effect = Change in Temperature

GPW ≠ Change in Temperature

Change in Temperature = GWP X Quantity

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Manufacturing Capabilities

Production facilities existing.

Commercial quantities available now.

Adequate capacity *for* future market needs.

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Perfluorohexane For Streaming Applications Summary

Due To Perfluorohexane's Exceptional
- -Physical Properties
- -Fire Performance
- -Toxicological Characteristics
- -Compatibility
- -Handling / Recovery Ease
- -Thermal Decomposition Values

And Its Environmental Acceptability;

Perfluorohexane Warrants Serious Consideration As The Streaming And Local Application Replacement Agent for Halon 1211

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