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A COMPARATIVE ANALYSIS OF FIRE PROTECTION SYSTEMS FOR ESSENTIAL ELECTRONIC DATA PROCESSING EQUIPMENT

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LSSR 31-80

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This research analyzed the controversy between Halon 1301 and sprinkler systems as to the preferred method of fire protection for essential electronic data processing equipment (EDPE). The existence of such a controversy, backed by the importance of EDP capability to the Air Force, advances in computer technology, and lack of a formal Air Force study in this area suggested that such a study was needed. A comparative analysis methodology was then developed which incorporated eight evaluation criteria representing factors important to the Air Force. The eight criteria were reliability, maintenance, cost, safety, adaptability, catastrophic fire, overseas support, and equipment downtime. Based on an assignment of equal weight to all eight criteria, the comparative analysis revealed that sprinklers were markedly superior to Halon 1301. Therefore, the Air Force should reassess its policy of commitment to Halon 1301 as the primary fire protection system for essential EDPE and take action to avert substandard performance of existing Halon 1301 installations.

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A COMPARATIVE ANALYSIS OF FIRE PROTECTION SYSTEMS FOR ESSENTIAL ELECTRONIC DATA PROCESSING EQUIPMENT

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Facilities Management

By

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CHAPTER I

INTRODUCTION

Background

With the tremendous technological advances made in electronic data processing (EDP) capability, this equipment has become a vital and commonplace tool for an organization's day-to-day operations. The ability of this equipment to handle complex and large quantities of work led to the widespread use, installation, and concentration of exceptionally costly apparatus in single locations. As more emphasis was placed on incorporating the EDP systems into the modern Air Force's daily operations, former data processing methods and record keeping chores were abandoned, and their source material was no longer available should the EDP system become inoperable. In addition, much of this electronic equipment became essential to carrying out vital military missions. According to AFM 88-15:

> Electronic equipment is essential when it:
> (1) Is necessary to national security.
> (2) Performs an operation that must be continued to completion without interruption.
> (3) Requires a long lead time to replace [43:p.13-8].

Because of this dependence on essential electronic equipment, it has become crucial that all possible provisions be made to protect this equipment against fire and to insure its continued availability. These provisions should include at a minimum the following:

1. the electronic data processing equipment (EDPE) should be located in such a way so as to minimize external fire hazards, since according to recorded losses, this equipment is usually the victim of a fire which originates outside the EDPE, not within the equipment itself (7:2;41:29);

2. the EDPE should be installed in buildings or rooms which are constructed of flame retardant or non-combustible materials;

3. the amounts of combustible materials, such as paper products, which are used in the day-to-day operations should be minimized and never permanently stored in the same area as the EDPE;

4. and finally, the EDPE should be protected by an early warning fire detection and suppression system.

Various fire suppressing agents have been developed which have the capability of extinguishing electronic equipment related fires. Because of its extinguishing characteristics and low toxicity, the most widely used and generally recommended is Bromotrifluoromethane (Halon 1301) (32:p.7-26). According to present knowledge, Halon 1301 (with a five to seven percent concentration by volume) extinguishes fire by inhibiting the chemical reaction of fuel and oxygen (1:1). Over twenty years of medical research on both test animals and humans indicated that Halon 1301 in concentrations up to seven percent by volume could be used with a high degree of safety (13:11). However, its decomposition products can be dangerous for short exposures, so safeguards, such as quick evacuation and prompt search and rescue for unconscious persons, should be considered to avoid injury or death to personnel (34:pp.12A-47 to 12A-49).

Water, though it has been used as an extinguishing agent since the discovery of fire, has had an uncertain role in fire protection of EDPE. This was due to a combination of factors such as: desire for continuity of operations, fear of water damage to equipment (corrosion or electrical shock hazards). Due to the advent of advanced, solid-state technology, damage from moisture is not as likely to occur as it was with older vacuum tube data processing equipment, and provided equipment salvage operations begin promptly, the high cost of replacement equipment and lost productivity can be reduced (22:3-5). Additionally, numerous studies and analyses of the shock hazard involved with the use of water in extinguishing electrical fires have shown that present standards and modern equipment insure a more than adequate margin of safety (42:60-61).

The re-emergence of water as an appropriate extinguishing agent for EDPE fires has been led by the U.S. Department of Commerce (42:23) and has been acknowledged by Factory Mutual System (22:3), an insurance underwriter widely recognized for its preeminence in loss prevention, property conservation, and the fundamental study of fire and its suppression. Thus, considerable support has been given to the use of sprinkler systems as an effective means to extinguish EDPE fires. See Appendix A for more information concerning the theory of fire extinguishment and the roles of both Halon 1301 and water as extinguishing agents.

Technology has advanced rapidly in the last decade. Research on effective fire protection systems has occurred, and practical experience has been gained. While it would be simple to recommend the use of both Halon and water, thereby gaining maximum protection, such a proposal would be costly and perhaps unnecessary. However, analysis and study of the knowledge gained in the past decade offers the potential for starting the Air Force out on the right foot in the 1980s.

Problem Statement

A comprehensive analysis of the issues surrounding appropriate fire protection systems for installed essential electronic data processing equipment could enhance Air Force fire protection policy for the 1980s. To date, such an analysis has not been performed.

Research Objectives

There are three main objectives associated with the study:

1. In the context of USAF needs and resources, formulate criteria by which an evaluation of the suitability of fire protection systems for EDPE may be performed.

2. Evaluate the two contending fire protection systems, Halon 1301 (automatic bromotrifluoromethane total flood system) and sprinklers (automatic sprinkler system), using these criteria to determine if there are significant advantages or disadvantages associated with either system.

3. Incorporate the evaluation results into a recommendation concerning which system is most appropriate for the protection of EDPE.

Literature Review

National Fire Prevention and Control Administration

The National Fire Prevention and Control Administration (NFPCA), an organization within the U.S. Department of Commerce, published in August 1978 a document entitled "Standard Practice for the Protection of Essential Electronic Equipment Operations (RP-1)." The role of the RP-1 is explained as follows:

> RP-1 is recognized in the Federal Property Management Regulations and is used by federal agencies as the guide for the fire protection of essential electronic equipment. . . . This revision was prepared by an inter-agency committee under the guidance of the National Fire Prevention and Control Administration. . . . The enclosed recommendations represent the concerns of the committee and are promulgated for use by all agencies at the discretion of their management [42:iii].

Lending credence to the recommendations contained in the RP-1 was the representation of the National Aeronautics and Space Administration, the National Security Agency, the Federal Aviation Administration, and the Internal Revenue Service on the committee. The RP-1 declares,

> Automatic sprinkler protection is required for all electronic equipment and record storage areas and shall be installed in accordance with NFPA No. 13, 'Sprinkler System' [42:23].

Despite RP-1's unequivocal stand on automatic sprinkler protection, it does allow the optional use of automatic

Halon 1301 extinguishing systems in a supplementary capacity for extraordinary situations (42:26).

USAF Policy

The U.S. Air Force also recognizes the importance of automatic sprinkler systems in AFM 88-15, "Air Force Design Manual--Criteria and Standards for Air Force Construction." It contains the general policy statement:

> Automatic sprinkler systems will be provided in facilities or areas thereof to insure the maximum degree of life safety or property protection where the size, type of construction, occupancy or other conditions create severe monetary or strategic fire loss potential [43:p.13-3].

This general statement prefaces a more detailed statement of use for automatic sprinkler systems which would appear to include essential electronic equipment:

> . . . automatic sprinkler systems will be installed in buildings and structures of the following occupancies. . . . Technical and industrial type buildings, including shops and laboratories, which are used for production, repair, experimental testing, electronics, overhaul facilities, or other processes, services, or equipment of a critical nature, severe fire hazard, high monetary value or of vital importance. (Type "C" or type "N" construction) [43:pp.13-3 to 13-4].

Later, attention is specifically directed at electronic equipment:

> House essential electronic equipment in existing type "N" structures. The use of type "C" structures will require HQ USAF approval. On approval, existing type "C" structures may be used provided the building is completely protected by a properly installed and maintained automatic sprinkler system and the inclosure for the equipment complies with requirements of paragraph 13-28 [43:p.13-8].

These statements, while recognizing the importance of automatic sprinkler systems, leave open the question: Are sprinklers required when essential electronic equipment, specifically EDPE, is contained in type "N" structures?

AFM 88-15 also devotes special attention to the use of Halon 1301. Unfortunately, the initial reference once again reveals the indecision surrounding this issue: "Halon 1301 Fire Suppression Systems. These systems, installed only where required and approved, will follow criteria in attachment 18 [43:p.13-9]." Attachment 18 of AFM 88-15, "Halon 1301 Suppression Systems for Essential Electronic Facilities of Type N Construction," offers the following policy statements:

> The use of Halon 1301 to suppress fire originating within essential electronic facilities provides a high degree of protection to data processing facilities. Certain electronic equipment facilities, including critical testing and processing apparatus, are of sufficient value or importance to warrant special protection. . . . Halon 1301 systems and associated alarm equipment must be installed to provide alarm and warning of potential fire and smoke damage due to fire originating external to the data processing area, and provide early detection and suppression of fires originating within the data processing center including . . . associated critical support areas . . . [43:p.A-72].

The working interpretation of this policy is that Halon 1301 systems must be installed in essential electronic equipment rooms. The result has been a recent predominance of Halon 1301 systems, though some Air Force facilities have both Halon 1301 and sprinkler systems (37).

National Fire Protection Association

The National Fire Protection Association (NFPA) is a national standard setting body similar to the body that publishes the National Electrical Code (NEC) or the American Society for Testing and Materials (ASTM). The NFPA has prescribed design considerations for both Halon 1301 and sprinkler systems and has listed electronic equipment as one of the activities suitable for a Halon 1301 fire extinguishing system (34:p.12A-8). No discussion is made of preferred fire extinguishing systems for essential electronic equipment and it was not possible to place the NFPA clearly on one side or the other of the Halon 1301 vs sprinkler systems issue.

Research Questions

In order to accomplish the research objectives, these research questions will be addressed:

1. What are the criteria that should be used to evaluate the suitability of fire protection systems for EDPE?

2. How do the two contending fire protection systems, Halon 1301 and sprinklers, compare with each other when measured against the evaluation criteria?

3. How can the evaluation results be incorporated into a recommendation concerning the most appropriate system to be used for fire protection of EDPE?

CHAPTER II

METHODOLOGY

Achievement of the stated objectives required the development of a methodology according to which the research would be conducted. This methodology consisted of establishing operational definitions, outlining a data collection plan, developing an analysis design, and stating appropriate assumptions and limitations.

Operational Definitions

Type "C" Construction

Type "C" combustible construction refers to the design of any structure in which one or more of the major components, such as walls, floors, roof, etc., consist of materials or assemblies which can burn (43:p.2-1).

Type "N" Construction

Type "N" noncombustible construction refers to the design of any structure in which the major components consist of materials or assemblies which either do not burn or have a Fire-Resistive Rating of at least one hour (43:p.2-1).

Fire-Resistive Rating

An evaluation (in units of time) of the demonstrated fire endurance capability of construction materials or assemblies to withstand failure or the passage of fire from one area to another (43:p.2-1).

Halon (Automatic Halon 1301 Total Flood System)

Halon shall designate a fire protection system which employs bromotrifluoromethane (Halon 1301) as the extinguishing agent. The Halon 1301 is stored as a liquid in pressurized containers that are either located at a central point (engineered central storage system employing a piping network to carry the agent to the discharge point) or at each discharge point (modular system). The system is actuated by a fire or smoke detection subsystem which may utilize a wide variety of detection devices such as products of combustion detectors, infrared detectors, and thermal detectors (either rate-of-rise or fixed temperature). As one detector senses a fire condition, an audible alarm sounds and the outside air intake of the air conditioning system shuts down. If a second detector senses the presence of a fire, a second alarm is sounded, all electrical equipment (EDPE, air handling units, etc.) is shut down, room openings are closed, a time delay between this detection and actual discharge of the Halon 1301 is initiated. If an abort switch is not activated within thirty to sixty seconds (which means the occupants were unable to locate and/or to extinguish the fire), the Halon 1301 is discharged. When discharged, the liquid agent quickly vaporizes and spreads throughout the room's atmosphere. The system is designed to "flood" the protected room with a five percent by volume concentration of Halon 1301 within about ten seconds. This concentration should last about ten minutes (9:108).

Sprinklers (Automatic Wet-pipe Sprinkler System)

Sprinkler(s) shall designate a fire protection system which employs water as the extinguishing agent. A basic wet-pipe sprinkler system is an integrated network of underground and overhead piping (either specially sized or hydraulically designed) which connects an adequate water supply with a specified number of systematically patterned automatic sprinklers (35:p.13-7). This system employs an independent automatic fire detection system which may utilize the same variety of detection devices as the Halon system. As the detectors sense a fire condition, an audible alarm sounds warning occupants that a fire is in its incipient stage and action should be taken to locate and extinguish the fire manually and/or evacuate the area. When sufficient heat is generated by a fire, the automatic sprinkler(s) will activate, discharging water over the fire area. The system also includes a water flow monitoring device which sounds an audible alarm and shuts down all electrical equipment when it senses movement in the system.

Data Collection Plan

Information on the two fire protection systems under study and the evaluation criteria used to establish their relative merits were obtained from four sources:

1. Federal and Department of Defense publications and reports;

2. Business, industry, and professional association reports, pamphlets, brochures, standards, and correspondence;

3. Books and periodicals; and

4. Personal and telephone interviews.

To become familiar with the state of the art and identify potential information sources, interviews with fire protection officials from the Air Force Engineering and Services Center, major air commands, and Wright-Patterson AFB, OH were conducted. Each individual contacted performed a key role in the development of Air Force policy for EDPE fire protection systems or was personally involved with the design, installation, and maintenance of specific systems. In addition to the knowledge gained from these interviews, secondary data in the form of standards, regulations, reports, periodicals, and intra-Air Force correspondence was furnished on a continuing basis.

The next step in the data collection process was library research of appropriate books and periodicals. To ensure a consistent data search effort, the following list of "key words" was developed:

Bromotrifluoromethane

Data Processing Centers, Fire Protection of

Fire Extinguishing Systems

Fire Suppression

Fire Protection

Fluorocarbons

Halon

Halogens

Sprinklers

Water

This list provided the basis for development of the initial bibliography and subsequent data retrieval.

In conjunction with the library research, correspondence was prepared and sent to leading manufacturers and installers of the two fire protection systems, explaining the relevant purpose of the research effort and requesting the most up-to-date, documented information concerning their respective systems' features and comprehensive performance characteristics. Similar correspondence was sent to leading manufacturers of EDPE requesting their position on the fire protection systems and supporting material for that position.

This correspondence was standardized so that each addressee would receive essentially the same guidance concerning the purpose of the research effort and the information desired. Four examples of the letters used are in Appendix B.

Even though 15 of 25 addressees did not respond (see Appendix C for correspondence schedule), a considerable amount of material was received and both fire protection systems were represented adequately.

The validity of each source was subjectively assessed according to such criteria as consistency with other references, quality of documentation (support for assertions), personal or employer related prejudice, and purpose of the information transmission (to advertise, to educate, to investigate). The assessments were difficult, and validity was a constant concern.

Analysis Design

In order to evaluate and compare the two fire protection systems, criteria were formulated that incorporated the needs of the Air Force and the preferred characteristics of an ideal fire protection system. Certain common evaluation factors emerged from the research. The genesis of these factors occurred as follows.

The authors of one book on computer security proposed these tests which the ideal extinguishing system must pass:

> 1. The system must quickly detect and promptly extinguish any fire, 2. The system must be safe--that is, people using the extinguishing agent must not be harmed thereby, 3. The system must be reasonable in cost and easy to install and maintain, and 4. The agent must leave no residue that may damage delicate equipment or costly objects, or create expensive clean-up problems [27:43].

National Aeronautics and Space Administration (NASA) used four similar criteria in reviewing the relative merits of Halon and Sprinklers during a 1978 policy review: "Reliability, agent effectiveness, minimal physiological/toxicological impact on personnel, and cost effectiveness [10:2]."

Selected Criteria

From these two references, four factors were selected as measurement devices against which to compare the merits of each system:

1. Reliability. Will the system work the way it is supposed to when it is supposed to? What is the possibility for error in design, installation or testing, for a malfunction, and what effect would any or all of these events have on the effectiveness of the system?

2. Maintainability. How frequent and of what scope is the maintenance requirement and how available is the expertise?

3. Cost. What costs can be expected for installation, agent charge(s), and maintenance?

4. Safety. To what extent are the safety and health of personnel endangered?

Additional Criteria

The authors of this research effort proposed four of their own criteria, gleaned from their experience in USAF Civil Engineering and discussions with fire protection engineers.

1. Adaptability. Base Civil Engineers are constantly confronted with requests for interior remodeling from all base activities, including computer installations. A fire protection system that was difficult to expand or alter would be less desirable than one that could be readily modified. Can the fire protection system, then, be adapted to the new scheme or layout and with what ease?

2. Catastrophic Fire Potential. While USAF has pursued a policy emphasizing non-combustible construction for new facilities, many computers still reside in structures of less fire resistant construction. Even in the case of non-combustible construction, such post-design variables as the compromise of floor-to-floor integrity for utilities and the presence of combustibles in the room introduce the prospect of catastrophic fire (27:35). How well can the system deal with a catastrophic fire?

3. Overseas Support. Overseas environments often pose unique challenges. Will the system suffer degradation of effectiveness due to any unique overseas problems?

4. Equipment Downtime. Most managers are familiar with the disruptive implications of the feared phrase, "the computer is down." Certainly in the Air Force, where many vital tasks are performed by computers, downtime can be costly. A system that would impose a long equipment downtime following activation would be unacceptable to at least some activities. How quickly, then, can the equipment be returned to operation and is this quick enough to meet Air Force requirements?

Systems Evaluations

A modified version of the comparative research method of analysis as described by Robert G. Murdick (33:180) was used to interpret the similarities and differences of the two fire protection systems according to each of the eight criterion. A determination was made as to whether one system was superior or equal to the other based on a careful but subjective critique of the evidence produced by the data collection effort.

The decision to use a comparative analysis with unweighted criterion was made because of the following considerations:

1. verification of a weighting system which would have represented the needs of all EDP functions in the Air Force would have required extensive survey, investigation, and coordination with upper echelon policy makers and was beyond the scope of this research effort;

2. the variety in missions and priorities which existed within the Air Force due to the broad application of EDP to many activities suggested that no single weighting system could have satisfied such a diverse constituency; and

3. use of a set of unweighted criteria represented the "a priori" judgement of the authors on the

most reasonable method to compare Halon and Sprinklers due to the difficulty of measurement, in any objective way, of the characteristics of these systems.

The system recommended as the most appropriate was the one with the most "superior" ratings, provided it met the minimum requirements of the Air Force.

Assumptions and Limitations

Assumptions

No new fire protection concepts or agents for electronic data processing equipment would be developed in the next decade. Similarly, no new EDPE would be developed which would drastically alter fire protection requirements. Future Halon installations would be predominantly modular in design, reflecting the industry trend. Since EDP areas require careful climate control, there would be no danger to Sprinklers of freezing pipes.

Limitations

This research effort related strictly to essential electronic data processing equipment which was housed in buildings (either type "C" or type "N" construction) having all normal utility and emergency services. Equipment specifically excluded was that contained in aircraft, mobile vehicles and trailers, remote sites, and flight simulators. Also excluded from specific study were the under-floor and above-floor portions of EDP rooms. These exclusions were based on the presence of unique requirements that were beyond the scope of this research effort. Additionally, evaluation of the two systems against the measurement criteria, though documented, was subject to the opinions of the researchers.

CHAPTER III

ANALYSIS

During the course of the data collection phase, several observations were made that had significant impact on the analysis. First, it became evident that the amount of information available was not in any way related to the importance of each criterion. Second, the fact that the two systems were quite different in concept made a direct, point by point, comparison within each criterion category difficult. Consequently, each system was discussed separately (within each criterion category), followed by a summary of the key research findings relative to the particular criterion and a statement describing the results of the comparative analysis for that particular criterion. Following the convention established in this report, system discussions began with Halon and were followed by discussions of Sprinklers.

Reliability

Establishing the reliability of the two systems required an investigation into many facets of their operation. The purpose of the investigation was to assess the ability of each system to do what it was supposed to, when it was supposed to, how it was supposed to. However, the interrelatedness of many facets of operation and the form in which data was received made a comparison based on common features difficult. Consequently, the basic format for analysis consisted of a description of key functions or operations followed by a search for failure opportunities.

Halon

Reliability was recognized as a desirable attribute by proponents of Halon. One of the better known manufacturers of Halon systems expressed this well in one of their publications where it was stated that they had

> . . . a tested, proven system to match your requirements. In these systems, sensitive and reliable detection devices are linked to ultra fast means of alarm and extinguishment. They are perfectly timed to respond rapidly and positively, even after years of stand-by alert. There is no room for error [24:2].

These definitely represent desirable features for a fire protection system and indicate the potential that Halon has in the fire protection role. Strong endorsements could also be found for the effectiveness of Halon in fighting fire. One description of a Halon installation in a computer room commented that it

> . . . combines highly effective smoke detection devices with specially developed mechanical components

for automatic, high-speed, "fire-stop" spraying. Testing of the system has established that: It takes only five seconds from fire detection to spray activation; the spray is effective in limiting flame propogation, as well as damage to fragile equipment . . . [47:34].

Examination of these claims and the relative merits of Halon required a careful investigation into the sequence of activities and operations that characterize Halon, including a final look at the efficacy of the gas, Halon 1301, itself.

The first activity for consideration involved the design of the system. Consideration must be given in design to the scope of hazard protection--how much area or which rooms should be protected--and the nature of the hazard, particularly as it related to the concentration of Halon 1301 needed to accomplish extinguishment. Questions that must be answered included: Where should the agent storage be located? Where should controls, especially manual controls, be located? What method of automatic actuation was best? What alarms (remote?) were needed? These questions went beyond the issue of technical adequacy--a "working" design--into the area of human engineering. Was the system designed so that it would not be inadvertently defeated by the inherent fallability of human beings? Such questions only touched on the variety of items that needed consideration (2:69). The sensitivity of Halon to human influence and unforeseen contingencies became evident as the actual system functions were analyzed.

Automatic detection of a fire in its incipient stage was a feature common to both Halon and Sprinklers. However, whereas in the case of Sprinklers automatic detection served mainly to warn personnel, Halon also depended on detection to actuate the system. Consequently, detection was a crucial element in the operation of a Halon system. Two variables essentially determined the effectiveness of detection. The first was the type of detector. The heat detector was one of the most reliable. Smoke detectors were also used.

> Products of combustion detectors or ionization detectors compete with optical smoke detectors and expertise is needed to determine which is best for an individual location. Examples of where they might be used are computer rooms (ionization) and associated paper records storage (optical) [2:69].

Often, a mixture of two or more detectors was distributed throughout the area protected to compensate for the shortcomings of each type of detector. The second variable was the pattern in which the detectors were wired. A generally accepted principle in wiring detectors was the concept of zoning.

> Arrangements where alternate detectors are wired to individual controls (zones) and require the activation of more than one detector for discharge are called cross-zoning. This is popular in occupancies such as computer rooms to reduce the likelihood of system actuation with a controllable small fire [2:69].

Actually, detection inherently presented a tradeoff between timeliness and proper operation. Detection as early as possible improved the potential for limiting fire loss, but as the sensitivity of the detection increased, the greater was the possibility of false actuation. And false actuations were expensive and annoying (2:69). Several manually operated devices could compensate for detection system failure. In the case of a false alarm, false smoke signal (as from cigar smoke), or very small fire, an abort switch provided a means of stopping the system between initial detection and the start of the discharge. Such a control could be electronically supervised to assure that it was not accidentally deactivated. Similarly, a manually operated "pull" station could be incorporated which overrode all other systems to release the extinguishing agent upon command (47:34). The abort switch was a valuable device because false alarms, whether introduced by the detection circuit or some other source, were not uncommon. An interesting sidelight on detection was that often halogenated gases were used to test detectors. This meant that the release of Halon 1301 under actual or test conditions, if not rigorously confined, could spread to other zones or rooms not requiring a response and set them off as well. Such an occurrence would be costly as well as result in a temporary loss of protection. The detection function operated in two stages. The first detector to actuate rang an alarm bell, drawing attention to the area so that an investigation could be made. This, theoretically, allowed time for EDP personnel to assess the danger and attempt hand extinguishment if appropriate. Central control panels, referred to as annunciators, offered lighted displays to signal vital information to occupants and aid in identifying the location of the danger. But things did not really begin to happen until the second detector was actuated.

Actuation of the second detector initiated a number of actions. Most, if not all, of these actions were supervised by the annunciator panel. One action was to engage a timer which allowed a fixed period of time, such as one minute, for evacuation of personnel and/or tripping the abort switch. Another action was to de-energize the EDP room and its equipment. This was not so much to prevent damage from the Halon 1301 gas (which was not likely) but to prevent damage from short circuits and arcing or other hazardous condition originating within the equipment or its associated wiring. A third and extremely vital action was to seal the room. This was necessary because loss of agent could lower its concentration below the extinguishment threshold. One implication was,

> When using gaseous agents, efficient system design dictates that outside air not be added to the protected area nor the extinguishing gas removed before the agent has done its job. Any air supply or room exhaust that takes place after the gas discharge has started will require additional extinguishing agent [2:69].

All central building air conditioning systems serving the computer room and all separate computer room air conditioning systems which allowed the entry of outside air had to be shut down. Duct dampers were necessary to seal ducts. In certain cases, rooms with their own dedicated air conditioning systems might continue to operate, which would assist in distributing the Halon 1301, and the filtering and cooling provided by the air conditioner would limit the amount of smoke and heat entering the EDP equipment (18:9). There was another factor that had to be dealt with.

> No room enclosure is absolutely tight. Miscellaneous small openings will not complicate design and, in fact, may aid by venting pressure buildup. But uncloseable openings, such as wall or door louvers, wide openings under doors, and undampered vents can significantly reduce the time a fire suppressing concentration is held within the protected enclosure [2:70].

In addition to providing self-closing devices for these openings that were coupled to the operation of the Halon system, doors, shutters, etc., that might be open during normal operations had to also be closed. Caulking and sealing usually had to also be taken into account in the design (4:3). Following sealing the room, the final action was release of the agent. The exact manner in which the agent was released depended on whether the system used modular or central storage. The modular system consisted of properly positioned containers outfitted with a dispensing nozzle (or two). The signal from the annunciator panel typically set off an explosive which broke the seal on the container, releasing the Halon 1301. In the case of central storage systems, a somewhat more complex procedure was invoked since these systems depend on a piping network to deliver the agent. Consequently, it was first necessary to open the proper directional valve to route the agent to the affected zone and then open the cylinder(s) protecting that zone (24:10). The piping itself presented some additional complexity which had to be accommodated. For instance, computers calculated flow rates and pressure drops to determine optimum nozzle and pipe sizes. The computer program, based on NFPA Standard 12A, incorporated two-phase (liquid and vapor) flow calculations (24:10). Performance of the piping was closely related to the quality of the installation.

> Of concern in installation is the proper preparation of the pipe (reaming and cleaning). Improper installation can affect the calculated flow, while improper cleaning can cause the plugging of nozzle orifices or valve malfunction. Of concern also is that halons are excellent solvents. For instance, if the pipe is not completely clean, a discharge can cause oil or other substance in the pipe to be picked up in the discharge and result in staining of the ceiling and room surfaces.

> It is important that nozzle locations and pipe runs be consistent with the calculated design. All too often, however, planned pipe or nozzle locations are found in the field to interfere with structural or equipment items and, therefore, must be relocated. In some cases relocation can be done without rechecking the design; in other cases, the locations are critical, and the system designer should be consulted in each case for guidance [2:71].

The discharge of the agent itself usually had to be accomplished within ten seconds (19:19) and might take much less time (47:34).

Before proceeding, it should be mentioned that the various actions now identified as part of the operation of Halon depended on a reliable power source. Even those systems relying on pneumatic controls still required some functions to be electrically operated. Battery operated standby power was, therefore, usually necessary. This standby power was to be adequate, long lasting, and reasonably free of maintenance (2:70;18:9).

The previous discussion on the reliability of Halon has demonstrated the number of complimentary actions that must be performed for successful operation of the system and identified the variables that can influence the success of operation. Several comments are pertinent to this observation. First, the aspect of Halon was recognized by responsible officials and the concept of "supervision" and the practice of testing were applied to control the potential uncertainty in the system. Supervision generally referred to the ability to monitor, and occasionally alleviate, trouble.

> It is often a good investment to provide continuous electrical supervision of the power supply and key electrical control circuits. There are two classes of supervision available. One signals when system trouble develops. Another signals and establishes an alternate electrical circuit for equipment operation. But costs increase substantially as sophisticated features are added, and such features often increase equipment delivery times [2:70].

Full discharge testing, at least upon system acceptance, would seem to be "de rigueur." Yet, this was not always the case, often because of the cost involved, even though Halon 122 was commonly used as the test gas for Halon to reduce the test cost. Even full discharge testing, though, could be of dubious value when the system was helped along via manual closing of openings and artificial generation of the initiating detection signal. Be that as it may, from whatever kinds of full discharge tests that have been performed,

> Experience has demonstrated that, in a reasonably high percentage of installations, unknown or unexpected conditions that would affect system performance are discovered [2:71].

A survey done by Industrial Risk Insurers (IRI) (8:14) revealed that 67 percent of installations failed their acceptance test the first time around and that this situation was due to the following reasons:

A. System control units
 ·air conditioners do not shut down
 ·alarms do not sound

- annunciators are improperly wired
- auxiliary alarm functions fail
- control panels are used beyond amperage capacity
- dampers do not close
- detectors do not work
- doors fail to close automatically
- emergency generators fail
- exhaust fans are improperly started
- power shutdown fails

B. Halon system components
- agent storage containers are empty or improperly filled
- nozzles are loose
- pipes are obstructed
- selector valves fail

C. Hazard requirements
- ceiling tiles are dislodged
- leaks go unnoticed
- minimum discharge requirements are not met.

It would not be unreasonable to suspect that one or more of these failures could recur even after successful completion of an acceptance test. Other reliability problems included the following:

1. use of components from different manufacturers offered potential for varying degrees of incompatibility;

2. internal circuitry problems could cause indicator lights to behave erratically or malfunction;

3. power failures have been known to alert Halon;

4. electric impulses from unknown sources (static electricity?) have been known to discharge Halon;

5. false alarms were not uncommon.

Though many of these difficulties were surmountable, there appeared to be considerable opportunity for a malfunction regardless of efforts to the contrary. There remained yet one issue of interest.

The last issue to be discussed in conjunction with the reliability of Halon was that of the effectiveness of Halon 1301 gas in putting out a fire. Part of its value came from the fact that it was effective on a wide range of combustibles (2:65). Also, because it was a gas, it could penetrate into every recess and compartment within the equipment, let alone the room, attacking the fire at its source. Its limitations became evident when attention was focused on the nature of the fire: was it surface burning or deep-seated?

> Surface burning materials are those in which the burning matter is fully accessible to the extinguishing agent. Barring a continued external source of ignition, the fire remains extinguished once the open burning of these materials is stopped. Deep-seated burning materials are those that burn with an open flame and at the same time create a penetrating burning, which insulates itself with the ash of the material burned and the remaining unburned matter. Stopping open burning does not mean that the fire will remain extinguished in this case. The deep-seated hot core will continue to consume the surrounding unburned material and will rekindle to open burning when the suppressant concentration is vented [2:66].

Halon 1301 could easily handle surface fires but in concentrations in the five to seven percent range, it would not totally extinguish a deep-seated fire in any reasonable amount of time. This was relevant for, while cables, circuit boards, tapes and other materials common to computers were surface burning (2:66), Class A combustibles such as paper and cardboard were not. Consequently, there was potential for reignition when these materials were present and had become involved in the fire. Nevertheless, since the concentration was supposed to be held for ten minutes (9:108), this should have given sufficient time for Fire Department or other concerted response. Therefore, the problem of deep-seated fires was not considered to be a threat to the suitability of Halon 1301 as an extinguishing agent.

Sprinklers

The case for Sprinklers relied strongly on the principle of reliability. As was seen in the opening discussion on the reliability of Halon, similar claims had been made for Sprinklers. In a paragraph entitled "Summing It Up for Sprinklers," one source stated,

> They are always ready and operate soon after a fire starts, before the flames can gather dangerous headway. Only those sprinklers in the immediate vicinity of a fire operate. They use water with maximum efficiency and without causing extensive damage away from the fire area [23:17].

Some of the enthusiasm for sprinklers undoubtedly drew on the long history of the use of water as an extinguishing agent and the fact that the first automatic sprinkler system was invented and put into practice in

1874 (39:42). This latter fact was important because it meant there was over 100 years of experience and development from which to draw on in this analysis.

The concept of a wet-pipe sprinkler system was relatively simple: the piping network, which is tied in to a water supply, is constantly filled with water, and the opening of a sprinkler head (actuated by heat) dispenses water directly beneath that head (or however many heads have been actuated by heat). The head(s) continues to dispense water until the control valve is closed. Despite this apparent simplicity, the successful operation of an automatic sprinkler system did depend on the proper execution of a number of different factors.

The design of a sprinkler system was mainly concerned with technical adequacy. An adequate water supply must be provided; municipal water supplies were usually, but not always, sufficient. Where supply was a problem, alternatives such as dedicated storage, hydraulic design (112:9) and other techniques could compensate for limited water supplies. The hardware for the system had to be properly selected:

> Care must be exercised that orifice sizes, temperature rating, deflector style, deflector distance from ceiling, sprinkler spacing and pipe sizes are in accordance with National Fire Protection Association rules or the approving body having jurisdiction [45:5].

Appropriate alarms had to be selected. And, last but not least, human engineering and fallability also needed to be considered.

An automatic detection system was not necessary for operation of Sprinklers. Nevertheless, its inclusion offered advance warning of a possible hazard, giving the occupants time to explore the situation, shut down power, and attempt manual extinguishment and it could be used to notify the Fire Department. The reliability of detection depended on selection of the proper type(s) of detector(s), use of zoning, and the choice between sensitivity, timeliness and false alarms. All of the characteristics of detection systems described previously in the discussion of Halon applied with one crucial distinction: operation of Sprinklers was unrelated to the behavior of an automatic detection system. Instead, each sprinkler head had its own detector, a simple heat sensitive coupling which fused when the design temperature or rate of temperature rise was reached, opening the head and dispensing water. A corollary detection system, consisting of water flow alarms, existed to warn of any movement of water in the system. Such devices gave an alarm notification when water flowed through risers or mains supplying the system.

> These devices are designed and adjusted to give an alarm if a water flow equal to the discharge of one or more automatic sprinklers occurs in the sprinkler system [32:p.14-50].

Water flow may be due to fire, leakage, or accidental rupture of the piping. A water flow alarm was an integral part of a sprinkler system:

> A sprinkler system with a water-flow alarm serves two functions: that of an effective fire extinguishing system, and that of an automatic fire alarm. Immediate notification by an alarm of the operation of sprinklers is important to complete extinguishment of the fire and place the system back in service. Under some conditions the sprinklers do not immediately or completely extinguish the fire, and it is vital to have someone notified to complete extinguishment, either by portable extinguishing devices, private hose streams, or fire department equipment [32:p.14-49].

The detection offered by water flow alarms also provided a signal source to automatically de-energize (or "switch off") electronic equipment.

Now, switches are to electrical circuits as valves are to plumbing. Sprinklers were equipped with a master control valve and possibly other control valves to facilitate maintenance on the system and to stop water from flowing through the system once a fire had been extinguished. The danger was that the valve could be (left) closed when a fire occurred. Two methods existed to deter closed-valve conditions. One long-standing practice in the industry was the use of a formalized "Red Tag" system.

> It provides for affixing a red warning tag to the hazard, for taking certain fire-safety precautions during the impairment, and for notifying the insurance company so that its engineers can help management remember that the valve is shut and should be reopened at the earliest possible moment [39:44].

A weakness was that it did not motivate management to insist on its use or to make sure that it was being used. The second approach involved the use of new valve designs. New designs incorporated high visibility indicating systems to reduce the chance for a valve to be left closed. Indicators on these valves could be seen from several hundred feet away from any direction (39:44). Another design was the Normally Open Valve Assembly (NOVA). It stayed open until someone applied manual energy to close it. As soon as the closing effort ceased, it would promptly reopen. Special energy units would be used to lock the valve closed when absolutely necessary.

A wet-pipe sprinkler system, since it was constantly under pressure, certainly seemed to possess leak potential. The relevant findings were that leaks were more likely to occur from damage due to external forces than from failure of the system components.

> . . . a sprinkler system is very rugged, and the pipe, sprinklers, and fittings are made to stand far greater water pressures than are met with in practice. The supports are strong also, and the system is so installed that it should remain intact, even under severe mechanical strain, including any anticipated earthquake shock or movements [32:p.14-69].

In regards to the first comment about water pressure, the NFPA required that

> All piping and devices under pressure (including yard piping and fire department connections) are tested hydrostatically for strength and leakage at not less than 200 psi pressure for two hours, or at

> 50 psi pressure in excess of the maximum static pressure when that pressure is in excess of 150 psi [32:p.14-15;35:p.13-12].

The NFPA also required that all aboveground leakage had to be stopped (35p.13-14). Nevertheless, industrial accidents, explosions, or freezing could rupture the system, though their occurrence was likely to be infrequent, particularly in EDP rooms.

The long history of sprinkler systems and their widespread use led various organizations to collect data on the effectiveness and reliability of these systems. For instance, one major insurer, Factory Mutual, found, among its clients, that in fires where sprinklers operated, 71 percent were extinguished or controlled by five sprinklers or less, and an additional 23 percent by 25 sprinklers or less. Only two sprinklers were necessary to control the average fire (23:17). Another source stated that sprinklers were 96.2 percent effective, the result of analyzing some 58,0000 fires over a 30-year period (44:2). This report also stated that in six out of ten cases, sprinklers extinguished fires without any assistance, and in the other cases held it under control until the fire department arrived. In the 3.8 percent of fires where sprinkler failure occurred, an improper water supply or increased fire hazard was at fault. An improper water supply meant that there was either insufficient water or that the water was turned off before the sprinklers operated (or before the fire was extinguished). Increased hazard situations were those in which fire hazards were allowed to grow beyond the original scope of the sprinkler system and without a corresponding modification of the system. Furthermore,

> The odds against accidental discharge of sprinklers due to manufacturing defects are estimated by an internationally recognized fire testing laboratory as 16,000,000 to 1 [44:3].

Nevertheless, there was some evidence that in recent years the percentage of satisfactory sprinkler operations had declined. NFPA statistics for the period 1970 to 1974 indicated the percentage to be only 81. But this could have been due to the nature of the NFPA's data gathering method which concentrated on those fires resulting in larger losses. Other studies (such as the New York Board of Fire Underwriters, Factory Mutual, etc.) that were based on nearly 100 percent reporting showed considerably higher success rates (32:p.14-4).

Summary

The two systems, while prone to claims of high reliability, were found to possess numerable opportunities for malfunction. Halon was relatively sophisticated and relied on a carefully executed sequence of operations to perform successfully. Failure of any of a number of operations could jeopardize this performance. Experience from acceptance testing suggested that a properly functioning system was not the standard. Sprinklers benefitted from a much lengthier history of development and a simpler concept. Sprinklers depended not so much on any sequence of operations to perform successfully but rather the existence of a certain set of conditions. Deviations from these conditions could reduce system effectiveness or result in failure, but the opportunities for deviation were few and the record suggested that Sprinklers were highly effective. Consequently, it was concluded that Sprinklers provide significantly greater reliability than Halon.

Maintenance

There are few systems known to man that do not require some form of maintenance. In fact, without maintenance, most systems will eventually break down. Halon and Sprinklers were no exception to this principle. However, due to the different natures of the two systems, the maintenance requirements were correspondingly different. The following analysis will first examine Halon maintenance requirements, follow with an examination of Sprinkler maintenance requirements, and then compare the two in the Summary.

Halon

Maintenance had been referred to as the single most important part of any Halon system (4:1). This source, a widely respected installer of Halon, had 96 percent of its 600 plus Halon installations under service contract for maintenance. And the reason some reports had quoted high figures for the percentage of Halon systems that did not work was not the equipment, but poor installation and no maintenance (4:1). Before proceeding further, a review of the maintenance requirements was in order. The following maintenance program was assembled by combining best industry practice with minimum and suggested NFPA criteria.

The monthly maintenance actions consisted of the following:

1. Check pressure gages on storage containers. If the pressure is below the minimum allowable, the cylinder must be repressurized by a qualified recharge agent (38:31).

2. Check for mechanical damage or tampering (38:31).

3. Check that lead and wire seals and manual pull stations are in place and intact (38:31).

The semi-annual requirements were:

1. Repeat monthly checks.

2. All detectors will be tested, cleaned, and readjusted if necessary (31:1).

3. Refill batteries to proper level and adjust battery charger unit to proper voltage (31:1).

4. Megger (check for grounds in) all wiring in the initiator circuit (the initiator opens or breaks a

seal on the Halon 1301 storage container, allowing the agent to discharge) and test the initiator circuit to assure proper firing current (31:1).

5. Test the master control unit for proper operation (31:1).

6. Activate each detector to make sure the alarm is operating properly and that the annunciator (the panel that relays information concerning which zone is in alarm status) is working properly (31:1).

7. Check all agent storage containers for proper liquid level, i.e., proper quantity of Halon 1301. (May require some disassembly of Halon system in order to remove containers for weighing. Some effort may be saved if containers have a direct reading calibrated probe (109:10). If weight loss is greater than the maximum amount allowable, the container must be recharged by a qualified recharge agent and the system reassembled (38:31).

8. Test all field wiring for proper values and continuity (31:2).

9. Test all lamps, switches, interlocks, alarms, and other electrical components (31:2).

10. Examine containers and piping for evidence of corrosion or mechanical damage. Examine bracketing, supports, pipe hangars, etc. for damage and looseness (34:pp.12A-104,12A-105).

The following were done annually:

1. Repeat semi-annual checks.

2. Check closely for uncloseable openings and sources of agent loss which may have been previously overlooked (32:p.15-38).

3. Check interlocks for proper shutdown of electronic and ventilating equipment (32:p.15-38) and closure of doors, louvers, vents, etc.

In addition, there were several other maintenance considerations. The Halon 1301 containers had to be hydrostatically tested every five years (34:p.12A-18). Defective and deteriorating items, such as batteries and explosives, had to be replaced. And, if the system was actuated, it then had to be reconditioned, which would at least require filling and pressurizing the agent storage containers and replacing components expended or destroyed during operation of the system, as well as performing many of the semi-annual maintenance tasks.

Halon maintenance was not a simple nor infrequent activity. Its extent and technical nature once again demonstrated the sophistication characteristic of Halon. But who, then, was qualified to maintain Halon? Some contractors, recognizing the special expertise necessary, offered maintenance by contract and many clients seemed to prefer this arrangement (4:1). The Air Force also decided to contract its Halon maintenance. This may have been more of a necessity than an option if training opportunities were any indication of the organic ability of the Air Force to maintain Halon. It was instructive to note that neither the Fire Protection School at Chanute AFB, IL, nor the Civil Engineering Technical Training School at Sheppard AFB, TX, offered any training in Halon maintenance (16:28). These two schools provided the primary training for Base Civil Engineer personnel, and it was the Base Civil Engineer who would normally inherit the responsibility for the maintenance of fire protection systems. The lack of training courses suggested that the Base Civil Engineer, hence the Air Force, was generally not able to maintain Halon and had to rely on contractor services. This undoubtedly increased administrative hassles when entry into secure areas was required and, most importantly, jeopardized the performance of Halon (thereby jeopardizing the essential EDP activities protected by same) in the event of any emergency or unusual situation in which contractor services were not readily available. Dependence on contract maintenance may or may not have been a serious problem, since many private organizations, at least some of whom could be expected to possess essential EDP functions, did depend on contract maintenance (4:1). One might suspect, though, that the situation the Air Force currently found itself in was one of de facto submission rather than official policy.

Sprinklers

Regular maintenance of sprinkler systems was vitally important to successful system operation despite the intuitive tendency to lump Sprinklers in with general purpose plumbing which often went neglected until a break or malfunction occurred. Sprinkler effectiveness was strongly related to the quality of maintenance as could be seen by the following maintenance requirements.

The weekly maintenance actions were (36:p.13A-9):

1. Inspect main control valve to make sure it is open, inspect other valves for proper position and that all are in good condition.

2. Inspect sprinkler heads to make sure they are in good condition, clean, not painted, and not bent or damaged.

3. Read gages showing water pressure to make sure normal pressure is being maintained.

The following were quarterly requirements (36:p.13A-10):

1. Perform a water flow test (at the water supply test pipe).

2. Test water flow alarm devices and water-motor gongs.

3. Test electric alarm operation and emergency power, including battery condition.

The following were done semi-annually:

1. All detectors will be tested, cleaned, and readjusted if necessary.

2. Activate each detector to make sure the alarm is operating properly (and that any hazard location panel is working properly).

3. Test all switches, interlocks, alarms and any other electrical components.

And the annual requirements were:

1. Inspect sprinklers for installation in the position for which they were designed and marked.

2. Inspect sprinklers for proper temperature rating.

3. Check accuracy of water pressure gage.

4. Inspect condition of piping and hangars; are any hangars loose or piping not properly supported?

In addition, there were several other maintenance considerations. During the water flow tests, a reduction in flow or the discharge of obstructive material could indicate obstructive potential. If there was danger that sprinklers could be affected, a complete flushing program was to be carried out. All sprinkler heads were to be replaced after 50 years (45:5). They were also to be replaced when they became painted, corroded, or otherwise damaged. Also,

> Once fused, automatic sprinklers cannot be reassembled and reused. New sprinklers of the same size,

> type and temperature rating must be installed. A cabinet of replacement sprinklers should be provided for this purpose [45:5].

Furthermore, a sprinkler that was dropped or damaged in any way was not to be installed unless it was retested by the manufacturer. It was also necessary to use only the special sprinkler wrench provided by the manufacturer for sprinkler head removal and installation. Any other type of wrench might damage the sprinkler (45:5). In the fall, the building was to be inspected to make sure cold air would not enter, nor unduly expose, sprinkler piping to freezing.

Regular Sprinkler maintenance could not be ignored if an effective system was desired. However, the types of components used in Sprinklers (piping, valves, and gages) and the general relationship to standard plumbing practices indicated that highly specialized training was not required for Sprinkler maintenance. This might explain why no real evidence was found for the existence of Sprinkler maintenance contracts in the Air Force. In other words, perhaps there did exist an organic ability within the Air Force to maintain these systems. Though the Civil Engineering Technical Training School at Sheppard AFB, TX, only provided an introduction to sprinkler systems in its basic technical course for plumbers (16), the Fire Protection School at Chanute AFB, IL, went much further. The Fire Protection School offered training in all areas of fire protection. Among the courses offered was a Fire Prevention Inspector Course which explained, in detail, the operation of sprinkler systems. Actual working sprinkler systems in their laboratory enhanced this training. When graduates of the course returned to their base, and as they rotated into inspection positions within the Fire Protection Branch, they were able to perform many of the necessary maintenance tasks on sprinkler systems in conjunction with the periodic facility inspections that were the responsibility of the Fire Protection Branch. If and when problems were discovered, appropriate Civil Engineering craftsmen might be called in to make repairs (28).

Summary

Regular maintenance was necessary if Halon and Sprinklers were to function as intended. Whether one system or the other required "more" maintenance could be debated, but it was quite apparent that Halon maintenance was much more sophisticated than Sprinkler maintenance, required specialized training, and that the Air Force did not possess such special skills, while it did have the simpler skills required for Sprinkler maintenance. Leaving unresolved the questions of whether or not Halon was prone to maintenance related failure and Sprinklers were more immune to poor maintenance practices, it had to be concluded that Sprinklers were more compatible with Air Force maintenance capabilities and that the sophistication of Halon imposed difficult maintenance requirements. Consequently, Sprinklers had a definite advantage over Halon in the area of maintenance.

Cost

Fire protection systems vary in cost depending on the type of system, scope of protection, and the number of features. Consequently, in comparing any two systems, if the costs were not much different, such variables as these could account for the difference. Demonstrating that a difference exists required either very precise calculations with respect to features or evidence that one system was by its very nature a more expensive system, in which case the difference between the two would more than make up for the presence or absence of special features. The costs of fire protection also had to be kept in perspective: an expenditure of even $10 per square foot for fire protection was hardly significant in the wake of the EDP system itself, which might have an average dollar density in the range of $2,000 to $6,000 per square foot (18:1).

Halon

Several figures were obtained regarding the cost of a complete, installed Halon system. One source estimated the cost of an engineered (central storage) system at about $10 per square foot, based on an average nine foot ceiling height and a one foot raised floor (4:1) (a modular system would be slightly more expensive). This particular firm included in their price a final checkout of the system, complete drawings, a technical training session with client personnel, and a one year maintenance contract. Their price included about 20 to 30 percent for the automatic detection system (both above and below the floor) and about 20 percent for the below the floor Halon 1301 dispensing system (6). Subtracting 12.5 percent for below floor detection and the 20 percent for a below floor dispensing system left about 67.5 percent or $6.75 for a complete, above floor Halon system. This compared favorably with the price quoted by Means' "Building Construction Cost Data 1980" (26:226). Means suggested a range between 60 cents to 95 cents per cubic foot for Halon, which in a room with a nine foot high ceiling would translate to $5.40 to $8.55 per square foot.

The cost of the agent had to be considered also. At the time of this research, Halon 1301 cost $6.50 per pound (4:3). To give an example of how this translated into total agent cost for an EDP installation, figures were obtained for the EDP center at HQ AFLC (Air Force Logistics Command), which was located at Wright-Patterson AFB,OH. While the size of this protected area might not be typical, the costs, which were illustrative, are shown in Table 1 (5:1).

TABLE 1

HQ AFLC EDP CENTER HALON 1301 REQUIREMENTS

Firing Zone	Area	Weight of agent Required	Price per Pound	Cost of Agent
1 & 4	13,430 SF	2,750 lbs	$6.50	$17,875
2 & 5	18,600 SF	4,500 lbs	$6.50	$29,250
3	11,830 SF	2,500 lbs	$6.50	$16,250
Total	43,860 SF	9,750 lbs	$6.50	$62,375

Discharges under test or actual conditions could not be considered inexpensive due to the cost of Halon 1301. A discharge under false alarm conditions would be particularly discomfiting. For tests, Halon 122, a much cheaper gas, could be used. Nevertheless, the large volumes and significant quantities involved caused some users to be reluctant to perform an adequate test of the installation. Once the system had been filled with the more expensive Halon 1301, they were reluctant to adequately check the system on a periodic basis for fear of a false actuation, and they might have been reluctant to trip the system for the extinguishment of a small fire (7:4). Such reluctance could jeopardize the effectiveness of Halon since tests were valuable in revealing system problems.

Sprinklers

Several figures were obtained for the cost of complete, installed sprinkler systems. Two observations were necessary in regard to these figures. Though there were different sprinkler systems available (wet-pipe, dry-pipe, pre-action, deluge, fire cycle, etc.), cost figures were not necessarily appropriate for a wet-pipe sprinkler system. But this merely added an element of conservatism to the analysis since wet-pipe systems were the least expensive of the lot (26:228). The second observation was that commonly quoted costs for sprinkler systems did not include a separate detection system such as found with Halon and as identified as part of Sprinklers. To insure a balanced comparison, the same cost for detection would be used for each system. The cost for above floor detection thus turned out to be $1.25 per square foot.

A sprinkler manufacturer suggested that pre-action or deluge systems cost approximately $1.20 per square foot. A computer firm advised,

> We normally provide for ordinary hazard protection which is approximately 100 square feet coverage per head. We find that the cost for installing a system in an open area is approximately $1.75 per square foot [30:1].

This would result in a slight over-design and over-expense since the NFPA regards data processing as a light hazard occupancy (35:p.13-119).

Means (26:228) recommended the cost for a wet-pipe, office environment, concealed piping installation be calculated at $145 per sprinkler head. Since the NFPA specified that "Under smooth ceiling construction . . . the protection area per sprinkler shall not exceed 200 square feet [35:p.13-70]" and some consideration ought to be given to overlap, a figure of 100 square feet per sprinkler head would be conservative. This would translate the Means' cost to $1.45 per square foot. These figures suggested an average of about $1.50 per square foot, but this was without detection. Adding the $1.25 per square foot detection cost brought the total cost for <u>Sprinklers</u> to about $2.75 per square foot. Since water was the agent, the cost of agent was considered negligible.

<u>Summary</u>

The cost of <u>Halon</u> was found to range between $5.40 and $8.55 per square foot, suggesting the influence of special features on cost. This compared with a cost of approximately $2.75 per square foot for <u>Sprinklers</u>. The Halon 1301 agent cost about $6.50 per pound while the cost of water was negligible. These differences may be best visualized by examining the costs that would be experienced in outfitting a hypothetical 10,000 square foot EDP room. Typical costs are shown in Table 2.

TABLE 2

COST COMPARISON

(Hypothetical 10,000 square foot EDP room)

System	Room Size	System Cost per square foot	Total System Cost	Agent Recharge Cost
Halon	10,000 SF	$5.40 (Low)	$54,000	15,000*
		$8.55 (High)	$85,500	15,000*
Sprinklers	10,000 SF	$2.75	$27,500	---

*based on relationships expressed in Table 1.

Table 2 demonstrated that Halon was a significantly more expensive system than Sprinklers.

Safety

Concern for the safety of personnel had a strong tradition in the Air Force. In this atmosphere, it would not be unusual for a unit of equipment or a system to be rejected if it were to jeopardize the safety of personnel. While fire represented an unsafe condition that had to be remedied, the danger posed by fire would not, by itself, warrant the use of dangerous means of extinguishment. This portion of the Analysis attempted to identify the dangers of both Halon 1301 and water to determine if there were potentially serious health effects resulting from their use.

Halon

An indication that Halon 1301 possessed toxic characteristics was conveyed in the limits for human exposure established by the NFPA (see Table 3).

TABLE 3

HALON 1301 EXPOSURE LIMITS

	Concentration, % By Volume In Air	Maximum Time of Exposure
Normally Occupied Areas	7% or lower	5 minutes
	7-10%	1 minute
Areas Not Normally Occupied	10-15%	30 seconds
	above 15%	prevent inhalation

The claim had been made that within these limits there was a high degree of safety (12:1). Yet the rather restricted nature of the exposure times suggested a further inquiry. The search for data on the hazards of Halon 1301 produced results when the science of toxicology was investigated.

An understanding of toxicology was useful in identifying the knowledge that could be obtained from this area of research. The rationale behind toxicology was this:

> The human body functions through a complex set of chemical and physical processes which maintain it in a state of metabolic equilibrium. Most foreign chemicals are capable of interfering with this delicate

> chemical balance to produce temporary or permanent injury, or even death. The study of the deleterious effects of substances on natural human functions is called "toxicology" [14:2].

Halon 1301 was implicated in this field of study in the following manner:

> Foreign chemicals can enter the body in three different ways to produce toxic effects: by ingestion, by inhalation, or by absorption through the skin. With gaseous chemicals such as . . . Halon 1301, inhalation is the primary route of entry. Halon 1301 and related chemicals exert their principal toxic effects upon the central nervous system while gases which are corrosive or chemically reactive are characteristically irritating and produce their damaging effects primarily by attacking the respiratory passages, the skin, and eyes [14:2] .

A review of numerous, independent clinical tests on the effects of both Halon 1301 and its decomposition products was contained in the Du Pont publication, "Toxicology of Du Pont Halon 1301 Fire Extinguishant" (14). The results of the many tests described suggested that Halon 1301 was reasonably safe for use as an extinguishant. The following discussion focuses on significant findings of those tests. With respect to pure Halon 1301, two main types of effects occurred: anesthetic and cardiac. The anesthetic effect was one akin to mild intoxication accompanied by an impairment of mental and physical performance. The effects were not considered serious at levels below ten percent, however, they could be significant for anyone who had to make immediate and critical judgements. These effects disappeared shortly after exposure was terminated. The report did go on to state, "Prolonged exposure to concentrations above 10% (on the order of 15 to 20%), may lead to unconsciousness and possibly death [14:8]." Many of the tests performed did produce death in test animals, but again, at concentrations or exposure times much greater than those experienced with Halon. Cardiac effects seemed to be related to the levels of adrenalin in the body. This phenomenon was known as cardiac sensitization.

> It has been known for some time that inhalation of vapors from certain organic materials, which include such compounds as carbon tetrachloride and gasoline, can make the heart muscle abnormally reactive to elevated adrenalin levels with resulting cardiac arrhythmias. These arrhythmias are frequently ventricular in origin and may result in sudden death [14:4].

Since fire was a life-threatening emergency which could cause high circulating levels of adrenalin in people engaged in extinguishing the fire or those whose escape may be blocked, some research had given attention to this fact. The results of

> . . . cardiac sensitization experiments in animals . . . show that the inhalation of Halon 1301 at a concentration of 7.5% in the presence of high circulating levels of adrenalin carries with it the risk of causing serious cardiac arrhythmias, while at the 10% level deaths have been observed in dogs [14:8].

The applicability of this research to humans in fire and accidental discharge conditions was summarized as follows:

> For humans this cardiac risk cannot be forecast accurately because the state of susceptibility of the persons who may be exposed to Halon 1301 will vary. In most foreseeable situations, the risk associated with a fire would be greater than that caused by the prompt use of the fire extinguishing agent.

> In the case of an inadvertent discharge of Halon 1301, no fire would be present to cause apprehension and high circulating levels of adrenalin. Under these circumstances, if the release of the extinguishing agent can be accomplished without this in itself causing alarm, then no serious health effects need be anticipated from short exposures where 7% by volume is not exceeded [14:8].

The converse, that serious health effects could be anticipated, almost seemed implied since Halon used loud alarms to warn occupants of an impending discharge and the discharge of thousands of pounds of Halon in less than ten seconds (19:19) could certainly have been frightening. While much emphasis had been placed on the fact that Halon systems, particularly as they applied to EDP rooms, usually were designed to achieve concentrations at or below seven percent, no mention was ever made concerning the fact that Halon 1301 had a density approximately five times that of air (19:24) and whether or not this could precipitate pockets of higher concentration, such as near the floor. The reason might have been that once mixed with air, the agent would not settle out.

Despite the fact that Halon 1301 was the most thermally stable of the halogenated extinguishing agents, temperatures above 900^{o}F to 1000^{o}F caused Halon 1301 to decompose. The decomposition products were identified as: HF (hydrogen fluoride), HBr (hydrogen bromide), Br_2 (bromine), and COX_2 (carbonyl halides, consisting of carbonyl fluoride, COF_2, and carbonyl bromide, $COBr_2$).

This knowledge prompted toxicology research on the decomposition products of Halon 1301. Such products could cause irritation of the respiratory tract, skin, and eyes if present in sufficient concentration. Quantities of these products generated depend on the size of the fire, type of fuel, temperature of the fire, enclosure size, degree of ventilation and rapidity of flame extinguishment. If a fire was extinguished rapidly, irritating levels of these products were not likely to be achieved, while irritating and potentially hazardous levels might be produced if extinguishment was delayed. Two observations were necessary to place this issue in perspective. First, ". . . the irritating nature of the Halon 1301 decomposition products provides a built-in alarm to warn personnel well in advance of toxic levels [14:1]." And, secondly, it was more likely that

> . . . the fuel decomposition products, especially carbon monoxide, coupled with smoke, heat, and oxygen depletion create a greater hazard than the thermal decomposition products of the Halon 1301 extinguishing agent [14:1].

The substances generated by a fire (not in a Halon 1301 environment) definitely deserved recognition in this debate.

> The major constituents of smoke from burning wood, paper and many fabrics include carbon monoxide, hydrogen cyanide, aldehydes, alcohols, hydrocarbons, carbon dioxide, and water vapor. Major constituents of smoke from burning PVC insulation include carbon dioxide, carbon monoxide, hydrogen chloride and

> hydrocarbons. The highest level of toxic gas concentration from combustion of materials occurs when they burn with a limited supply of air or when they are heated to a high temperature without burning. Both of these phenomena characteristically occur in building fires.
>
> One major concern . . . is that typical PVC insulation releases hydrogen chloride gas when it burns or thermally decomposes. Hydrogen chloride is more toxic than carbon monoxide. However, the burning of a pound of ordinary combustibles--such as wood or paper--produces much more carbon monoxide than the amount of hydrogen chloride produced from burning a pound of PVC insulation [3:278].

PVC seemed to be a popular subject when discussing the hazards of decomposition products, as another author went so far as to say, ". . . the byproducts of burning materials like PVC can be more hazardous and damaging than any byproducts created with a normal extinguishing agent [2:68]." In addition, a fire characterized by temperatures in the vicinity of 2000°F and an exposure time of at least 15 minutes were the kinds of conditions necessary for Halon 1301 decomposition products to be lethal (14:9). Whether such conditions would occur, whether an individual would become trapped, and whether or not the other effects of the fire would be survivable under those conditions, were open to speculation; the industry conclusion was basically that the dangers from fire were greater than those presented by the products of decomposition, particularly when early detection and prompt discharge were the case, which characteristics Halon was designed to have (4:2).

The nature of Halon 1301 presented some hazards other than those identified by the science of toxicology. These hazards stemmed from the fact that convenient storage of Halon 1301 required that it be kept in a liquid state. This was brought about through a combination of proper pressure and proper temperature. Thus, the operating temperature range was between -40°F and +130°F (25:1;38:2). When below freezing (32°F) temperatures were the case,

> Direct contact with the vaporizing liquid being discharged from a Halon 1301 system will have a strong chilling effect on objects and can cause frostbite burns to the skin. The liquid phase vaporizes rapidly when mixed with air and thus limits the hazard to the immediate vicinity of the discharge point [19:25].

A related hazard was the reduction in visibility which might occur due to the condensation of water vapor brought about by the cooling capability of the Halon 1301 (19:25). This effect was likely to be minor due to the controlled climate conditions associated with the operation of EDP equipment. Nevertheless, some unsubstantiated accounts had been received that indicated this could be a very real problem.

Following extinguishment and elimination of the hazard, ventilation had to be restored to remove the Halon 1301. There could be some hazard at this point as personnel returned to restore operation of the EDP center since Halon 1301 was difficult to detect through normal human senses: it was colorless and odorless (19:24).

In recognition of the hazards of Halon, the following actions were prescribed (19:29) to reduce the chances for injury to people:

1. provide clear (at all times) and sufficient routes of exit;

2. provide emergency lighting and directional signs;

3. provide alarms that operate immediately upon detection of a fire;

4. provide continuous alarms at entrances until the atmosphere has been restored to normal;

5. provide warning signs at entrances to and inside areas protected by Halon informing people that such a system is installed and how they should respond;

6. provide for prompt discovery and rescue of unconscious personnel; search the area immediately with trained men using proper breathing equipment;

7. instruct and drill employees to ensure their correct action when the system operates;

8. provide prompt ventilation once the emergency is over; the contaminated atmosphere must be dissipated and not just moved to another place; forced ventilation usually is necessary.

Sprinklers

Since water is a common feature of man's existence and the environment, any hazards would not be associated with its chemical properties. The only hazards identified were those of electrical shock and drowning.

The NFPA had researched the relationship between water and electrical shock. The closest it came to addressing the hazard posed by water discharged from a sprinkler head falling on an EDP equipment unit was the following statement.

> There is usually little danger to fire fighters directing streams of water onto wires of less than 600 volts to ground from any distance likely to be met under ordinary fire fighting conditions. However, it is dangerous when fire fighters, standing either in puddles of water or on moist surfaces, come into physical contact with live electrical equipment. In such cases the fire fighters' bodies complete an electrical circuit, and the current from the electrical equipment relayed through their bodies is more readily grounded than if it were conveyed through dry, nonconductive surfaces [32:13-3].

The U.S. Department of Commerce and the National Fire Prevention and Control Administration's Fire Protection of Essential Electronic Equipment Operations Task Group had investigated further--into the hazards posed by essential electronic equipment. They reported:

> There is little likelihood of a practical hazard of shock to operators and firefighters in an essential electronic equipment area in which water is being used to extinguish a fire. Numerous studies and analysis of shock hazard/water stream/distance from equipment have been done and their results vary. The expected voltage levels will commonly not exceed 240 volts to

> ground and generally will not exceed 480 volts to ground and between conductors. These voltage levels are present in the electronic system power supplies, but the voltage levels distributed to modern equipment subsystems are generally much less, e.g. in the 12 to 30 volt range. Therefore, acceptance of the generalized statement that a 4-foot distance should be maintained from live electrical apparatus and water fire extinguishers, in essential electronic equipment areas with plain water type extinguishing equipment and systems as herein specified, should provide a more than adequate margin of safety [42:70].

These statements were based on the assumption that the equipment had remained energized. This was not likely to occur since Sprinklers provided up to three opportunities for de-energizing the equipment: through the automatic detection system, through the water-flow alarm, and by manual operation of a pull switch. Even if the equipment was to remain energized, the fact that most fires were extinguished with very few sprinkler heads (23:17) suggested that the area affected by water would be quite small. Furthermore, prompt evacuation of personnel should have prevented their exposure to electrical shock hazard. Nevertheless, allowing for a worst case scenario, there was potential for harm and personnel should have been trained to exercise caution and trained in their responsibilities. Some of the previous arguments, such as prompt evacuation of personnel and that few sprinkler heads were usually necessary to contain or extinguish a fire, also suggested that drowning was not only not a hazard but nigh to impossible. The record confirmed this: "Never has anyone been "drowned" by a sprinkler system [44:3]."

Summary

The use of both Halon 1301 and water as extinguishing agents presented concerns for the safety of people. Halon 1301 was found to cause anesthetic, cardiac, and frostbite effects, with severity depending on concentration of the agent, exposure time, and proximity of the individual to the discharge. Under the conditions expected during operation of a Halon system in an EDP environment, these effects were considered to be minor and procedures could be instituted to keep the risks to a minimum. The decomposition products of Halon 1301, on the other hand, irritated the respiratory tract, skin, and eyes when present in sufficient concentrations and could pose a threat to life under severe conditions. Again, these conditions were unlikely, but if they occurred, factors other than the presence of decomposition products would more than likely determine survivability. Halon 1301 therefore appeared to be reasonably safe for use as an extinguishing agent. Sprinklers used water as the agent and the only hazard associated with the use of water in an EDP environment was the potential shock hazard. This hazard was considered controllable and minimal. In conclusion, the safety of both Halon and Sprinklers was considered to be acceptable and, therefore, equal.

Adaptability

Change is inevitable. EDP installations were no exception to this fact of life, especially as they responded to the phenomenal advances in computer technology seen in the last decade alone. The Air Force might not change as fast as private firms which are not as institutionalized; but, nonetheless, changes in the configuration of facilities and expansion of space requirements were common occurrences and constant concerns throughout the Air Force. EDP installations were bound to be represented in this phenomenon and to require adaptation of the fire protection system to the new configuration. With what ease, then, could Halon and Sprinklers be adapted to new room layouts or expanded?

Halon

Since Halon systems came in two styles, adaptability was strongly related to the style chosen for discussion. Traditional, "engineered" systems featuring long piping runs connected to central agent storage containers were sensitive to modification. Such a system should have had all piping recalculated and resized if an EDP expansion required additional protection (4:2). This was not a simple proposition as sophisticated computer programs were necessary to determine piping requirements and repiping might involve nearly as much work as the initial installation. But with the development of modular systems, modification or expansion was greatly simplified. The modular approach provided flexibility of design and simplified installation. Agent storage containers were mounted on the wall, usually above the drop ceiling, required very little piping, and were located within or immediately adjacent to the area being protected. Alterations were made by adding or moving elements and installing the control mechanism (electric wire or pneumatic). Should the need have arisen to expand an area, one could determine whether there was additional capacity in the containers presently installed or add additional containers to protect the additional space (15:3). There was no need to eliminate or redesign any piping or other hardware.

Sprinklers

Sprinkler systems relied on piping networks to distribute the extinguishing agent. Any modification to the area protected by the system would require modification of the piping network. But the piping network possessed a considerable degree of resiliency to demand as did normal water lines. This was mainly due to the oversize nature of most piping, which, in turn, was largely due to the existence of a limited selection of pipe sizes. Also, the design did not have to take into account, or at least not to the same degree as in Halon, the influence of friction losses and the vagaries of two-phase flow. Consequently, adaptation might involve merely extending onto the existing grid or, in the worst case, provision of a new supply line from the main <u>Sprinkler</u> supply point to the new area to be protected. Reconfiguration of walls might not require any modification since the existence of many "point sources" decreased the impact of losing or isolating any sprinkler heads and sprinkler systems did not require the consideration of concentration (volume).

<u>Summary</u>

Both <u>Halon</u> and <u>Sprinklers</u> could be adapted to changes in facility configuration, and that with apparent ease, provided the Halon system involved was modular. Predicting that future Halon system installations would be predominantly modular, and lacking any data to truly discriminate between the ease with which both <u>Halon</u> and <u>Sprinklers</u> might be adapted, the adaptability of each was considered to be equal.

Catastrophic Fire

Major fire losses still occurred despite the widespread installation of both Halon and sprinkler systems. Though the Air Force had had few major fire losses to our knowledge, the potential for a major fire could never be entirely eliminated. Noncombustible construction and good housekeeping practices notwithstanding, essential facilities merit additional attention to protection from disastrous fire. Such fires might originate from within or without the EDP room(s). They might develop slowly, or they might begin violently, particularly if sabotage was involved. The importance of essential EDP operations and their vulnerability to sabotage made them prime targets of malcontents. For fires originating outside the EDP center, the best that might be expected from an EDP fire protection system was to stall the fire in hopes the fire department would be able to overcome the fire before it swallowed the EDP center. The subject of major fire was observed to be one that was too often ignored but also one that was difficult to assess.

Halon

Though Halon could be exceptionally effective for certain applications, it normally provided protection for a period of minutes (19:3). And there was usually only one shot, one chance, to put out the fire. This was entirely appropriate when a fire, originating within the protected volume, was detected in its earliest stage of development. But caution had been expressed when the subject of open flame or major fire conditions was mentioned (4:3). This might have been partly due to the fact that Halon 1301 provided little, if any, cooling of the fuel (since it apparently worked by inhibiting the chemical reaction between the fuel and oxygen). If the core of the fire was still at near to ignition temperature following extinguishment by Halon 1301, then following dissipation of the Halon 1301 there remained the danger of reignition and unchallenged fire spread.

> In fact, more recent investigations have confirmed that Halon 1301 may only slow certain types of glowing combustion, that extinguishment is ultimately achieved only if and when a favorable negative heat balance is obtained in the fuel array [21:4].

In any case, there had been recognition within the industry that Halon systems complement sprinkler systems:

> It is not intended to replace water but to complement it by protecting the contents of a room. Water will protect the structure but Halon is intended to protect what is inside the structure [4:3].
>
> . . . For important, high value occupancies and facilities, both Halon and carbon dioxide systems should be backed up by automatic sprinklers [21:4].

Sprinklers

Sprinklers offered two desirable features when considering their effectiveness against major fire: water provided a cooling effect and it was usually available in large quantities. The cooling effect of water was one of its primary extinguishment mechanisms. This was particularly availing when deep-seated fires were involved and in cooling walls to deter the spread of fire. And the water could be applied continuously until the supply was exhausted or a water main was broken. But, consequently, there were limits on the duration of protection. "Water supplies for standard sprinklers . . . are normally designed to provide protection for one-half to 4 hours duration . . . [19:3]."

Summary

In view of the fact that halon provided protection for a limited period of time (ten minutes was common) and did not offer any cooling effect, and in view of the extended protection offered by water (one-half to four hours) and its cooling effect, Sprinklers only offered reasonable protection against the threat of major fire. The Department of Commerce and the National Fire Prevention and Control Administration's Fire Prevention of Essential Electronic Equipment Operations Task Group (42:59) spoke of this in their publication on the fire protection of essential electronic equipment:

> It is clearly in the interest of the Government to protect an essential electronic equipment area from a major catastrophe. Review of actual fire situations consistently demonstrates that wherever sprinklers have activated the magnitude of the loss was low. Conversely where sprinklers had been deactivated or were not installed, a major loss was suffered on more than a few occasions.
>
> Application of the water though dependent upon the size of the reservoir is generally much more effective and of longer duration than the one or two shot reservoirs provided for gaseous agents.

Thus, it was concluded that Sprinklers were superior to Halon when confronted with the threat of major fire.

Overseas Support

The overseas environment presented many diverse and perplexing difficulties for private and governmental organizations alike. Besides the expected communication, supply, and compatibility problems, there was the problem of non-uniformity of standards. Looking at Europe for example, a variety of governments and Authorities, different insurance markets, and different climates and environments (regulatory) characterized the European scene. Attempts were being made to standardize the fire safety scene, particularly through several all-Europe organizations, but the presence of many research laboratories, government institutions, insurance associations, and industrial societies required multinational companies to give quite a bit of autonomy to in-country subdivisions (46:71,72). While this article was directed at multinational companies, the Air Force was not immune to these aspects of the overseas environment. Equipment and systems comprising U.S. components frequently had to rely on the installing firm for maintenance. Since the firm was not likely to be as well represented (geographically) as in the States, this aspect could impair the maintenance, hence performance, of such equipment and systems. Extra security precautions might also be expected with contractor personnel. However, if the Air Force had its own maintenance capability, these availability and security problems could be alleviated. With regard to fire protection for computers, the reduced sophistication of and existence of some Air Force capability to maintain Sprinklers would be definite advantages for Sprinklers with respect to this criterion. However, there might have been other aspects of the overseas environment to consider and supporting documentation was not readily available. Consequently, no advantage was given to either Halon or Sprinklers.

Equipment Downtime

The performance capability of EDP systems had become essential to the accomplishment of many vital Air Force tasks. This rise in importance was largely due to the ability of EDP systems to process large and complex quantities of information in a very short time. Because time was a valuable commodity to military leaders faced with the need for real-time information, because time lost on important projects or even in accomplishing routine Air Force business could have far-reaching consequences, and because computer time was valuable in and of itself, loss of EDP capability was a serious matter. Following any interruption of EDP operations, restoration of EDP capability had to be accomplished as quickly as possible.

While fire would seem to be a serious enough interruption, the effect of the operation of the fire protection system on the speed with which EDP capability could be restored also had to be considered. With systems as different as Halon and Sprinklers, a variety of effects could be expected.

Halon

Halon had been widely represented as the ideal fire protection system for EDP equipment because the agent, Halon 1301, left no residue and merely needed venting to remove it from the room. Therefore, equipment was not damaged by any reaction with or deposits left by the agent and clean-up was minimal. Furthermore, its fast acting nature (detection of fire in the incipient stage) and ability to penetrate equipment (because it was a gas) minimized damage to the equipment. Were these the only effects, the equipment could be returned to service as soon as it was checked for proper operation. What had been omitted was that discharge of a high pressure gas from point (nozzle) sources into a quiet room was not about to occur unnoticed. This forceful discharge might dislodge lightweight and/or poorly secured items as well as knock ceiling panels down and damage the ceiling support grid. This commotion would loft dust into the air and send it around the room where it might find its way into sensitive electronic equipment. Particles dislodged from ceiling panels might be similarly distributed. The lack of published material on these effects perhaps signified that they were not serious.

Once the Halon system had operated, the affected enclosure was to be promptly ventilated. Forced ventilation should have sufficed, but precaution should have been taken to make sure the hazardous atmosphere was actually dissipated and not just moved to another location (34:pp.12A-54,12A-55). Because Halon 1301 was heavier than air, care should have also been taken to make sure pockets of high concentration did not remain.

The only other major aspect of recovery from a Halon discharge was reconditioning the Halon system to return it to operational status. This required filling and pressuring the containers and checking detector circuits, control circuits, and pull stations for proper operation. A competent Halon outlet should have been able to accomplish this work within 24 hours of system discharge.

A couple of examples of actual Halon actuations illustrated the quickness with which EDP capability could be restored and Halon restoration accomplished.

1. Mount Prospect State Bank in Illinois reported an incident in which

> One evening last February, a fire erupted in one of our magnetic tape drives, due to a short circuit.

> Our Halon 1301 total flooding system prevented what could have been a disastrous fire. Because of it, our computers were back in operation within an hour following the alarm [40:1].

2. A large corporation saved $250,000 in computer time in one day when

> A fire resulted from an electrical short and sent a flame ball shooting into the computer room. The . . . system reacted seconds later and extinguished the fire. The system shut down the entire power supply to the room plus all air conditioning. We had the system recharged and back in service within 22 hours. No damage to computers or personnel was reported. This activation paid for the system [4:2,3].

The fast acting nature of Halon and the absence of residue left by the presence of Halon 1301 were definite advantages. While proper ventilation had to be instituted to remove the Halon 1301 and some damage might result from its discharge, these problems did not appear to be serious, allowing prompt restoration of EDP capability. However, extra precaution was to be taken until the Halon system was reconditioned.

Sprinklers

The use of sprinkler systems to protect EDP equipment had generated considerable controversy, particularly as to concern for the effects of water on EDP equipment. This concern was natural and appropriate for the early generations of computers when vacuum tubes and primitive wiring were the standard but the situation had changed. Modern computers incorporated transistors, integrated circuits, and sealed circuit boards, which were less susceptible to water damage. However, mechanical devices such as switches, motors, tape and disc drives and printing mechanisms, which possessed varying degrees of susceptibility to water damage, remained. Nevertheless, the threat of water damage appeared to be declining, as evidenced by these statements.

> Fear of damage by water to electronic components in computer units is often the reason given for refusal to install needed automatic sprinkler protection. Loss experience shows that such fears are greatly exaggerated. In the event of a serious fire in the area, the damage from water is not likely to be as great as the fire or smoke damage. Most wet components can be dried satisfactorily. In sprinklered areas, there is no need for large hosestreams and their large volume of water [18:3].

> There should be little concern . . . that the water will cause excessive damage to equipment in installations of this type. Experience has proved that if a fire develops sufficiently enough to operate sprinklers, the sprinklers, if properly installed and maintained, provide for effective fire control and extinguishment . . . with no measurable increase in damage to electrical or electronic equipment (as comparable to damage traceable to heat, flame, smoke, and the possible need to use manual hose streams) [32:p.13-5].

To assess the true effect of water, it was helpful to understand the factors that influenced damage from a fire extinguished by the operation of an automatic sprinkler system.

The fact of a fire of sufficient intensity to actuate an automatic sprinkler head in an electronic equipment area presupposed the involvement of a significant part of an equipment unit (42:60). While the degree of involvement would vary depending on the type of equipment, the unit might be expected to require major repair. The purpose of the sprinkler system then became containment and to prevent, or at least minimize, the loss of additional equipment units. Nevertheless, the damage incurred before actuation of a sprinkler head and the damage incurred because the water could not readily penetrate an equipment unit (as compared to a gas) had to be attributed to Sprinklers. With respect to the containment function mentioned, the area affected by water, and hence susceptible to water damage, was usually not large.

> A major feature of sprinkler systems is that they use only the amount of water necessary to control the fire. Records show that 37.4% of all fires in which sprinklers operate are controlled by 5 or fewer sprinklers, and 85% are controlled by 10 or fewer sprinklers [44:3].

The volume of water discharged could also be held to a minimum by closing the control valve after the need for sprinkler discharge had passed. The next aspect to investigate was the actual damage caused by water.

Water damage had to be viewed in the context of modern computer technology. For instance, though the power supply was usually 120 volts, a step-down transformer provides the proper operating voltage for logic circuits, which was commonly less than 30 volts RMS. So circuit voltages would not be high were the equipment to be left energized. And were the equipment to remain energized, the most susceptible component to shorting would probably be the transformer. Yet, excessive current draw by this component (or any other, for that matter, whether due to arcing or shorting) would trip a fuse before damage to other components could result and EDP equipment was not only "fused," but double fused and triple fused. Solid state components such as transistors and LSIs (Large Scale Integrated Circuits) tended to be hermetically sealed, preventing water damage. Inter-circuit connections and mechanical devices might be similarly protected but nonetheless probably presented the main opportunities for water penetration, foreign material deposits, and rust. Regarding water penetration, "Tests conducted in Sweden indicated that circuit cards wet down with water worked well after drying [22:4]." The problem of foreign material deposits was not well addressed in the literature but appeared to respond well to application of a detergent solution. Minimization of rust depended on prompt and effective salvage. In fact, nothing was probably as critical to limiting water damage as successful salvage. A successful salvage operation should have resembled the following scenario:

> Quickly re-establish and accelerate the normal air supply and exhaust ventilation. Swift removal of smoke and humid air will limit continuing damage and hasten the recovery.
>
> With the help of the computer operators, start the water washdown--preferably, with a warm detergent

solution and a distilled-water rinse--of all heavily smoked, wetted, and debris-covered gear. Dry with small fans, hair dryers, and other pinpoint blowers if possible. Better still, have the computer maintenance technicians--the customer engineers--move key units of the computer components into drying ovens. Fire hose dryers can be used [29:71,72].

Heat was to be applied cautiously, though, due to the sensitivity of electronic components to heat. The value of salvage was particularly potent for magnetic tapes, which at first might seem to have been ruined by water. On the contrary,

> Experience and tests have shown that water does not cause permanent damage to magnetic tape. In fact water is sometimes used to clean the tape. The data contained on tapes are not harmed by sprinkler discharge or by immersion in water. It is, however, advantageous to remove any water and promptly dry the magnetic tape after exposure [18:5].

Some examples illustrated the recoverability of tapes.

> Basement areas of an appliance manufacturer located along a harbor were flooded by abnormally high tides. Reels of master tape were wet. An outside specialist was called in who washed and dried the tapes, then transferred the information onto new tapes which read well. Similar good salvage was reported by computer facilities that were flooded as a tropical storm swept up the eastern seaboard. Ordinary detergent and water solutions were used by some; commercial tape cleaning compounds by others [22:4].

Returning to the general subject of downtime, it was originally established that minimizing downtime was vital. The remaining subject relevant to downtime was the time required to repair the damaged unit(s). Manufacturers did design maintenance features into their equipment, such as modularity, which facilitated repair by replacement of the modular component rather than the actual individual item that failed. Replacement components were usually readily available from either regional distributors or the main distribution center. When the component was obtained, actual replacement might take as little as one-half hour. But this might be preceded by several hours of testing to locate the damaged or defective component. When a whole unit had to be replaced, a new one from the factory could require several months due to a backlog of orders. A more reasonable approach might have been to acquire something through the rental pool, which, though probably not the same exact unit or even the same brand, would enable the user to get by until the proper unit could be procured.

Despite the understanding gained through this analysis of the relationship between EDPE, Sprinkler actuation, and downtime, the relationship was still not clearly understood. As in previous sections, case reports helped resolve this deficiency. The following case reports were found to be relevant.

> Many cases can be cited where computers, exposed to water, were returned to service after promptly started steps at salvage and repair were taken, with repair costs limited to a few hundred or at most a few thousand dollars. At one computer operation, high winds tore off roof covering and rain leaked onto equipment. The computers were first carefully

wiped. Then drying was accelerated by large fans set up to blow air at the computers and by the room's air conditioning which was set high. The computers were returned to service with no problem. In another case leaking steam filled a computer room causing a sprinkler over a computer to operate. Drying and minor repairs cost $4,000. An incendiary explosion at a government building broke water pipes. Water leaked through a ceiling onto computers in the story below. The equipment was shut off and covered with plastic sheeting until the leaking stopped. Later, equipment was gradually turned on, and by the end of the day, no problems were encountered [22:3,4].

A few years ago we had an accident where a sprinkler head discharged after it was struck by a contractor's ladder. The head discharged for approximately five (5) minutes before the system was shut off. Several pieces of equipment in a large system were rather thoroughly wet down. The equipment was dried out and back in service within a few days and there was no long-time detrimental effect to the equipment [30:2].

During installation of sprinklers in a ceiling space over a computer room, water was accidentally turned on while piping was open. Water leaked through the ceiling and into tape drives, disc drives and the central computer unit. The room air conditioner was started, and water mopped off the raised floor and from within the space below the floor. Fans were brought in to help circulate the air, and equipment dried and returned to service five hours later. Loss less than $5,000 deductible [17:4].

Loss experience shows that fears of water damage to computers from sprinkler leakage have been greatly exaggerated. Eighteen sprinkler leakages affecting computers were reported in the five years 1972 through 1976. In most cases, the computers were dried, checked out and returned to service within a few hours [17:1].

These case reports indicated the ruggedness of EDPE when exposed to water provided prompt salvage was invoked. Non-water damage incurred before actuation of sprinklers could be significant but depended heavily on the source

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A COMPARATIVE ANALYSIS OF FIRE PROTECTION SYSTEMS FOR ESSENTIAL--ETC(U)
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of origin, which often was not in the equipment itself but in storage media (such as paper or tapes). The time required to restore EDP capability frequently appeared to be less than one day.

Summary

Restoration of EDP capability following any emergency could not afford the luxury of time. The degree of damage allowed by a fire protection system influenced the time required to restore EDP capability as did the degree of clean-up required. Halon's fast acting nature, absence of agent residue, and limitation of clean-up to venting endeared it to the EDP function. Damage from discharge and system reconditioning had to be taken into consideration but did not seem to be serious obstacles to restoration of EDP capability. The advent of modern, solid-state technology had returned Sprinklers as a viable means of protecting EDPE. But though the danger of water damage was small, non-water damage incurred before actuation of sprinklers could significantly increase the amount of damage to EDPE and the repair time. Also, prompt and effective salvage could not be taken for granted and failure to provide such salvage could greatly increase the degree of damage. Consequently, Halon was considered superior to Sprinklers with regard to the criterion of equipment downtime.

CHAPTER IV

CONCLUSION

The results of the comparative analysis of Halon and Sprinklers were best evidenced by a simple listing of the eight criteria against which the two systems were evaluated. Such a listing is shown in Table 4.

TABLE 4

SUMMARY OF FINDINGS

Criterion	Conclusion
Reliability	Sprinklers superior to Halon
Maintainability	Sprinklers superior to Halon
Cost	Sprinklers superior to Halon
Safety	Both equal
Adaptability	Both equal
Catastrophic Fire	Sprinklers superior to Halon
Overseas Support	Both equal
Equipment Downtime	Halon superior to Sprinklers

The results show that Sprinklers were found to be superior on four occasions, Halon was found to be superior on one occasion, and the two were considered equal on three occasions. (It should be remembered here that a rating of superior was only given when there was justification for a significant difference in performance of the two systems.) However, neither system was believed to be so deficient in any one criterion as to risk disqualification from consideration. The determination of the overall ranking of the two systems depended on the weight assigned to each criterion. As established in CHAPTER II, METHODOLOGY, equal weight was so assigned because the variety of applications and missions in the Air Force suggested that development of a weighting scheme was beyond the scope of this research effort, no single weighting scheme could have satisfied such a diverse constituency, and use of an equal weighting scheme was not unreasonable. However, certain echelons or activities might wish to revise the weighting scheme to suit their unique requirements, which could affect the overall ranking of the two systems. Nevertheless, the results of this research effort indicated that Sprinklers were markedly superior to Halon as a fire protection system for essential EDPE in the Air Force. Halon undoubtedly has its usefulness, but not as primary protection for essential EDPE.

Since other groups (notably NASA and the Department of Commerce) have come to the same conclusion, one naturally wonders why the Air Force has remained so committed to Halon. One reason was undoubtedly the traditional fear of mixing water with electronics. But advancement in the state of the art has eliminated much of the basis for that fear. There were probably other, equally tenable, reasons that led to the formulation of the present policy. Recognizing that in the past there were such overriding factors, the latest evidence nonetheless seriously questions the Air Force position, making it extremely important that the Air Force reassess its policy. To assist the Air Force in this reassessment, the recommendations contained in the following chapter have been offered.

CHAPTER V

RECOMMENDATIONS

Since existing Air Force policy and practice is not consistent with the findings of this research, the Air Force should investigate its policies and practices to determine what changes, if any, need to be made. The following recommendations were developed to assist the Air Force in benefitting from this research.

1. Appoint a policy review group at Air Staff level, composed of senior officials from the Civil Engineering and Data Automation functional activities and representatives from the Engineering and Services Center at Tyndall AFB, FL, and each major command, to study the findings of this research and then reasses present policy.

2. Revise the Air Force Design Manuel, AFM 88-15, to allow for the installation of Sprinklers in EDP facilities, with caveats for MAJCOM approval to provide for the unique requirements of each major command, until present policy is revised in accordance with Recommendation 1.

3. Retain existing Halon installations intact but increase proficiency of EDP personnel in manual fire extinguishment techniques, operation of Halon, and good housekeeping practices.

4. Discourage the use of Halon as a fire protection system for EDPE except for truly critical activities. When used for such activities, Halon should be backed-up by Sprinklers.

5. Review Halon maintenance programs at all installations to ensure that maintenance is being performed and is similar to that suggested in CHAPTER III. Most maintenance should be performed by an authorized Halon installer through a service contract.

6. Review fire protection policy for EDPE again (in addition to that recommended in Recommendation 1) no later than 1990 as new evidence and more experience will be available to assess the qualifications of fire protection systems and advances in EDP technology may obsolete current fire protection methods.

7. Perform further research in the area of underfloor protection to determine whether special requirements or considerations exist that would alter the suitability of either Halon or Sprinklers for this environment.

8. Perform further research in the area of Overseas Support to determine the suitability of Halon and Sprinklers for this environment and whether or not significant advantages accrue to either system with respect to the Overseas Support criterion.

APPENDICES

APPENDIX A

THEORY OF FIRE EXTINGUISHMENT

The heat generated by fire is transferred to surrounding substances in three ways: conduction, convection, and radiation (20:5). The transfer of heat by conduction is accomplished by direct contact of the surfaces. Convective heat, on the other hand, follows the fluid motion of gases produced by combustion. The heat contained in these gases is transferred by the physical movement up, out, and sometimes back into the fire. Until the late 1960s, it was believed that convection played the dominant role in the transfer of heat in large fires. Through experimental research by the Basic Research Department of the Factory Mutual Research Corporation (20:5-7), it was determined that heat transfer by radiation, not convection, was actually the dominant process in major fires. Radiation is ". . . the transfer of energy as waves moving at the speed of light [20:5]." It is also known that these waves travel in straight lines rather than following the movement of convective heat transfer. With this understanding of how fires burn and propagate, a clearer insight into the theories of how Halon 1301 and water extinguish fires may be gained.

The common theory of fire extinguishment stems from the "fire triangle" concept. The triangle sides are labeled fuel, oxygen, and heat and all three must be present for combustion to occur. If an extinguishant is able to "break" the triangle (e.g., the mechanical separation of fuel from the oxidizer with foam) combustion will cease. While science lacks a detailed understanding of the exact part water plays in suppressing fire, it is known that water cools the burning material (at least, on the surface). From water spray studies conducted by Factory Mutual System scientists (20:7), it was found that in addition to cooling, the water spray from the sprinklers helped to smother the fire by forcing oxygen-poor combustion gases back down from the ceiling to the fire source (20:7). Additionally, as the water spray absorbed heat, it turned to steam. This combination of steam and water formed a radiation shield around the fire which reduced or eliminated its propagation through radiation (39:46).

Although use of the "fire triangle" concept helped to explain how water was able to extinguish fire, it did not satisfactorily explain the effective extinguishing characteristics of Halon 1301. It is believed that a chemical reaction occurs between the Halon 1301 and the combustion products responsible for flame propagation, thereby interrupting the oxidation process.

Two theories attempt to explain this chemical reaction, the free radical theory and the ionic theory.

Halon 1301 is a halogenated hydrocarbon with a chemical formula of $CBrF_3$.

In the free radical theory, a bromine radical is first formed through thermal decomposition of Halon 1301:

$$CBrF_3 \longrightarrow CF_3^{\bullet} + Br^{\bullet}$$

The bromine radical reacts with hydrogen in the fuel to give hydrogen bromide:

$$R\text{-}H + Br^{\bullet} \longrightarrow R^{\bullet} + HBr$$

The hydrogen bromide then reacts with the active hydroxyl radicals:

$$HBr + OH^{\bullet} \longrightarrow H_2O + Br^{\bullet}$$

The bromine radical may now react with more fuel to repeat the process to remove more active radicals from the fire.

According to the ionic theory, elemental oxygen must be activated by absorbing free electrons before it can react with the fuel. The bromine atom on Halon 1301 provides a much larger target for the capture of electrons than does oxygen, and thus reduces the probability of oxygen activation 11:4,5 .

Regardless of which theory explains most exactly the chemical reaction which inhibits combustion, it is apparant that Halon 1301 is extremely effective at suppressing a combustion process.

APPENDIX B

EXAMPLES OF CORRESPONDENCE

Chemetron Fire Systems
Rt. 50 & Governor's Highway
Monee, IL 60449

12 February 1980

Dear Sir:

In the context of the Master of Science program thesis requirement at the Air Force Institute of Technology, we are performing research in the area of fire protection systems for electronic data processing equipment (EDPE) installations. The goal of the research is to keep the U.S. Air Force both current and forward looking in its policy on fire protection systems for EDPE.

As a major manufacturer of fire extinguishing systems, your expertise and experience in the areas of both Halon 1301 (total flood) and sprinkler systems (water) would be of invaluable assistance to our research. Even though Halon 1301 systems have been the fire protection systems of choice in recent years, sprinkler systems represent the tried and true capability to date. We are most interested in your research findings and professional opinions of both systems. Areas at which attention is being focused include: cost, maintenance requirements, design procedure and considerations, adaptability to computer room modification or expansion, EDPE downtime duration following activation, safety, advantages (and disadvantages, if any), and the systems' role in major fires.

Thank you for your assistance on this timely project. If possible, it would be most helpful if your information were to arrive by 7 March 80 at one of the two addresses below. (Please be advised that this request in no way obligates the U.S. Air Force.)

Sincerely,

Robert L. Doerr, Capt, USAF
3746 Patterson Rd., #D
Dayton, OH 45430

Thomas H. Gross, Capt, USAF
925 Chestnut Cr.
WPAFB, OH 45433

Fenwal Incorporated
Protection Systems Division
400 Main Street
Ashland, MA 01721

12 February 1980

Dear Sir:

In the context of the Master of Science program thesis requirement at the Air Force Institute of Technology, we are performing research in the area of fire protection systems for electronic data processing equipment (EDPE) installations. The goal of the research is to keep the U.S. Air Force both current and forward looking in its policy on fire protection systems for EDPE.

As a major manufacturer of fire extinguishing systems, your experience and expertise with Halon 1301 (total flood) systems would be of invaluable assistance to our research. Specifically, since Halon 1301 has been the fire protection system of choice for some years, we are most interested in your research findings and professional opinions of this system. Areas at which attention is being focused include: cost, maintenance requirements, design procedure and considerations, adaptability to computer room modification or expansion, EDPE downtime duration following activation, safety, advantages (and disadvantages, if any), and the system's role in major fires.

Thank you for your assistance on this timely project. If possible, it would be most helpful if your information were to arrive by 7 March 80 at one of the two addresses below. (Please be advised that this request in no way obligates the U.S. Air Force.)

Sincerely,

Robert L. Doerr, Capt, USAF
3746 Patterson Rd, #D
Dayton, OH 45430

Thomas H. Gross, Capt, USAF
925 Chestnut Cr.
WPAFB, OH 45433

Viking Fire Protection
P.O. Box 5
Dayton, OH 45449

22 February 1980

Dear Sir:

In the context of the Master of Science program thesis requirement at the Air Force Institute of Technology, we are performing research in the area of fire protection systems for electronic data processing equipment (EDPE) installations. The goal of the research is to keep the U.S. Air Force both current and forward looking in its policy on fire protection systems for EDPE.

As a contractor for the installation of fire extinguishing systems, your experience and expertise in the area of (water) sprinkler systems would be of invaluable assistance to our research. Specifically, since sprinkler systems represent a tried and true capability, we are most interested in your research findings and professional opinions of this system. Areas at which attention is being focused include: cost, maintenance requirements, design procedure and considerations, adaptability to computer room modification or expansion, EDPE downtime duration following activation, safety, advantages (and disadvantages, if any), and the system's role in major fires.

Thank you for your assistance on this timely project. If possible, it would be most helpful if your information were to arrive by 14 March 80 at one of the two addresses below. (Please be advised that this request in no way obligates the U.S. Air Force.)

Sincerely,

Robert L. Doerr, Capt, USAF
3746 Patterson Rd., #D
Dayton, OH 45430

Thomas H. Gross, Capt, USAF
925 Chestnut Cr.
WPAFB, OH 45433

International Business Machines Corp. 19 February 1980
Old Orchard Road
Armonk, N.Y. 10504

Dear Sir:

In the context of the Master of Science program thesis requirement at the Air Force Institute of Technology, we are performing research in the area of fire protection systems for electronic data processing equipment (EDPE) installations. The goal of the research is to keep the U.S. Air Force both current and forward looking in its policy on fire protection systems for EDPE.

As a major manufacturer of EDPE, your expertise and experience in the protection of this equipment from fire would be of invaluable assistance to our research. Even though Halon 1301 systems have been the fire protection systems of choice in recent years, sprinkler systems represent the tried and true capability to date. We are most interested in your research findings and professional opinions of both systems. Areas at which attention is being focused include: cost, maintenance requirements, design procedure and considerations, adaptability to computer room modification or expansion, EDPE downtime duration following activation, safety, advantages (and disadvantages, if any), and the systems' role in major fires.

Thank you for your assistance on this timely project. If possible, it would be most helpful if your information were to arrive by 7 March 80 at one of the two addresses below. (Please be advised that this request in no way obligates the U.S. Air Force.)

Sincerely,

Robert L. Doerr, Capt, USAF
3746 Patterson Rd., #D
Dayton, OH 45430

Thomas H. Gross, Capt, USAF
925 Chestnut Cr.
WPAFB, OH 45433

APPENDIX C

CORRESPONDENCE SCHEDULE

CORRESPONDENCE SCHEDULE

Addressee	Response
Manufacturers of Fire Protection Systems	
Ansul Company	No response
"Automatic" Sprinkler Corp. of America	No response
Chemetron Fire Systems	No response
Fenwal Inc.	Brochures (3)
Fike Metal Products Corp.	Letter, Brochure
Grinnell Fire Protection Systems Company, Inc.	No response
Pyrotronics	Brochure
Viking Corp.	Brochure
Walter Kidde & Company, Inc.	No response
Installers of Fire Protection Systems	
Cincinnatti Sprinkler	No response
Daysco	No response
Greater Dayton Heating and Cooling	No response
Hughes-Bechtel	No response
Hydro-Security	No response
John T. Crouch	No response
ORR Safety	Letter, Brochure
Viking Fire Protection	No response
Manufacturers of EDPE	
Burroughs	Letter, Referral (2)
Control Data Corp.	No response
Datapoint Corp.	No response
Honeywell Information Systems	Letter
IBM Corp.	Letter, Brochure (1,3)
NCR Corp	Letter, Referral
Sperry UNIVAC	No response
Factory Mutual System	Letter, Brochure

(1) Provided copies of specified standards required by their insurance carriers
(2) Internal Corporate Referral--no further correspondence received
(3) Duplicate of information received from other sources

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