Argon fire extinguishing systems - the simple solution

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Abstract

Basic studies were carried out which led to inert gases being considered as fire extinguishing agents to replace Halon 1301. After a test phase with various inert gases, argon was chosen as the optimum solution.

Argon is an absolutely inert gas. No chemical reaction has been known. This makes it a genuine clean agent:

- Argon is itselfnon-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.
- Argon will remain stable even in high-temperature environments which makes it suitable to be used against oil and gas fires, e.g. in gas turbine stations.
- Argon has zero ODP.
- Argon has zero GWP

As well as toxic gases formed by the fire, the possible effects of hypoxia on humans must be considered when a fire is to be extinguished by means of an inert gas. In their Significant New Alternatives Policy (SNAP) list the US EPA recommend Argon. The NFPA have now included Argon in their Fall '95 Report on Proposals of their NFPA 2001 document with oxygen concentrations down to 12% for occupied spaces.

The technology for discharging Argon is very similar to and based on the technology of CO, systems which is well-known in Europe. In the end this includes even design concentrations. The performance has been verified by the fact that hundreds of fires have been successfully fought with CO, systems. Argon can easily be fed through pipes of a considerable length, a design feature where Argon is very different from halon and most of the other chemical agents. Thus, a multi-zone system for a number of extinguishing areas can be built using directional valves. Here the supply can be combined for several zones. This greatly reduces the total quantity of agent.

Typical applications are risks such as EDP centres, switch gear rooms and enclosures where humans may be present.

Introduction

The damage caused to the ozone layer by CFCs and thus also by halon means that halon fire extinguishing systems can no longer be used. An equally effective alternative to halon from the point of view of fire-fighting technology is offered by the new extinguishing agent "Argon". Compared to CO_2, it offers better human tolerance and is therefore preferred by many operators when modernising existing halon equipment. The German Association of Property Insurers (VdS) have approved this extinguishing system which is in principle suitable for total flooding and for enclosed facilities, to protect DP or similar areas. Based on acceptance by the US EPA, the **NFPA** is including Argon into their **NFPA** 2001 guidelines.

Guidelines for the design and installation of inert gas systems are presently being drafted and are expected to be published soon. Until then, the systems can be built by close analogy with the existing rules for CO_2 equipment.

Argon in fire extinguishing systems

Because of the halon banning, it was necessary to rethink the possibilities of fire protection, and in particular to study the aspect of environmental protection in these concepts with great care. The range of requirements for automatic extinguishing systems was reconsidered with different priorities:

- environmental compatibility,
- high level of personnel safety,
- reliable extinguishing,
- early detection of fires,
- extinguishing agents without after-effects for protected areas,
- acceptable space requirements,
- acceptable costs.

This list of requirements meant that it was virtually impossible for Minimax to continue using chemical extinguishing agents. For this reason, Minimax decided in favour of argon after long reflection.

Argon is a readily available inert gas which is present in the earth's atmosphere in quantities of 0.93 % by volume. It is chemically inert and is not known to have been used for fire extinguishing purposes in the past. So far, argon has been widely used in technological applications, e.g. in metal fabrication in inert-gas-shielded welding, in metallurgy for backing melts, in science and medicine as a carrier gas for gas chromatography and as a filler gas in the lamp industry.

From this wide variety of applications, the use of argon in its natural condition is state of the art and does not need any fundamentally new technological adaptation.

Argon is not a typical fire extinguishing agent, but 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 oxygen is reduced to below the specific level required for combustion of a specific material.

CO_2 fire extinguishing systems were already playing a significant part in fixed-system fire protection before and also during the "halon era" in the 70s and 80s. "CO_2" has always been a particularly well-proven, efficient and approved solution and is at present a pragmatic alternative when converting from halon systems and also for first installations in such typical **risk** areas.

The indirect extinguishing effect by gases not involved in the combustion is quite different from halon, which interferes chemically with the reaction chain of a combustion process. For this reason, Argon is not a substitute for halon in the true sense of the word, but is rather a displacement gas.

As an innovative solution in fire extinguishing technology, especially in systems using inert gases, critical studies and careful consideration of other alternatives have shown that Argon is especially recommendable, which is almost self-explanatory because of the characteristics already referred to. Argon's properties as a gas and its physical data relevant to the extinguishing process, such as its density and molar mass, are similar to those of CO_2 and are more suitable for extinguishing systems than N_2. The deposition and penetration properties are largely comparable. In an emergency, the flooding area is filled quickly and evenly by the gaseous extinguishing agent. **A** total flooding effect is thus provided. The concentration will, as a rule, be sufficient for extinguishing purposes when the oxygen level of the air in the room is reduced from its normal level of 20.9 % by volume to <15 % by volume. In order to achieve that, about 1/3 of the volume of air in the room must be replaced by the inert gas, so that a concentration of >34 % by volume is established.

In the case of certain combustible materials with a high affinity to oxygen, this concentration needs to be increased. After the fire has been extinguished, it may be necessary, in order to prevent the fire from re-igniting, to maintain the extinguishing concentration until hot surfaces have cooled down sufficiently.

Argon (purity >99.99 %) is stored in compressed gaseous form in pressure cylinders. With regard to the storage volume and thus of the amount of space required, it would be interesting to store liquid argon, but that is a second step which is still in the development stage. In view of argon's critical point, it can **only** be stored in a refrigerated liquefied state at a temperature below approx. -123 °C.

An advantage of providing the extinguishing agent in a gaseous form is that there is no evaporation as it flows out, and the air in the flooding region is only cooled down to a relatively slight extent in the course of the adiabatic expansion. This means that there is neither mist nor condensation, which, in combination with breakdown products from the fire, might cause consequential damage (especially in electrical plants). The "cold shock", which is a constant **risk** with CO_2 systems, and which manifests itself in the formation of dry ice (CO_2 snow) on sensitive equipment in the flooding area, can be ruled out completely because it is virtually impossible to create a solid state with Argon.

System structure / components
Design, planning, installation

The physical similarity of Argon and CO_2 offers the advantage that fire extinguishing systems using Argon as the extinguishing agent can be based to a considerable extent on the planning and installation guidelines for CO_2 extinguishing systems. It is merely necessary to make a few adjustments to system engineering and to include changes according to specific Argon data in the calculation methods.

Additional security is provided by the fact that the many years of experience in installing CO_2 extinguishing systems and the reliability of the system hardware have been transferred into the system without increased functional risks. The performance has been verified by the fact that hundreds of fires have been successfully fought with CO, systems, **with** only a small rate of 2% to 3% of failures, due to unknown reasons.

Used in high-pressure extinguishing systems Argon is stored in compressed gaseous form, in high-pressure steel cylinders according to DIN 4664, with a test pressure of 250 bar.

Cylinder sizes are determined by the application. The use, size and capacities can be taken from table 1.

The various cylinders are provided with quick-opening valves and are grouped in cylinder banks. Cylinder banks with a maximum of 16 cylinders in one assembly are available. If more extinguishing agent is needed, a number of these assemblies are installed. Systems with more than 250 cylinders have already been installed.

The equipment is operated by mechanical components already **familiar** from CO_2 equipment, where a mechanical/pneumatic delay unit is integrated into the operating sequence. The flow of extinguishing agent from the various cylinders is fed via high-pressure hoses and non-return valves to manifolds from where a common line leads to the nozzle pipework, depending on the different system concepts. Single-zone and multi-zone systems can be installed.

Object protected	Size of cylinder			Max. protected space/cylinder (m^3)
	Nominal content (l)	Mass of agent (kg)	Volume of agent (m^3)	
DP room	67.5	18.6	11.2	17.7
	80.0	22.1	13.2	21.0
False floor	67.5	18.6	11.2	17.7
	80.0	22.1	13.2	21.0
Electrical switch gear and distribution rooms	67.5	18.6	11.2	21.9
	80.0	22.1	13.2	26.0
Panel injection systems for the protection of electrical and electronic equipment	10.7	2.9	1.8	2.8
	13.4	3.7	2.2	3.5
	20.0	5.5	3.3	5.2
	40.0	11.0	6.6	10.2

Tab. 1 Examples for Argon fire extinguishing systems

The structure of the entire system with groups of components forming parts of a system makes it possible to extend and adapt it to the objects to be protected as required.

One special feature compared to other systems is a consequence of the operating pressure. The highly compressed gas in the storage containers permits very high mass flows in the "high-pressure region", with small pipe cross-sections. The maximum pressure resulting from the permissible operating temperature of exhibition rooms is taken into account when designing the components. This results in operating pressures of 170 bar for the components. All the parts are designed to comply with the technical regulations for pressurised gas or the pressure vessel ordinance and the calculation methods laid down in the regulations.

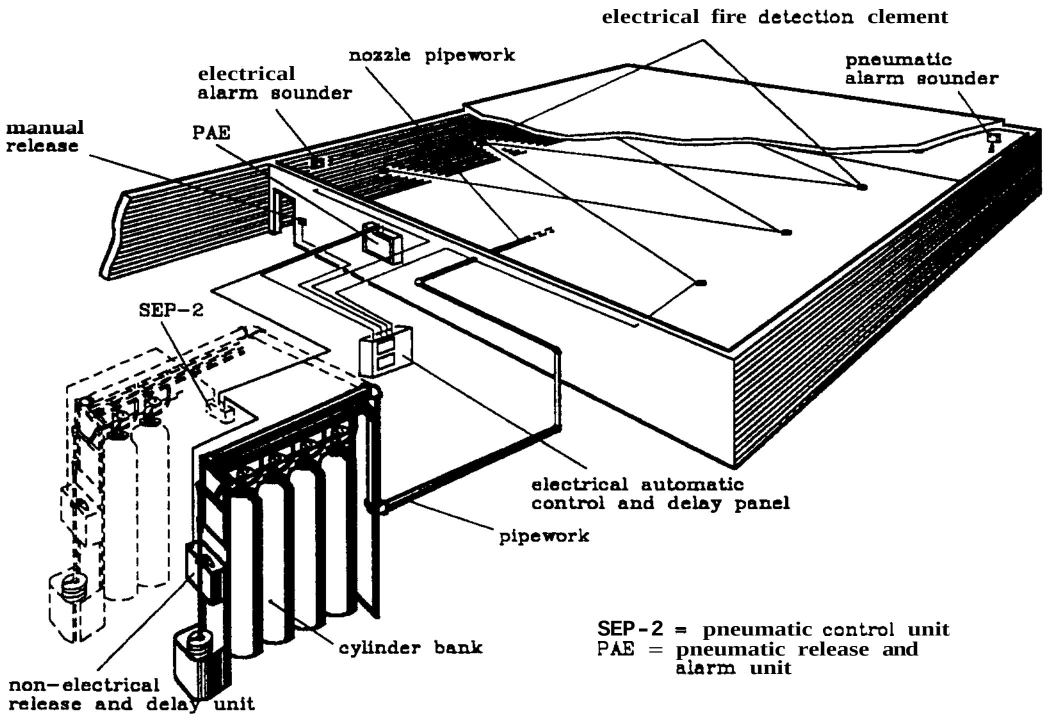
The design of a system with a lower pressure in the nozzle pipework can be achieved by means of pressure reducers at appropriate positions.

With an Argon fire extinguishing system, it is possible to protect a number of separate areas and to supply them from a common supply of extinguishing agent via pneumatically operable selector valves. Here the supply can be combined for several zones.

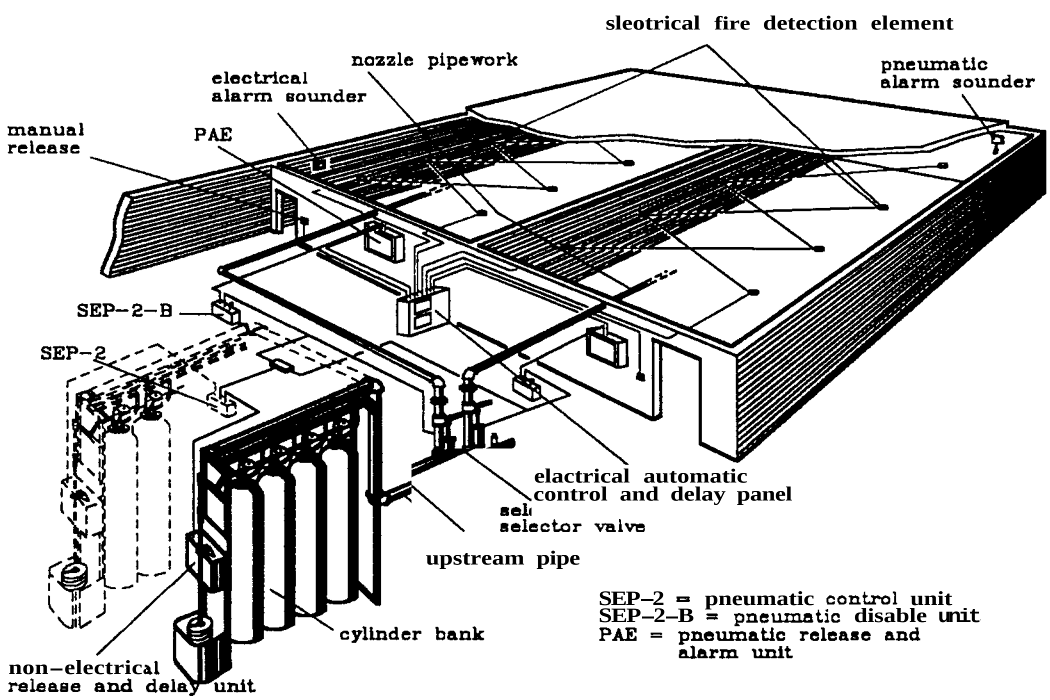
In multi-zone systems of this kind, the size of the Argon store depends on the largest area to be protected and on the most problematic area from the point of view of the concentration requirements specific to the substance. Also, supply and release mechanisms may be concentrated in one room.

This is a great advantage over systems that can be arranged as single-zone or modular systems only, especially over systems employing chemical agents where the agent is very expensive. Two design examples are shown, see figures below. It can easily be seen that a single supply can be used for a number of zones. To protect zones of different size, simply appropriate groups of cylinders can be combined.

If necessary, the protected areas can be supplied with different concentrations of extinguishing agent. So, different concentrations of oxygen can be achieved for the extinguishing process.



Single-Zone Argon Fire Extinguishing System



Multi-Zone Argon Fire Extinguishing System

The discharge control operates according to recognised rules of safety engineering, with reliable and approved fire detection, delay and alarm equipment. Despite the "safety reserves" provided by Argon, it is always necessary to adopt the worst-case approach in questions of human safety; that also applies, of course, to other inert gases or inert gas blends.

Design and dimensioning

The quantities are calculated by analogy with the CO_2 guidelines for total flooding systems. Because of the difference in specific gravity, Argon is 10% more productive than CO_2.

The intention is that the Argon concentration reaches >34 % in the room after a flooding time of one minute.

The pressure development is calculated on the basis of the Argon design quantity and a complete isometric diagram, which enables the system to be precisely dimensioned with the aid of computer programs. Preliminary dimensioning is possible on the basis of standard values.

During flooding, the cylinder pressure drops according to an exponential function. For this reason, the pressure inside the cylinder must be constantly determined according to the laws of gas flow in order to calculate the pressure drop and the nozzle flow rate.

At the beginning of the discharge, there is a peak mass flow. Pressure relief facilities are needed, as with CO_2, and must be designed with this peak mass flow in mind.

The medium reaches the speed of sound as it comes out of the nozzle. The discharge noise is therefore not inconsiderable (>110 dBA).

Because Argon is stored in gaseous form, the total container volume to hold the Argon supply is about twice as large as in the case of pressure-liquefied CO_2. Compared to Halon 1301, about ***5-8*** times as much storage space is needed (e.g. for DP areas; depending on the concentration factor).

Possible applications

In principle, Argon can be used wherever CO_2 can be employed. ***An*** exception is uncovered free-standing objects (local application of agent). Here, since the agent comes out in gaseous state to form the jet from the nozzle, it will be difficult to create a sufficient concentration since air will always be drawn into the jet zone, which means that the extinguishing agent will be mixed with O_2.

Because of the unfavourable storage situation, Argon systems can be considered in particular for smaller rooms or small enclosed facilities and **risks** with a relatively high danger for people. In other words, the classic applications for halon systems are equally conceivable for Argon systems. These are primarily electrical/electronic **risks,** i.e. computer centres and electrical switch gear rooms.

Thus, when it comes to converting existing halon systems, there is a choice between CO_2 and Argon fire extinguishing systems. In the case of converting halon systems, it is realistic to assume that extensive rebuilding work, and possibly a completely new installation will be necessary. For Minimax systems as of model year 1985, it might be possible to retain the nozzle piping. If existing pipework continues to be used, pressure-reducing units are available for Argon systems. A careful examination is necessary in each individual case.

As an aid to decision-making, it is also advisable to consider the costs:

Argon as an extinguishing agent is currently about 2 times as expensive as CO_2. Because of the greater space requirements of the gas, storage costs for the extinguishing agent in an Argon system are higher than for a CO_2 system to cover the same object. On the other hand, argon is a non-toxic gas and the restrictions therefore less hard. Thus, Argon systems tend to be less complex and, therefore cheaper.

Human tolerance

Unlike halon (TLV: 1,000 ppm) or CO_2 (TLV: 5,000 ppm), argon is not dangerous to human beings, because it is absolutely non-toxic and produces no secondary reactions in the metabolic process of the human organism. The danger to human beings in this case is caused exclusively by concomitant phenomena connected with the fire to be fought and its use as a fire extinguishing gas. This situation applies to all inert gases:

- Oxygen deficiency as the concentration drops rapidly.
- Inhalation of toxic combustion gases and decomposition products.
- Fear and shock reactions.

Argon does not cause any additional physiological risks as extinguishing agent itself On the contrary, it offers a substantial safety improvement and reserve.

In order to understand this better, the risk of asphyxiation must be seen in the proper relation on the basis of the pertinent literature on human and industrial medicine, with regard to the O_2 concentration in the air in the room, the exposure time for individuals and the personal constitution of those concerned (health, fitness etc.). Thus, while attention should be drawn to differences in the effects on different individuals, the hazards resulting from short term exposure - which is the most that can be expected when fire extinguishing systems are actuated - can be evaluated roughly as shown in table **2** for a mixture of air with a low oxygen content.

O_2 in vol %	Effects and Symptoms	Classification of Hazards Potential to People
20.9 > 19	normal inhaled air none (badly ventilated surroundings)	
19- 17 15 - 17	hardly noticeable reduced physical and mental performance capability declining performance capabilih	harmless minor impairment
12 - 15	declining performance capability, shortage of breath, dizziness, tiredness	marked impairment
10 - 12	declining performance capability, nausea, exertion not possible, reduction in powers of judgement	danger
8 - 10	declining performance capability, danger of collapse and unconsciousness	marked danger
< 6	immediate unconsciousness, **death** within **6** - 8 minutes (fast treatment can save life)	critical immediate effects

Tab. 2 Relative Hazards to People from Low Concentrations of Oxygen

Compared to this, when CO_2 is used as an extinguishing agent, there is a physiological hazard even before the asphyxiating effect occurs, because there is a noticeable influence on the human organism with concentrations of <5 %, and certainly with concentrations of >10 %.

Since we are only discussing the use of pure argon here, we do not need to consider hazards that exist in the case of inert gas blends including CO_2. If we bear in mind that CO_2 and CO are produced in the event of a fire, and that there is a reduction in oxygen because of the fire itself, it is indispensable to allow calculation and filling tolerances. Differences occur in the homogeneity of the mixture, and structural changes in the protected area during the life of an extinguishing system cannot be ruled out; for this reason, it must be ensured that human beings do not remain in the flooding area during the extinguishing process.

For the use of Argon, Minimax has therefore "played for safety" in every respect. It is recommended, therefore, that the technical safety standards of reliable actuation delay and fire alarm facilities (prewarning time) are left completely unchanged, because, despite the human tolerance of the extinguishing agent, the intolerance of the concomitant phenomena described above remains and still constitutes a hazard for human beings.

Nevertheless, these circumstances regarding safety benefits have a very positive effect as far as the applications technologies are concerned. In an emergency, the time available for evacuation is increased beyond the advance warning time set, by at least a part of the time necessary to build up an extinguishing concentration, because no critical O_2 levels and virtually no reduction in visibility are caused in the flooding area during this period.

Considerable benefits exist here in applications involving local protection for equipment or false floors, because there is a wider range of use for the protection of equipment (covered objects) with no delay facilities. The threshold level for CO_2 of 5 % by volume laid down by German Professional Association, corresponds to a comparably harmless Argon concentration of 20 - 25 % by volume (corresponding to >15-17 % by volume of O_2). The **NFPA** 2001 (currently under revision) states an oxygen level of no less than 12% for occupied spaces. German regulations allow for a level of no less than 10% provided that appropriated safety measures have been taken.

Indirect hazards from a carry-over or leakage of extinguishing agent are incomparably lower than in CO_2 systems. Nevertheless, weighing units on the containers (to monitor for a loss of <10 %) are used. It can be assumed that it is therefore not vitally necessary to add an odour. After flooding, rapid access to the extinguishing area will certainly be prevented far more by toxic combustion gases than by the Argon concentration, which can likewise be corrected by venting the room.

Environmental compatibility

In the atmosphere close to the surface of the earth, there is a far higher concentration of argon than of CO_2. Dry, clean air is composed as follows:

Nitrogen (N_2)	78.1 % by volume,
Oxygen (O_2)	20.9 % by volume,
Argon (Ar)	0.93 % by volume,
Carbon dioxide (CO_2)	0.03 % by volume

and a few other trace gases.

Virtually the only way of obtaining argon is by "removing" it from the ambient air, where it returns after use.

It is obtained technically by air separation, by fractionating the liquefied air. In this method, the liquefied air is vaporised at the respective boiling points of the air components, which are extracted by repeated condensation and distillation. Argon is also concentrated from the high content of ambient air in the recycle gas during ammonia synthesis and is separated from that in turn by fractionated liquefaction and rectification of the condensate.

Air separation is not performed in order to obtain argon. In fact, argon is a "waste product" in isolating O_2 and N_2. It thus also makes a contribution to environmental protection from the point of view of the energy balance if the inert gas can be put to good use.

It is certain that Argon does not involve any

ODP (Ozone Depletion Potential) or

GWP (Global Warming Potential).

State of approval

The development of Argon fire extinguishing systems has been accompanied by a series of internal and external trials and approval procedures.

Extensive tests and particularly total flood tests have been carried out to verify performance and design concentrations. More than 400 extinguishing areas have now been protected with Argon.

As a gas left in its natural state, Argon is not subject to the obligation to obtain a permit under specific test procedures in the sense of regulatory ordinances.

The **German** Association of Property insurers have granted approval for the system.

An approval by the Kuwaiti KFD & MEW has been obtained.

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