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Fire Extinguishing Agents: Sort and Comparison

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Abstract: ***With the advancement in technology, industrial operations and processes are becoming more and more complex and hazardous day by day. The major threat for industries now a days is fire and fire hazards. Water is no longer capable to extinguish all classes of fire. Water is not a clean agent, it leaves residue after its function. It cannot be used with costly equipment and with class C fire hazards. Hence new and improved extinguishing agents are developing day by day. According to National Fire Protection Association, these new agents are termed as "Clean Agents". These new agents are much more effective and capable of extinguishing fire in its initial stages with very less concentration of agents in comparison to water. Many agents are invented for example Argon Gas, Nitrogen Gas etc. but with new technology various new agents are being invented till today, for example Novec 1230. Earlier halons are used with most of the fixed fire fighting systems but because of its high Ozone Depleting Potential (ODP) and Global Warming Potential (GWP), halons are banned for general applications. Halons were most effective in extinguishing fire than any other agent till date. Various halons replacements are invented but no ideal halon replacement is found till date. So there is need to compare various agents available in market on various properties like ODP, GWP, atmospheric lifetime, design concentration etc. and hence to determine the best agent.***
Keywords: Argon, Argonite, Carbon Dioxide, Clean Agents, FE-13, FM-200, Halons, Nitrogen, Novec-1230 etc.

I. INTRODUCTION

As per NFPA classification of fire, there are five classes of fire, Class A: Fire involving combustible hydrocarbons, Class B: Fire involving combustible and flammable liquids and gases, Class C: Fire involving electrical equipment, Class D: Fire involving metals and Class K: Kitchen fire as in [3]. Water is most commonly used fire extinguishing agent but now a days fire are becoming more and more complex which require special extinguishing agents, known as "Clean Agents" as in [50]. Halons were most commonly used for extinguishing almost any class of fire but because of its environmental impact, it was banned for general application by Montreal Protocol, 1987.

These clean agents are governed by NFPA 2001as in [48]. Water is not a clean agent. It cannot be used with costly equipment and against Class C fire. Hence clean agents are invented and developed as in [28]. Now a days various clean agent are available in market like: FE-13, FE-25, FE-36, FM-200, and Novec-1230 etc [11]. The problem is with so many agents available in market, it is very difficult to find the desired extinguishing agent. This paper contains comparison of various clean agents available in market based on various properties like: ODP, GWP, Atmospheric life time, SNAP, NOAEL and LOAEL etc. This paper helps to determine the desired extinguishing agent. This paper also contains the study of halon replacements and fire extinguishing process of clean agents, their advantages and disadvantages

II. THEORY

Gaseous fire suppression is a term which is used to describe the use of inert gases and chemical agents to extinguish a fire. It is also known as Clean Agent Fire Suppression as in [26]. These agents are governed by the NFPA 2001: Standard for Clean Agent Fire Extinguishing Systems.

A. Agents Used for Total Flooding

1) Halon 1301 ($CBrF_3$)
2) Argon Gas (IG-01)
3) Nitrogen Gas (IG-100)
4) Argonite Gas (IG-55)
5) Carbon Dioxide (CO_2)
6) Inergen (IG-541)
7) FE-13 (HFC-23, CHF_3)
8) FM-200 (HFC-227ea, CF_3CHFCF_3)
9) Novec 1230 (FK-5-1-12, $CF_3CF_2C(O)CF(CF_3)_2$)

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B. Agents Used for Local Application

1) Halon 1211 ($CBrClF_2$)
2) Argon Gas (IG-01)
3) Nitrogen Gas (IG-100)
4) Argonite Gas (IG-55)
5) Carbon Dioxide (CO_2)
6) Inergen (IG-541)
7) FE-25 (HFC-125, C_2HF_2)
8) FE-36 (HFC-236fa, C_3H2F_6)

C. Halon 1301

Halon is such halogenated hydrocarbon which was used widely as an extinguishing agent for a Class A, Class B and Class C Fire. It has low toxicity and great effectiveness as a flame inhibiter and explosion suppressant.it is considered as a clean agent which does not wet or leave residual material as in [29].

1) *Molecular Formula:* $CBrF_3$
2) *Molecular* Weight: 148.9 u
3) *Point:* -57.750 C
4) *Critical Temperature*: 66.9^o C
5) *Critical Pressure:* 39.56 barHalon 1301 as a Clean Agent:

Halon is a chemical compound of carbon, fluorine, and bromine. It is a pure compound and not a mixture of chemicals as in [24]. It is able to penetrate hard-to-reach places that may not be possible in case of other gaseous fire extinguishing agents. The exact process by which Halon extinguishes fire is not clearly understood, but it is generally through to be a chemical chain reaction rather than a physical effect. It perhaps interacts with the chemical chain required to support combustion and stops the fire quickly without leaving any residue. However, it will not extinguish fire involving burning metals, metal hydrides or materials that contain their own oxygen from fixed systems.

D. Of Halons as Fire Extinguishing Agent:

1) It is colorless, and electrically non-conductive, non-corrosive, non-abrasive liquefied gas which leaves no residual effect.
2) It can be stored indefinitely in metal container and requires, very less space for storage.
3) Halon leaves no mass; hence it is the ideal protection for delicate equipment.
4) It does not impair visibility and thus no movement hazard.
5) Safe in presence of electricity.
6) It does not impair visibility and thus no movement hazard.
7) Halon-system is a very simple process for installation and it does not require any associated times like piping, number of nozzles, stands etc.
8) 9. No clean up and salvage operations after fire.
9) By virtue of its lower toxicity, higher volatility and lower molecular weight, halon offers particular advantages for total flooding system.

E. Disadvantages of Halons as Fire Extinguishing Agent

1) Concentrations above 10 % are hazardous to life, so cannot be used for deep-seated fires.
2) Recharging costs are expensive.
3) Its GWP (Global Warming Potential) is 6900.
4) Its ODP (Ozone Depletion Potential) is 12.
5) Its atmospheric life time is 65 years.
6) Halon decomposition at approximately 482.20C. The products of decomposition are hydrogen fluoride and hydrogen bromide with small quantities of other chemical. So when fire reaches its flame stage Halon may create problems to persons entrapped
7) It is effective on two main classes of fire Class A, Class B but not on Class C.

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III. HALON 1211

Bromochlorodifluoro methane, also known by the trade name Halon 1211, or Halon 1211 BCF, or Freon12B1, is a halo alkane [29]. It is widely used in the maritime industries in the engine rooms of ships and also in the transport industry in vehicles as in [44]. Its efficiency as a fire extinguishing agent has also led it to be the predominant choice of fire extinguishing agent on commercial aircraft and is typically found in cylindrical hand-held canisters.

1) *Chemical Name*: Bromochlorodifluoro methane
2) *Chemical Formula:* $CBrClF_2$
3) *Point:* -3.7^o C
4) *Pressure:* 275.98 kPa Advantages of Halon 1211 as Fire Extinguishing Agent
5) It has lower toxicity than chemicals such as carbon tetrachloride.
6) 3. Halon 1211 does not act as carcinogen.
7) Halon 1211 has no known eco-toxicological effects.

IV. ARGON

Argon is a chemical element with symbol Ar and atomic number 18. It is in group 18 of the periodic table and is an inert gas. Argon exists as colorless gas exhibiting a lilac/violet glow when placed in a high voltage electric field as in [7].

A. Symbol: Ar
B. Atomic Number: 18
C. Boiling Point: -302.5°F (-185.8°C)
D. Melting Point: -308.8°F (-189.4°C)
E. Atomic Mass: 39.948 ± 0.001 u
F. Critical Temperature: -122.4^o C
G. Critical Pressure: 48.98 bar Argon as a Clean Agent:

Argon properties as a gas are relevant to the extinguishing process. It is more suitable for extinguishing systems than N2 as in [2]. In an emergency, the flooding area is filled quickly and evenly by the gaseous extinguishing agent, thus providing a total flooding effect. The conc. will be sufficient for extinguishing purposes when the O2 level of the air in the room is reduced from its normal level of 20.9 % by volume to less than 15 % by volume. In order to achieve that, about 1/3 of the volume of air in the room must be replaced by the Argon, so that a conc. of greater than 34 % by volume is established.

H. Advantages of Argon as Fire Extinguishing Agent:

1) Argon is a non-toxic and will not decompose in a real fire situation. It will not add to chemical reactions and so will neither contribute to the formation of toxic nor corrosive breakdown products
2) 2. Argon remains stable even in high-temperature environment, which makes it suitable to be used against oil & gas fires, E.g. In gas turbine stations.
3) Argon has zero Ozone Depletion Potential.
4) Argon has zero GWP (Global Warming Potential).

I. Disadvantages of Argon as Fire Extinguishing Agent

1) Ar is not as effective as halons thus cannot be used as halons replacement
2) 2. Ar hold time in an enclosure is very less.
3) Ar fire suppression system requires heavy steel cylinders and pipes.
4) Unlike other gaseous extinguishing agents which suppress fire by displacing oxygen as well as cooling, Ar has low cooling potential.
5) Ar requires more storage area as it cannot be liquefied easily.

V. NITROGEN

Nitrogen is a chemical element with symbol N and atomic number 7. At room temperature, it is a transparent, odorless diatomic gas (N2) as in [47].

A. Symbol: N
B. Atomic Number: 7

C. Boiling Point: -320.4° F (-195.8° C)
D. Melting Point: -346° F (-210° C)
E. Atomic Mass: 14.0067 ± 0.0001 u
F. Critical Temperature: -147^{o} C
G. Critical Pressure: 33.95 bar
Nitrogen works, like CO_2, by displacing the atmospheric oxygen. The extinguishing effect here is purely physical in nature, namely the suffocating effect which occurs when O2 is reduced below the specific level required for combustion of a specific material.

H. Nitrogen as a Clean Agent
Under Montreal Protocol, halons are banned. Hence, total flooding fire suppression systems containing nitrogen gas as the agent is developed and used as in [33]. The nitrogen gas is both the fire suppression agent and the cylinder pressurization agent. These systems are designed to replace Halon 1301 total-flood systems in a variety of applications as in [27]. Moreover, Nitrogen gas is not a global warming gas, thus, it does not have a GWP. It is not an ozone depleting compound either as in [12]. There are no byproducts of degradation resulting from the use, processing, manufacture, or disposal of nitrogen gas. When the agent is discharged in a fire situation the conc. of CO_2 and CO will increase.

I. Advantages of Nitrogen as Fire Extinguishing Agent:
Provides 24×7 round the clock protection, in the event of a fire outbreak, the Nitrogen Gas will be discharged by the fire suppression system and can extinguish fire in early stage of development also in a very short duration of time.
N_2 gas can extinguish fire at life supporting O_2 concentrations and can be used for wide range of applications.
No by products like no decomposition of halogen acid products.
N_2 can itself act as a pressuring agent i.e. no other agent is needed for pressurizing the extinguishing agent stored in the cylinder.
Nitrogen gas is by far the cheapest inert gas, it is listed as IG-100 in the International Standard Organization (ISO).
Some gaseous agents used by other fire suppression systems are toxic to the human body for example CO2, FM-200 etc. N_2 gas is nontoxic to human body, in fact N_2 is present in normal atmosphere generally 78 % by volume in air.
N_2 gas does not harm the environment; N_2 has Zero ODP and GWP.

J. Disadvantages of Nitrogen as Fire Extinguishing Agent
1) N_2 is not as effective as Halons thus cannot be used as Halons replacement.
2) N_2 hold time in an enclosure is very less.
3) N_2 fire suppression system requires heavy steel cylinders and pipes.
4) Unlike other gaseous extinguishing agents which suppress fire by displacing oxygen as well as cooling, N_2 has low cooling potential.
5) N_2 requires more storage area as it cannot be liquefied easily.

VI. ARGONITE

Argonite is a mixture of 50% pure Nitrogen and 50% pure Argon as in [43]. Argonite contains only naturally occurring substances, and as such, has no ozone depletion potential and no direct global warming potential.

A. Critical Temperature: -134.7^{o} C
B. Critical Pressure: 41.3 bar
Argonite extinguishes by means of reducing the oxygen content within a room to the point at which fire can no longer burn, but without compromising the safety of individuals present as in [30]. Most Argonite systems are designed to extinguish fires with a minimum agent concentration of 37.9 % achieved within one minute. This reduces the oxygen concentration in the air from the normal 21 % level to below the 15 % level needed to support combustion as in [11].

C. Argonite as a Clean Agent:
Argonite extinguishes by means of reducing the oxygen content within a room to the point at which fire can no longer burn, but without compromising the safety of individuals present. There are no toxicological factors associated with the use of Argonite. Argonite will not decompose or produce any by-products when exposed to a flame from a fire condition as in [2]. Most Argonite systems are designed to extinguish fires with a minimum agent concentration of 37.9 % achieved within one minute. This reduces

the oxygen concentration in the air from the normal 21 % level to below the 15 % level needed to support combustion. Argonite is stored as a gas within the cylinder assembly. It is available at a storage pressure of 2900 PSI (200bar).

D. Advantages of Argonite as Fire Extinguishing Agent

1) It is inert Gas Clean Agent Fire Suppression.
2) There are no toxicological factors associated with the use of Argonite.
3) Argonite will not decompose or produce any by-products when exposed to a flame from a fire condition.
4) It is safe for Personnel and Equipment.
5) It is Environmentally Friendly.
6) Its Ozone Depletion Potential (ODP) is zero.
7) Its Global Warming Potential (GWP) is zero.
8) Argonite has much larger hold time in an enclosure compared to Ar and N_2.

VII. CARBON DIOXIDE

Carbon dioxide is a colorless, odorless gas which is vital to life on Earth. This naturally occurring chemical compound is composed of a carbon atom covalently double bonded to two oxygen atoms as in [22]. It is non-combustible, it does not react with most substances and it provides its own pressure for discharge from the storage container. It leaves no residue. As a gas or as a finely divided solid called snow or dry ice, it will not conduct electricity as in [22]. When liquid CO_2 is discharged to atmospheric pressure, a portion instantly flashes to vapor while the remainder is cooled by evaporation and converted to finely divided snow or dry ice depending on the temperature of stored liquid.

A. Carbon Dioxide as a Clean Agent

Because CO_2 is denser than air (1.5 times) and will not support combustion, it has become one of the most significant methods of suppressing and fighting electrical and grease fires. In addition, the application of CO_2 in firefighting is clean, non-toxic and leaves no residue as in [43]. It can be stored for long period and it is easily available. It is very effective in enclosed areas. It can penetrate into places that cannot be reached by other means. But CO_2 is asphyxiating and cannot be detected by smell or color. About 9 % concentration causes unconsciousness as in [35]. Any compartment or enclosure where CO_2 system is installed should be properly vented to give path for escape of increased pressure in compartment or enclosure also compartment or enclosure should be fully ventilated before entering without breathing apparatus. CO_2 also has GWP as 1 for 100 years.

B. Advantages of CO_2 as Fire Extinguishing Agent

1) CO_2 is safe and clean agent in most cases, CO_2 is noncorrosive and does not leave a residue.
2) CO_2 is not harmful to most substances with exception of certain combustible metals, it is safe to use and will not react when applied.
3) CO_2 can easily penetrate to inaccessible areas, it has the ability to penetrate deep into areas which are not easily accessed by firefighters.
4) CO_2 is nonconductor of electricity; CO_2 is suitable for use on fires where electrical systems may still be under power.
5) CO_2 is heavier than air, CO_2 is 1.5 times denser than air and on discharge it will remain at low level where it will displace oxygen, useful when dealing with large surface area fires.
6) Unlike Halons, CO_2 does not thermally decompose and give off harmful products.

C. Disadvantages of CO_2 as Fire Extinguishing Agent

1) Insufficient concentration (7 %), CO_2 can be act as an asphyxiant.
2) CO_2 is easily dispersed by wind thus it is not very much effective against fires in open areas or in areas with strong wing currents.
3) CO_2 has a GWP of 1.
4) To store CO_2 as a liquid, it must be pressurized to over 50 bars, hence storage containers are relatively large and heavy.
5) Because of the discharge characteristics of CO_2, it tends to be noisy when being discharged which may surprise nearby persons.
6) CO_2 impaired visibility as it is discharged from container as a dense white cloud.
7) The application of CO_2 must continue until the fire is fully extinguished.

VIII. INERGEN

Inergen gas is a unique mixture of three gases. No other inert gas has the unique ability to rapidly extinguish a fire as well as provide a safe environment for any person within the occupied due to low oxygen levels.

A. Inergen Composition

1) Argon (Ar, 47 %),
2) Nitrogen (N2, 42.5 %) &
3) Carbon Dioxide (CO_2, 10.5 %)

Inergen is a natural gas mixture, not a synthetic gas thus, it has all the properties of the constituent gases. Once discharged, the constituent gases returns to their natural form in atmosphere. It is heavier than air and can cause suffocation of fire by reducing oxygen level. Inergen does not undergo a reaction with a fire to create extremely harmful toxic or corrosive by products as in [49]. It poses no ozone depletion or global warming threat. Inergen gas mixture extinguishes a fire by reducing the oxygen level below 15 %, (1999) the point at which most combustibles will no longer burn.

B. Advantages of Inergen as Fire Extinguishing Agent

1) Inergen has a unique composition, by the addition of a small amount of Carbon Dioxide (2-5%), the dangerous effect of low Oxygen is countered.
2) Inergen has no toxic decomposition thus provides effective damage control.
3) During Inergen discharge escape route remain visible and clear.
4) Inergen provides an atmosphere that will sustain full consciousness and ability to think and respond normally, even in case of extremely low Oxygen.
5) Inergen maintains its effect for a long time and can provide fully 3-dimensional flooding protection within any enclosure.

B. Disadvantages of Inergen as Fire Extinguishing Agent

1) Certain oxidizing materials may not be extinguished by Inergen.
2) Certain combustible metals may not be extinguished efficiently by Inergen, they may reignite.
3) The enclosure need to be completely air tight, only minor leaks are accepted.
4) Major changes to the enclosure, protected by Inergen, affecting the enclosure volume may require modifications to the Inergen installation.
5) Inergen has a GWP of 1 due to presence of CO_2 in its composition.

IX. FE-13

FE-13, also known as Hydrofluorocarbon (HFC) 23, is an ideal clean agent for total flooding applications where there is a high ceiling or a large space as in [37]. The vapor density of FE-13 is lower than other halocarbons. This high pressure and low vapor density allows it to mix throughout the enclosure quicker and stay mixed longer.

A. Chemical Name**:** Trifluoromethane
B. Chemical Formula: CHF_3
C. Molecular Weight: 70.02 g per mole
D. Density: 0.6799 g per cm^3
E. Boiling Point: - 82^oC
F. Critical Temperature: 25.9^o C
G. Critical Pressure: 48.36 bar

FE-13 is an ideal clean agent for the total flooding applications where people occupy the protected space during discharge of the agent and for Class B fire hazards. Class B fire hazards may involve hard to extinguish fuels like methanol, as well as spaces where the volume will vary with contents as in [17]. Examples are: Oil rig platforms, Flammable liquid processing areas, Railroad locomotives, and Surface mining equipment etc. Upon discharge the FE-13 is discharged as a gas through the nozzles to a predetermined concentration, usually within 10 seconds. FE-13 extinguishes the fire through a cooling affect at the molecular level. The agent cools the combustion process, thereby, extinguishing the fireas in [21].

H. FE-13 as a Clean Agent

FE-13 is an ideal clean agent for the total flooding applications where people occupy the protected space during discharge of the agent and for Class B fire hazards as in [23]. Class B fire hazards may involve hard to extinguish fuels like methanol, as well as spaces where the volume will vary with contents. Examples are: Oil rig platforms, Flammable liquid processing areas, Railroad locomotives, and Surface mining equipment etc.

FE-13 has zero ODP i.e. Ozone Depletion Potential but it has a GWP i.e. Global Warming Potential of 11700 measured for 100 years as in [45]. Even though the toxicity of this clean agent is low, precautions should always be made to limit the exposure. Upon discharge the FE-13 is discharged as a gas through the nozzles to a predetermined concentration, usually within 10 seconds. FE-13 extinguishes the fire through a cooling affect at the molecular level. The agent cools the combustion process, thereby, extinguishing the fire.

I. Advantages of FE-13 as Fire Extinguishing Agent:

1) It is low in toxicity, low reactivity and its density.
2) 3. It will not burn.

J. Disadvantages of FE-13 as Fire Extinguishing Agent

1) *It is a greenhouse gas.*
2) It has a high global warming potential.
3) Its atmospheric lifetime is 270 years.
4) Causes nervous system depression.

X. FE-25

FE-25, pentafloroethane or HFC-125 is a safe, clean, electrically non-conductive agent that is used to protect people and high value assets. FE-25 has the closest physical property match to Halon 1301in terms of both flow characteristics and vapor pressure as in [4]. The minimum extinguishing concentration (MEC) of FE-25 is 6.7% for class A fire. For Class B fire, the MEC is 8.7%.

A. Chemical Name: Pentafloroethane
B. Chemical Formula: CF_3CHF_2
C. Molecular Weight: 120.02 g per mole
D. Boiling Point: -48.3^o C
*E. Critical Temperature***:** 66.3^o C

F. Advantages of FE-25 as Fire Extinguishing Agent

1) FE-25 shows no decomposition at 150^{o}C in the presence of eight commonly used metals for one- month exposure test.
2) It is available in tank trucks, ton trucks and cylinders.
3) 4. It is non-toxic.

G. Disadvantages of FE-25 as Fire Extinguishing Agent:

1) The GWP of FE-25 is 2800.
2) In comparison to Halon, more concentration of FE-25 is required to suppress the fire.

XI. FE-36

FE-36 is a new fire extinguishing agent replacing Halon 1211 in streaming applications. FE-36 is electrically, non-conductive, non-corrosive, free of residue and has zero ODP as in [36].

A. Chemical Formula: 1, 1, 1, 3, 3, 3-hexafloropropane
B. Molecular Weight: 152 g per mole
C. Boiling Point: -1.4^o C

D. Advantages of FE-36 as Fire Extinguishing Agent

1) It is available in tank trucks, ton trucks and cylinders.
2) The ODP is zero.

3) It is non-toxic.

E. Disadvantages of FE-36 as Fire Extinguishing Agent:

1) Its GWP is 6300.
2) The atmospheric life time is 209 years.

XII. FM-200

FM-200, also called Heptafluoropropane or HFC-227, is a colorless, odorless gaseous halocarbon commonly used as a gaseous fire suppression agent as in [6].

A. IUPAC Name: 1, 1, 1, 2, 3, 3, 3 – Heptafluoropropane
*B. Chemical Formula***:** C3HF7
C. Density: 1.46 g per cm³
D. Melting Point: -131° C
E. Boiling Point: -16.4° C (thus, a gas at room temperature)
F. Molar Mass: 170.03 g per mole
G. Soluble in: Water
H. Critical Temperature: 101.7° C
I. Critical Pressure: 28.7 bar

FM-200 is a waterless fire protection system. It is discharged into the risk within 10 seconds and suppresses the fire immediately as in [46]. FM-200 does not reduce oxygen concentration from hazard or risk. FM-200 is a synthetic chemical fire suppression gas and extinguishes a fire by removing the free radicals or heat elements from the fire triangle (Oxygen, Heat and Fuel).

J. FM-200 as a Clean Agent:

FM-200 is a waterless fire protection system. It is discharged into the risk within 10 seconds and suppresses the fire immediately as in [10]. FM-200 does not reduce oxygen concentration from hazard or risk. The normal concentration of FM-200 gas is between 7.9% to 8.5%. The main advantage of FM-200 is that a small amount of agent is required to suppress a fire. Thus, it requires less space for cylinders storage. FM-200 can extinguishing fire in 10 seconds or less which means less damage, lower repair costs.

K. Advantages of FM-200 as Fire Extinguishing Agent:

1) Falls in the category of clean agent and is governed by NFPA-2001.
2) NOAEL level for cardiac sensitization is 9 % (United States Environment Protection Agency allows concentration of 9 % volume in occupied spaces without any mandate time).
3) First non-ozone depletion replacement for Halon 1301
4) It will not burn.

L. Disadvantages of FM-200 as Fire Extinguishing Agent:

1) Decompose at high temperature and produce hydrogen fluoride.
2) Expose would cause irritation
3) Normally stable, but can become unstable at elevated temperature and pressure.

XIII. NOVEC 1230

Novec 1230 agent is a next-generation halon alternative which provides outstanding performance, large margin of safety, and an excellent environmental profile as in [20]. Novec has zero ODP i.e. ozone depletion potential and a GWP i.e. global warming potential of 1. Once discharged, it has an atmospheric lifetime of 5 days.

A. Chemical Name: Dodecafluoro-2- methylpentan-3-one
B. Chemical Formula: $C_6F_{12}O$
C. Molecular Weight: 316.04 g per mole
D. Boiling Point: 49.2° C
E. Density: 1.72 g per cm^3
F. Critical Temperature: 168.7° C
G. Critical Pressure: 18.65 bar

Novec is applied as a gas, but is liquid at room temperature. It is electrically non-conducting in both the liquid and gaseous state. Novec evaporation rate is 50 times faster than water. Like other Halon alternatives, Novec 1230 extinguishes fire principally by removing heat from the fire triangle as in [8]. Upon discharge, Novec creates a gaseous mixture with air. This agent and air mixture has a heat capacity much larger than that of air alone. A higher heat capacity means that this gas mixture will absorb more heat energy for each degree of temperature change it experiences.

XIV. CONCLUSION

Table 1
Comparison of etinguishing agents based on different parameters

Parameters\Agents	Halon 1301	Halon 1211	Argon	Nitrogen	Argonite	CO_2	Inergen	FE-13	FE-25	FE-36	FM-200	Novec 1230
Safe For Humans	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes below 1000 ppm	Yes
Non Corrosive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Toxic By Products	Yes	Yes	None	None	None	None	None	Yes	Yes	Yes	None	None
Discharge Time (sec)	60	60	60	60	60	Till fire extinguishes	60	10	10	10	10	10
Banned	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Fire Class A [a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fire Class B [a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fire Class C [a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total Flooding	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Local Application	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No
Range	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Very Large	Medium	Medium	Medium	Medium
Extinguishing Method	By Breaking Chain Reaction	By Breaking Chain Reaction	Oxygen Displacement	Oxygen Displacement	Oxygen Displacement	Oxygen Displacement & Cooling	Oxygen Displacement	Cooling	Cooling	Cooling	Cooling & Breaking Chain Reaction	Cooling
Alternative To Halons	-	-	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Storage Space Required	Low	Low	Medium	Medium	Medium	Low	Medium	Low	Low	Low	Least	Low
ODP [b]	12	3	0	0	0	0	0	0	0	0	0	0
GWP [c]	7140	1890	0	0	0	1	1	3400	2800	6800	3500	1

Atmospheric Lifetime (Years)	65	11	-	-	-	-	-	270	29	209	33	0.014
SNAP [d]	No	No	-	-	-	-	-	Yes	Yes	Yes	Yes	Yes
NOAEL [e]	5 %	0.5 %	43 %	43 %	43 %	5 %	43 %	7.5 %	7.5%	10%	9 %	10 %
LOAEL [f]	7.5 %	1%	52 %	52 %	52 %	Not Available	62 %	50 %	10%	15%	10.50 %	>10 %
Safety Margin	Nil	Nil	-	-	-	7 %	-	30 %	20%	20%	3 to 20 %	67 to 150 %

a – US Classification of Fire

b – Ozone Depletion Potential

c – Global Warming Potential

d – Significant New Alternative Policy

e – No Observed Adverse Effect Level

f – Lowest Observed Adverse Effect Level

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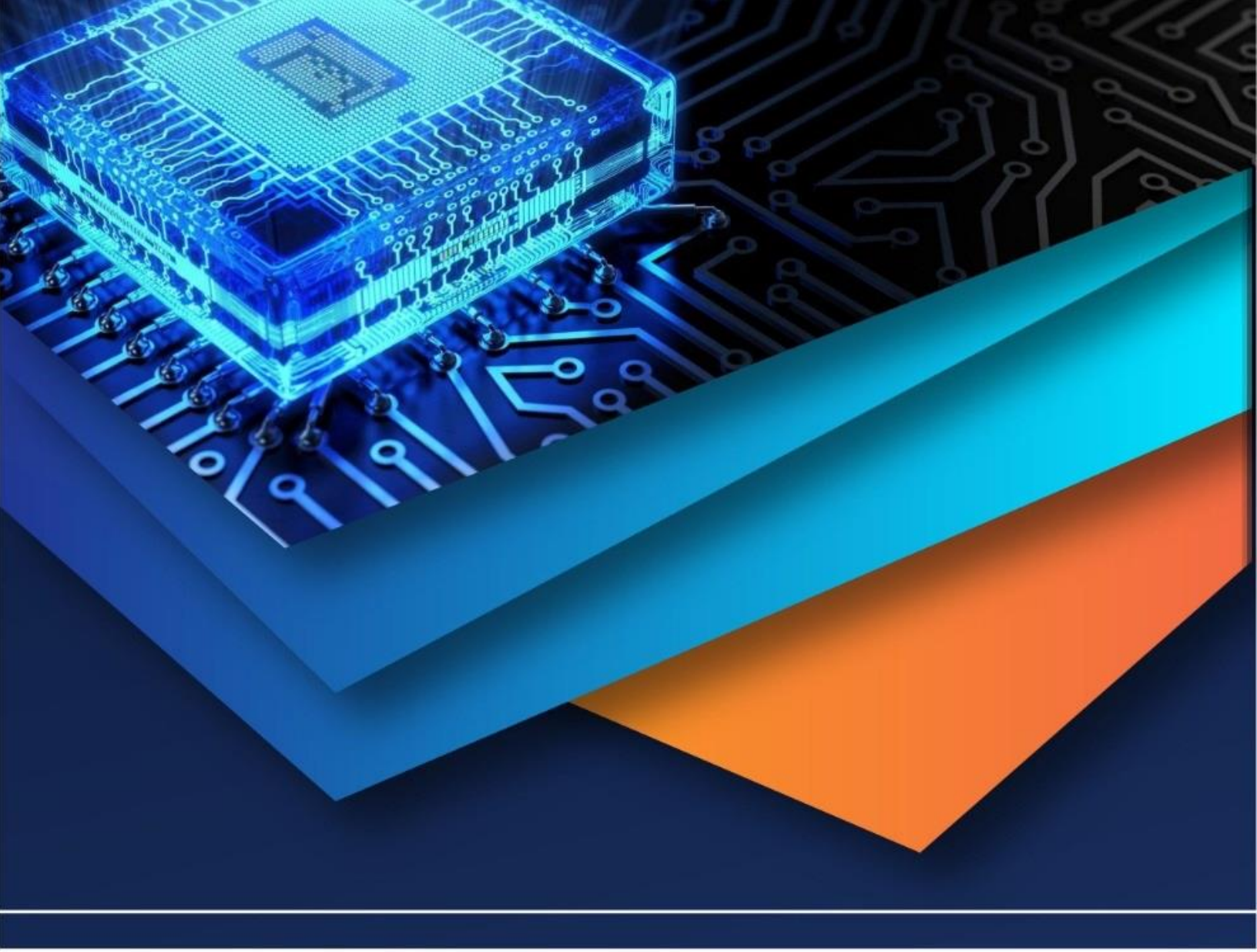

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