Use of HCFC as a Drop-in Halons' Replacement for Existing Buildings

K C LAM
Department of Building Services Engineering
The Hong Kong Polytechnic University

N G EDDY
Prime Pacific International Engineering Ltd.
Hong Kong, China

ABSTRACT

The application of a unique blend of HCFC for direct replacement of Halons is technically and economically viable for existing buildings fitted with Halon installations.

Use of this "drop-in" replacement of Halons is a useful interim solution to protection of life, property and the already damaged global environment.

With this "transitional product", building owners can immediately convert their existing harmful Halon installations to a safe and environmental-friendly fire extinguishing system. This is a significant contribution to the reduction of atmospheric bromine/chlorine loading over the next decades.

INTRODUCTION

Halons are serious ozone depleters with a long atmospheric life. Production has already been banned and uses are being reduced as supply declines. The fire protection industry has responded very effectively to the cessation of the production of Halon. Over the past few years, there has been a proliferation in the availability of clean agent replacement chemicals and new alternative technologies, the total of which will probably result in better fire protection than ever before. The choice of gaseous alternatives is between the chemical halocarbon agents, HFCs, HCFCs and PFCs, and the inerting gases. However, direct replacement agents are not going to be easy to find, and the existing Halon piping systems have to be replaced in most cases. This, of course, means extremely high costs to the building owners and requires disruptive replacements of the Halon systems in heavily serviced buildings which are neither easy nor possible in the congested ceiling voids. Obviously, these building owners are reluctant to give up their Halon systems, and the Earth and ourselves will still be suffered.

This paper attempts to:

- review the unique problem of existing buildings fitted with Halons; and
- give practical solution to overcome the present technical and economic constraints in satisfying the environmental issues regarding replacement of existing Halon systems in existing buildings.

RESPONSE TO THE MONTREAL PROTOCOL

Halon is linked with depletion of the stratospheric ozone layer, therefore, production is being banned, and Halon use will be decreased due to limited supply from the Halon bank and the difficulty encountered of using recycled Halon liquids from various sources with different product specifications since it is very difficult to assure a uniform standard of these mixed liquids.

The Montreal Protocol, obviously, gives fire protecting engineers, scientists, manufacturers and fire authorities a major opportunity to review the various alternatives for Halon. However, this national policy has created problems for all Halon users. Notably, all building owners and users (or our clients) will be directly affected in order to satisfy the important "Green Building" issue with no Halon use in buildings.

In the clients' best interests, a direct replacement of Halons should have good fire extinguishing capability, low toxicity, and is "safe" for the environment. At the same time, this substitute can make use of existing Halon piping installation, and without dismantling the existing Halon systems which is costly. Furthermore, long operational interruptions should be avoided as much as possible.

SELECTING HALON ALTERNATIVES

Every fire protection engineer has probably seen money wasted on inadequate fire prevention or protection methods. A realistic decision must be reached and should not be based on one particular type of extinguishing agent. The engineer's decision making process should take all factors into account for a systematic analysis, and the important criteria include:

- Cost : low initial cost and the cost of maintenance and recharge.
- Effectiveness : low quantity of agent needed to extinguish fire.
- Compatibility : the agent's ability to extinguish a fire without having undesirable chemical or physical side reactions.
- Responsiveness : the system's quick response to limit fire loss while allowing for occupant egress.
- Efficacy : the effectiveness of a system in a given application and its reliability for that application.
- Occupant Risk : low toxicity of the undecomposed or decomposed agent in the concentration necessary for extinction while maintaining human life.
- Cardiac Toxicity : a compound's ability to cause serious and sometimes fatal cardiac arrhythmia. The effect should be as little as possible.
- Electrical Conductivity : non conducting property is essential.
- Low Space or Weight : the weight based effectiveness of the agent and the system.
- Environmental friendly : Zero ozone depletion potential (ODP); Zero global warming potential (GWP); Zero atmospheric life (ALT); little water and soil contamination; little decomposition products and possible ultimate disposal by safe destruction.
- Health and Safety : low oxygen depletion; low noise level and little air turbulence; clear visibility for egress; safety with live electrical equipment; safe transportation handling.

- Enclosure requirements : sufficient strength to retain the agent; minimum leakage paths and necessary venting in addition to fire resisting construction.

It can be seen from the listed characteristics that a perfect fire extinguishing system which can satisfy all the criteria is hard to find. We have to live with the fact that at present there is no perfect solution to the fire and environmental protection issues. We have to use a system which has minimum impact on ourselves and the global environment without sacrificing the important fire fighting effectiveness required. For new buildings the choice of an appropriate extinguishing agent is not so difficult. However, it would be extremely difficult for existing buildings that have both technical and economic constraints.

It is important, in today's drive for a sustainable society to acknowledge that products used in fire protection are selected in a responsible manner which benefits society. Therefore, we need to have a perfect system which is an effective fire suppressant, but also one which has: zero ozone depletion potential (ODP); zero global warming potential (GWP); zero lifetime in the atmosphere (ALT); low toxicity; no residues. Furthermore, it must be available for use in the near future. However, this ideal fire suppressant still does not exist.

Previously, scientists concentrated on the critical ODP issue, but the shifts in focus by leading environmentalists and government agencies to the global warming and atmospheric lifetime are evidenced throughout the world as the warming effect could bring with it significant changes to ecosystems. GWP is becoming of increasing concern, and many of the candidates being evaluated as alternative clean fire fighting agents have significant GWPs. Particularly bothersome about this is that one group of halocarbons having zero ODPs, perfluorocarbons, have very high GWPs. Therefore, if a product does have a high GWP and ALT, will it also be phased out at some point in the future? The serious concern is of course, that no one wants to have a very expensive system that quickly becomes a white elephant after a few years' times. Surely, concerns such as global environmental protection, technical and economic impacts and political issue must all be looked at when evaluating a particular Halon alternative. It is likely that future environmental requirements may be more stringent or limit production quantities.

HALONS IN EXISTING BUILDINGS

Most technical papers have discussed different alternatives to Halon fire fighting gases in great depth. However, very few papers have addressed the approaches to a sensible replacement of Halon systems in existing buildings. These existing Halon systems are in fact the major ozone depleting sources and must therefore be reduced as soon as possible. The paper therefore attempts to address this particular issue, and we hope that the suggestions provided will be of use and interest to all building owners.

Before we discuss the approaches to the use of Halons and the replacement of these gases in existing buildings, it is necessary to review these Halon systems and the problems or constraints in these existing buildings in Hong Kong as a typical example in Asia-Oceania countries.

USE OF HALONS IN EXISTING BUILDING

Both Halon 1211(BCF) and 1301(BTM) are the primary fire fighting gases used since 1960s. In general, Halon 1301 is the most commonly used gas for occupied areas (for human safety reason). Most of these fire protection systems are total flooding installations.

Surveys carried out by the Hong Kong Environmental Protection Department indicate that we have about 600 tonnes of Halon (Worldwide Halon 1301 stock is about 350,000 tonnes). With the exception of the Hong Kong Government and some of the large organizations, economic consideration for end-users in Hong Kong (same as in other countries) to use other Halon alternatives are very discouraging, and therefore the conversion process is very slow. In fact, most building owners would retain their Halon systems as long as they can. Surely, this would not be in our environmental interest since approximately 1.5 to 2.0% of the Halon stock would still leak into the atmospheric as a result of leakage.

As of January 1, 1994 the Hong Kong Government had banned the import of Halon 1301 and 1211. On January 20, 1995, the Hong Kong Fire Services Department also announced that there would not be enough supply of Halons to replenish existing fire protection systems. This means that building owners who currently use Halon fire extinguishants to operate their fire prevention systems should develop a sound transition strategy as quickly as possible. Those who choose to convert to an ozone safe alternative extinguishant today, rather than manage their existing Halon systems, only have one of two options at their disposal: replacement and retrofit.

PROBLEMS IN EXISTING BUILDINGS

Based on the authors' experience and investigation, we have identified that the slow phase out rate of Halon can be due to one or more of the following factors:

- Inadequate space for additional gas cylinders (with the exception of HCFC, other halon alternative will usually require more agent cylinders)
- Complete replacement of existing Halon piping is impossible or very difficult because of the existing process plants and congested ceiling voids. (only HCFC can use most of the existing Halon piping, other agents require complete new piping systems for delivering more agent)
- Most BTM installed are for total fixed flooding installations which will involve substantial cost for retrofitting or replacement to non-Halon systems. It must be noted that many of these BTM installations are comparatively new and still have about 15-20 years useful working life. Hence, most building owners are reluctant to change their Halon systems. Also, Halon can still be used in existing buildings under the law.
- Building owners can still obtain Halons for charging their Halon systems. And most Halon users have taken an "wait-and-see" attitude towards alternative agent before embarking on any new replacement programmes. Besides, there are Halon banks (in developed countries) which will encourage the use of Halons as long as supply is abundant.
- There is no perfect "drop-in" substitute for replacing the existing Halon systems. Also, this Halon alternative must be available for use in the near future (say 30 years). Most new

Halon alternatives are still not perfect and they fall short of the 'perfect mark' in one way or another: they either have an ozone depletion potential, a global warming potential, a lengthily lifetime in the atmospheric, are toxic, or far too much of the products is required to put out the fire, making it either too impractical or costly to use.
Furthermore, future environment policy may narrow the use of some long-lived and high global warming potential fire extinguishing agents which can affect building owners' decisions on charging their Halon installations.

ls seen from the above factors, it is not surprising that the amount of Halon to be phased out ; only about 35-40% of the total quantity of Halon installed in Hong Kong (similar scenario in ıther countries).

n Hong Kong, we still have 600 tonnes Halons. This is a big problems. What do we do about his? Shall we still retain this and keep on using Halons from the Halon banks? Or have we not earnt enough about the environmental impacts of Halons on our universe and still ignore the :nvironmental effects on ourselves.

There are no perfect solutions to these questions, but the obvious answers would be:-

- stringent control of existing Halon emission (very difficult in practice).
- complete removal of Halon gas from all existing Halon systems (again difficult because of cost and building constraints).
- possibility of replacing existing Halon systems with new agent and using the existing Halon system piping and hardware; this must be relatively inexpensive for the system conversion. The new agent must have low Ozone Depletion Potential, very low Global Warming Potential together with short Atmospheric Life Time.
- enough supply of new agent for at least 30 years as most buildings still have a useful life of 30 to 40 years in Hong Kong. Cost of recharging systems after discharge must also be reasonable.
- further actions should be taken when an ideal Halon alternative is available (still not available for the foreseeable future and within the next 10 years)

From our detailed analysis of the Halon alternatives (Fig. 1 & 2), we have come up with a compromise answer - the use of HCFC Blend A (NAF SIII is the tradename).

Table 1 & 2 show that HCFC is an effective alternative to Halon 1301 for the following reasons:

- HCFCs overall environmental impact is a great deal lower than other agents
- HCFC is an effective fire extinguishing agent
- HCFC is a very cost effective substitute for Halon 1301 in existing system hardware, and can be used without significant system alterations or modification/replacement.
- By using HCFC, Halons can be removed and destructed immediately to offset the problems of depletion; global warming and long atmosphere life time.

HCFC can contribute to the reduction of the environment impact latent in the installed Halons by 400 times (16 ODP of Halon 1301 divided by 0.04 ODP of HCFC Blend "A"). For Hong

Kong alone, the 600 tonnes Halon can produce 432 tonnes ODP (based on 4.5% emission rate of the 600 tonnes with an ODP value of 16, i.e. 0.045 x 600 x 16). When HCFC Blend "A" is being used, 660 tonnes will be required, but there is only 1.188 tonne of weighted ODP based on the same emission rate, i.e. 660 x 0.045 x 0.044 ODP value of agent.

N.B. The 4.5% emission rate (1.5% real fire; 1.0% leakage, test and false alarms, and 2% testing and training) is based on the United Nations Environment Programme - Halon Technical Options Committee's figure of existing Halon stocks.

Similarly, for the worldwide stock of Halon 1301 of 350,000 tons. This means the annual emission of 15,750 tons is equivalent to an annual emission of 252,000 ODP equivalent tons. Hence, it is imminent to reduce this harmful emission as much as possible by the use of an appropriate agent like HCFC for all existing buildings at minimum cost and least disruption to activities within buildings.

Of course, other Halon alternatives such as Carbon Dioxide, Inergen, Argonite, HFCs (FM200) can be used. However, they are not drop-in replacement agents and are very expensive. Furthermore, these agents cannot make use of existing Halon piping for immediate change-over from Halon to an environmental-friendly agent. Therefore, owners of existing buildings are very reluctant to replace their Halon systems, and our planet will be further damaged by Halon emissions.

DETAILED STUDY OF HCFC 'BLEND A' (NAF SIII)

HCFC Blend A is an effective fire extinguishing agent. With low toxicity and cardiac sensitization level and therefore, people can stay in the protected enclosure. Personnel may be exposed to HCFC Blend A vapours in low concentrations for short periods of time without risk to their health or safety. Similar to Halon 1301, exposure to high concentrations for prolonged periods may produce dizziness, impaired co-ordination and disturbances in cardiac rhythm. With the exception of HCFC Blend A low 0.044 ozone depletion potential, HCFC Blend A has remarkably low global warming potential (0.1) and atmosphere life time (7 years); acute toxicity (700,000 ppm); cardiac sensitisation (10% NOAEL/>10% LOAEL).

Overall speaking, HCFC Blend A impact on the overall environment is small when compared with other alternative gases. At the time of this writing, the usage of this gas is limited to year 2030 (base on ODP only) by the Montreal Protocol. It is however, expected that this cost effective 'drop-in' replacement of Halon 1301 will be re-evaluated again when HCFC Blend A low GWP, ALT and ODP are all considered instead of judging by its ODP alone.

The problem faced in the search for alternative agents is that fire extinguishing agents must not be detrimental to the environment and human beings. From the client's viewpoint, the agent must also be suitable as a "drop-in" replacement at a reasonable cost. Furthermore, the existing Halon system piping can be reused if possible. If not 100% feasible, minor modification to some of the pipework and nozzles is considered acceptable. The most important thing is, there should be no risk of long operational interruptions as well as that the protection given by the system is maintained, and this necessitates a very short change-over programme.

HCFC 'Blend A' is not a 100% perfect gas, but it is the best drop-in gas at this time. It can make use of the existing Halon piping installation, and is cost effective with respect to agent quantity, agent cost, cylinder cost, piping cost and compatibility with the existing Halon-based equipment, i.e. piping and hardware.

The authors from over 50 case studies have stated that all HCFC Blend A pipe sizes are nearly identical to those sizes selected for the corresponding Halon 1301 systems which were sized in accordance to NFPA 12, Halon Fire Extinguishing Agent Systems. We have also identified that there is no 100% "drop-in" capability, but still, it is possible to retain at least over 90% of the original Halon pipework. In many cases, over 95% of the Halon pipes can remain unchanged and the remaining 5% can be easily modified. Naturally, because of the different designs of nozzles between Halon and HCFCs, all existing nozzles would have to be dismantled and replaced by properly selected HCFC Blend A nozzles to ensure adequate coverage. From site experience, these alterations can be carried out without any difficulty.

From our numerous calculations of HCFC systems, we have also identified that for small total flooding systems with a room volume of about $50m^3$, the existing Halon piping can be completely re-used. For larger spaces, 100% of the existing pipes can be retained in many cases, however, some nozzles may not have ideal working pressure. Therefore, some branches have to be modified. These branches are short and can be easily replaced. By so doing, the whole system will match the computerized designs, and the performance can therefore be guaranteed.

Numerous case studies also confirm that in many cases, only an additional HCFCs cylinder is required to compensate for the extra mass of extinguishing agent required and the requirement of filling density. Therefore, extra space needed for installation of HCFCs cylinders is not a problem, and this explains why HCFC is particularly suitable for existing buildings which have storage space problems.

As HCFC Blend A and Halon 1301 follow the same two-phase flow equation and the existing Halon 1301 computerized program has been modified for HCFCs system. Therefore, the performance of a HCFCs system can be evaluated confidently. With this program, all existing pipe sizes will be fully evaluated, analysed, re-used whilst maintaining the proper flow of HCFC gas for effective fire fighting.

Therefore, retrofitting Halon 1301 systems with this gas is a scientific, simple, straight-forward task and without significant system alterations or modification/replacement. Apparently, using other alternative agents as a drop-in extinguishant would not be entirely feasible.

Similar to the Halon system, in order to avoid unnecessary discharge, intelligent detection system should be employed to prevent false alarm and subsequent gas discharge. Discharged gas should be recovered and destroyed because of its ODP.

It is the authors' opinion that unwanted Halons must be properly disposed of by means of total destruction in order to protect the environment. It is, however, possible to store Halons in a Halon bank for special situations such as "essential users". Nevertheless, this should be discouraged in view of the continuing Halon emissions from the Halon systems.

HCFC is still not perfect, this agent will be phased out in 2030. Most existing Halon installations would have a working life of less than 30 years, this problem then becomes insignificant. By that time, all these existing systems would have to be replaced anyhow. Therefore, it is economical and sensible to use HCFC for existing Halon systems and save our universe. Hopefully, we can have a perfect agent before 2030 which can satisfy fire and environmental need, and existing systems approaching the end of their useful life can be completely replaced by this perfect agent. In summary, HCFC 'Blend A' is a compromise solution to what we are looking at if we have to eliminate all Halons in the existing Halon installations as soon as possible and within cost and building constraints.

IMPROVEMENT OF FIRE EXTINGUISHING SYSTEMS IN EXISTING BUILDINGS

In addition to the immediate use of HCFC for direct replacement of Halons, building owners can also take the following rational approaches for further reduction of Halons:

- to group all Halon systems of similar capacities together and make use of directional control valves for individual zones. Each valve will be connected to a central Halon cylinder system. By so doing, we can reduce large storage of Halons, but the fire safety can still be maintained.
- for computer rooms, we can consider the use of special cabinets to totally enclose a computer. This cabinet will be provided with a modular HCFC or FM200 extinguishing system. The general computer room can now be protected by a sprinkler system.
- the largest Halon emission is due to false alarm and false discharge. It is therefore imminent to upgrade the existing alarm system (e.g. use of air sampling control with or without the existing smoke/heat detection systems). Furthermore, leakage detection system (e.g. pressure switch and alarm) should be provided for each Halon cylinder (the same will be applied to HCFC system). Last but not least, better maintenance should be given to the entire extinguishing system.

Clearly, the above suggestions are not straight forward, and the best approach is not to use Halon anymore.

CONCLUSION

'Environmental Protection' is an important issue, and we have already suffered from the effects of damage to the ozone layer and the sudden climate changes throughout the Earth.

We have learnt one thing: There is no perfect alternative to Halon at least for the time being, but the use of Halon should be banned without further delays.

Work to date indicates that the development of general purpose, direct replacements having attributes equal to those of the present Halons may be unrealistic in the short term. On the other hand, clean alternative agents with very low ODPs for specific uses are a realistic goal, if trade-offs in fire extinguishment capability, toxicity, and/or other characteristics are acceptable. In particular, such agents are available as short-term solution to fire protection applications could reduce the threat to the ozone layer.

New 'compromise' extinguishing agents are available with different characteristics and impacts on the vulnerable environment. It is essential to use one which can satisfy our needs in terms of: environmental protection, effective fire suppression, human safety, protection of equipment, economy, and compatibility with the existing Halon equipment. To discourage the use of Halon in existing buildings, HCFC Blend A as transitional agent can be considered and used to bridge the gap between highly damaging Halon and "perfect" or "near-perfect" product of the unforeseeable future.

It is hoped that if all countries can adopt this approach to save our environment by using HCFC 'Blend A' as "transitional product", our damaged universe can be recovered much quicker and that ourselves, our children and their children can be saved.

REFERENCES

Burkhart, D.J., May 1994, Selecting Halon Alternatives: No Cause for Alarm, Consulting - Specifying Engineer, U.S.A. pp. 54-58 (This paper should be read with Halon Update printed in July 94 of the same journal)

Clement, J.W., November 1993, Life After Halons, Building Services, U.K. pp. 57-58.

Commonwealth Fire Board, Dec. 1993, Fire Safety Bulletin No. 12., Australia.

Cortina, T., May 1995, Halon Alternatives Gain Industry Confidence, Consulting - Specifying Engineer, U.S.A. pp. 54-56.

Daws, S., March 1995, Halon Replacements Standards & Approvals, International Fire and Security Products News, U.K. pp. 24-35.

Lam, K.C., 1995, "Drop-in" Replacement to Halon 1301 and the Environmental Protection Issue, CIBSE National Conference, Eastbourne, U.K.

Miziolek, A.W. and Tsang, W., Aug. 1994, Halon Replacements, Technology and Science, ACS Symposium Series 611, U.S.A.

NFPA 2001, 1994, Clean Agent Fire Extinguishing Systems, National Fire Protection Association, U.S.A.

Young, R., March 1994, Evaluating Halon 1301 Alternatives, Fire Prevention, U.K. pp. 34-37.

Young, R., March 1995, Gaseous Fire Extinguishing Agents As Halon 1301 Alternatives, Fire Prevention, U.K. pp. 24-27.

Young, R., May 1996, Effective Alternatives to Halon 1301, Fire Prevention, U.K. pp. 16-18.

Information from NAF SIII, FM200, Inergen, Argonite and CO_2.

TABLE 1 - ALTERNATIVE AGENTS

Agent	Trade Name	Design Concent-ration	Toxicity LC 50%	Replace-ment ratio, kg	ODP	GWL	ALT	Drop-in Capability
Halon	1301	5.0%	80+	1	16	0.8	110	-
HCFC Blend A	NAF S-111	8.6%	70	1.1	0.044#	0.1	7	Yes*
HCFC-227ea	FM-200	7%	80+	1.7	0	0.6	42	No
IG-541	Inergen	37.5-50%	Reduce O_2 to 12.5%	2	0	0	0	No
IG55	Argonite	50%	Reduce O_2 to 12.5%	N/A	0	0	0	No
CO_2	Carbon dioxide	30-50%	Life threatening	2.72	0	1	N/A	No

Note: NAF SIII has the lowest environmental impact of the halocarbons if the full range of effects are taken into account.

*much of the existing Halon hardware systems can be retained for use with HCFC, especially the agent delivery pipework.

TABLE 2 - COST AND USAGE OF DIFFERENT AGENTS

Agent/Factor	1301	NAF S-111	FM-200	Inergen	Argonite	CO_2
Cylinder Volume	1	1.1	1.7	10	10	3.5
Agent Cost	1	1.8	5.2	1.8	N/A	<1
Piping Cost	1	1	>1	>1	>1	>1
Equipment Cost	1	1	2	10.3	N/A	>4
Total Cost	1	1.5	3.7	6	N/A	3.7
Type of Equipment, pressure in bar	25	25	25	>25	>25	25
Usage	Common	High**	High***	Low	Low	High****
Cylinder room size	-	Little	Larger	Very Large	Very large	Very large
Effect to human-being	Yes	Yes	Yes	Yes	Yes	Yes
Availability	Limited after 1994	Plenty, limited after 2030	Plenty	Plenty	Plenty	Plenty
Extinguishing concentration, n-Heptane mg/l, % vol	188 3.1	300-360 7.2-8.6	416 6.0	- 29.1	- 30	- 30

** NAF SIII is the closest available agent for ease of replacement for halon systems.

***FM-200 mainly for new installations

**** CO_2 mainly for existing installations