matic sprinkler systems, fog systems, or deluge systems. One thing has stood out like a sore thumb. The plants were completely destroyed, and in some cases lives were lost. The water systems by whatever name were distinguished by their failures and not by their successes. When anything has failed as conspicuously as sprinkler systems in extraction plants, it is high time to look for something better. That something better may be automatic foam protection. There is at least the promise that foam can put out the fire, and the same thing cannot be accurately said about untreated water in connection with a solvent fire.

In the event that we have not been able to extinguish the fire by whatever means might be available, then we would certainly want to try to control it and to limit the intensity. We would like to have as little solvent in the extraction area as possible. While water is completely ineffective in the primary purpose of extinguishing the fire, it can be used to limit the intensity, to keep things cool, and possibly to avoid the dumping of additional quantities of fuel through failure of structural supports, rupturing vessels, and so on.

Some thought must be given to the disposition of the water used in deluge systems. The water is likely to carry considerable quantities of solvent along with it, and this water needs to be held in some spot where burning solvent will do no damage.

Usually automatic foam extinguishing is combined with water deluge. One practical reason is that insurance companies tend to give no credit on premium for foam which will extinguish a solvent fire but will give credit on premium for water deluge which will not extinguish a solvent fire. Foam can be used to put out the fire while water deluge can be used to get the reduction on the premium.

THE NORMAL combined system applies foam while the supply lasts. The supply may continue for 10 to 20 minutes, at the conclusion of which time a foam blanket, possibly some two feet thick, will have been built up on all horizontal surfaces where it is not free to flow away. Depending upon the nature of the foam, some blanket may be present on vertical or inclined surfaces. When the foam supply has been exhausted, the same nozzles which have applied the foam will provide water. Naturally, if the fire has been smothered out before the foam supply is exhausted, there will be no need to throw on the tons of water by the deluge system.

The automatic application of foam can be actuated either by automatic vapor detectors or by rate of temperature-rise elements. Ideally both would be provided, and the provision of both means is not expensive. If the vapor detectors are well located, a solvent spill of any kind will be detected within seconds and the foam immediately applied. With an adequate purging system the interval of time during which the hazardous conditions exist will be very short. The space occupied by vapor in flammable concentration will be severely limited, and the chance of fire greatly reduced. The well-designed system can entirely prevent the fire which would have been, without such a system, but we shall not hear about that. We shall learn only of the ones that do start.

The economical installation of automatic foam protection puts some requirements on the extraction-plant design. Application to some existing plants might prove to be somewhat expensive. If the extraction plant design can be coordinated with the automatic foam system, the installation of automatic foam system can be for a relatively low cost in view of the protection that can be afforded.

[Received May 9, 1957]

Application of Mechanically Produced Airfoams to Fire-Protection Problems

W. E. AULT and E. B. RUMBLE, "Automatic" Sprinkler Corporation of America, Youngstown, Ohio

Part I. Development and Characteristics of Fire-fighting Airfoams

J. M. PERRI (1), in his chapter on "Fire-Fighting Foams, Foam Theory, and Industrial Application" by J. J. Bikeman, recalls the earliest practical experiment with fire-fighting foams. Chemical foam made by the reaction of solutions of aluminum sulfate and sodium bicarbonate obtained its buoyant property from the carbon dioxide thus formed and well dispersed in the solution. Stability of dispersion was accomplished through the use of saponin. Development of the chemical foam fire-protection field was rapid in the early 1900's and, with early application to the hand fire-extinguisher, quickly was adapted to the protection of large storage tanks containing flammable liquids. Principal modifications of chemical foam were in the selection of stabilizer materials, the method of producing solutions from easily stored chemical powders, and conduction and application of foam to the flammable surface.

The so-called mechanical or airfoam had its beginning in the mid-twenties. The principal differences between airfoam and chemical foam are found in the use of air in place of carbon dioxide as the buoyant constituent. Contrary to first observation, the air-solution suspension does not contribute to the burning mechanism nor does it have any lesser effect than carbon dioxide on the extinguishing mechanism.

One's earliest recollections of the production of mechanical foams undoubtedly date back to the egg beater, whipped cream, chiffon pie, and strawberry mousse. The domestic ability of any housewife is ultimately measured by the permanence of the "mechanical foam" which she can produce by inducting air through agitation and then holding it in fine suspension in the face of searing oven-heat and bated breath.

Economics takes its toll, and stabilized airfoam suspensions had to be produced from less expensive solutions. There seemed to be no synthetic stabilizers which would meet all of the tests of fire. Materials which shared the classification of protein were found to be most suitable. Standardized water solutions made from products like stockyard scraps, fish scales, soybean meal, and blood have met with commercial success. These hydrolyzed protein solutions are concentrated to be used in fire streams at the rate of either 6% or 3%.

Various techniques have been used for addition of air to the fire stream solution and for the proper emulsification of the air into the solution. There are two fire-fighting foam criteria: the amount of air held in suspension in the foam and the degree of permanency of suspension. Each of these factors contributes to the speed of extinguishment, the ability to insulate, the cooling property, the stability in the presence of heat, and the fluidity.

Mechanical or airfoam has as its principal property, buoyancy. Through high volume to weight ratio it can blanket and remain on flammable liquid surfaces with a density less than that of water. Water can be used in this way to cool, to isolate vapors, and to insulate flammable and exposed metal surfaces from the heat of fire. When gently applied to a burning gasoline surface, for example, the lighter-than-gasoline fluid flows around the surface to seal it from the heat of the adjoining fire; to insulate the surface, thus retarding flammable vapor production; and to cool the flammable liquid surface and tank sides, thus retarding the rate of vapor production below the flammable range.

The measure of fire-extinguishing ability of airfoams has often been tied to the measure of buoyancy, density, or expansion. Expansion, as the term applies, represents the number of times the original volume of solution has been increased by the addition of air. An expansion of four would indicate that the foam produced occupies a volume four times that of the solution from which it is made; or three parts of air and one part of solution make up the foam volume of the expansion of four. Another expression for expansion is found to be the reciprocal of the specific gravity for the particular sample of foam taken.

Smallness of bubbles and homogeneity contribute to stability of foams. The measure of stability is made by the technique of periodically collecting and measuring the drainage of solution from a standard volume of foam.

Criteria for stability are stated in terms of one-quarter life-time, the common reference for time constant in the experimental disintegration equation. A foam may, for example, have a one-quarter drainage time of 30 seconds as a measure of stability. It is first necessary to determine the expansion on solution content of the standard volume of foam before one-quarter time may be established.

Viscosity and fluidity are important factors in the efficient application of fire-fighting foams to flammable surfaces. Similarly viscosity of foam will determine to some degree the ability of the foam to stick to vertical surfaces and to insulate from excessive heat. Viscosity of foam is proportional to expansion and to drainage time. Viscosity can be lessened by reducing expansion or drainage time, or by an optimum combination of both factors.

The U. S. Navy Department, through both full- and small-scale experiments at the Naval Research Laboratory, has determined many optimum properties for fire-fighting foams. For example, it has found that aircraft-crash fire techniques require a particular range of expansion and drainage for most efficient dispersion over a large spill fire, on the one hand, and another combination of expansion and drainage for directed discharge over greater distance or range to blanket or insulate the fuselage of the aircraft. The most economical use of foam constituents, horsepower for generators, and for distribution onto the surface of deep storage of certain flammables has been found to require even another combination of drainage and expansion to devise optimum properties.

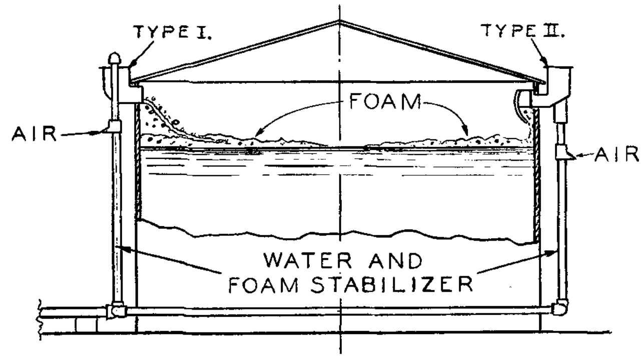

FIG. 1. The sketch shows two different types of airfoam units used for the gentle application of foam to flammable-liquid surfaces. Type I unit discharges the airfoam through a porous tube, which is rolled up in the unit until the system operates. Type II, discharges the foam against the sides of the tank and allows it to slide down to the flammable-liquid surfaces.

The commercial optimum must take into account limited budgets, already available water supplies, and the economic balance measured by possible loss to product, process, and profits—not to speak of personnel. Today's modern industry has available some very fine foam systems for the protection of the profit dollar.

Part II. Application of Fire-fighting Airfoams to Fixed Piping Systems

THE AIRFOAMS are not adaptable to all fire problems but rather are the most economically effective materials for the suppression of fire where flammable liquids with boiling points above atmospheric temperatures are part of a fire hazard. Their application by the fire protection engineer to fixed piping systems has provided a sound tool to increase substantially the safety margin where flammable liquids are stored, processed, or used.

This class of flammables may appear small in comparison to the Class A materials (carbonaceous solids); however its importance in fire protection has followed the development of the use of petroleum fractions, petro-chemicals, and synthesized compounds for the production of plastics.

Basic Methods of Application of Airfoams. From the first usage of foam, until well into World War II, the method of foam application was known as "gentle application." This description term meant the application of foam at a given point or several points in such a manner that the foam could slide to the flammable liquid surface and be pushed out over it gently as a continuously forming, unbroken mass or foam blanket (Figure 1). Such systems are described in (2) N.F.P.A.-N.B.F.U. Pamphlet No. 11.[1]

[1] This type of application is still necessary where airfoams designed especially for the extinguishing of alcohols or water-soluble flammable liquids are used.

During World War II the U. S. Naval Research Laboratory demonstrated the feasibility of applying airfoams from below the flammable liquid surface. This method was commonly used during the war by the British for the protection of flammable liquid storage vulnerable to bomb attack (Figure 2). A specially designed pump capable of mixing air, water, and foam stabilizer was used to inject the foam into the product line of the tank to be protected. This type of application has never "caught on" commercially in the United States.

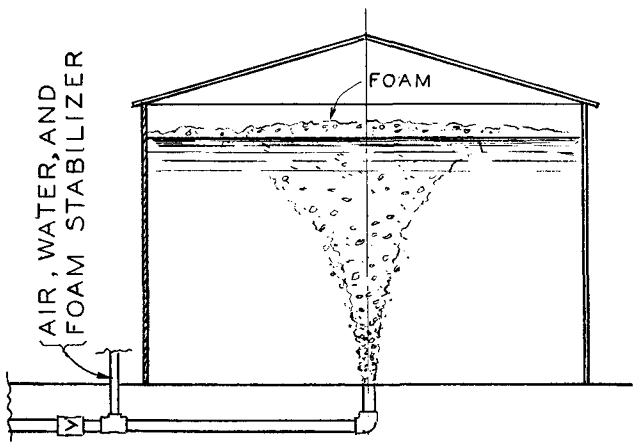

FIG. 2. Airfoam stabilizer, air, and water are mixed together in an airfoam pump, which in turn discharges the mixture into the product line of the tank. Foam then passes through the product line and floats to the surface of the flammable liquid.

During 1948 it was demonstrated that airfoam could be discharged in a dispersed condition from substantial heights above a flammable liquid surface and successfully extinguish a fire in the liquid.

This concept of the use of airfoam opened a new field of fire-protection design. Where originally airfoam, fixed-piping systems were mainly adaptable to the internal protection of vertical storage tanks and small open vats, now overhead application made possible the design of foam systems similar in form to the deluge-sprinkler system and the water-spray system. Such systems were quickly accepted by fire-conscious operators of chemical processes, flammable liquid loading and unloading facilities, airplane hangars, solvent-extraction plants, and other similar hazards.

In 1954 the National Board of Fire Underwriters recognized the usage of this type of system and published their N.B.F.U. Pamphlet No. 16, "Combined Foam and Water-Spray Systems" to describe and establish rules regarding its use.[2]

Design Advantages of Airfoam. The most important advantage of airfoams over the chemical foams (formerly the only fire-protection foam) is the fact that the solution of foam stabilizer and water can be handled as a liquid and aerated into foam at a discharge device. This overcomes the need of forcing foam through large-size lines or using a dual piping system.

General advantages are simplicity of distribution piping system; resistance to break-down when water is discharged on foam blanket; clean-up after system operation is minor problem (residue is water-soluble); foam liquid-stabilizer supply may be pumped to various areas and hose stations; reduced water-supply usage for same fire control as water-spray systems; positive extinguishing of spilled flammable liquids; no reflash probability; ability to lay vapor seal over spilled flammable liquid; reduced drainage requirement, simplifying construction of separator sumps; safety where adequate drainage is not practical—flammable liquid may be held safely under airfoam blanket while being evacuated through sump pump; and systems may be designed quickly to blanket large areas.

Application of Airfoam to Various Fire Hazards. To understand the application of airfoams to various fire hazards one must recognize the fundamental difference between the two published standards for their use. N.F.P.A.-N.B.F.U. Pamphlet No. 11 describes the use and requirements for the use of airfoam as a fire-extinguishing medium while N.B.F.U. Pamphlet No. 16 is developed to require those automatic and mechanical features necessary for surety of operation similar to that required of the automatic sprinkler-system.

When designing or purchasing such systems, it is essential first to establish the type of application of the airfoam and then be guided by the requirements published for that system. The following is a list of typical fire-hazards with applicable rules noted: conical roof storage tanks: usually protected internally, hose streams used for outside protection (N.F.P.A.-N.B.F.U. No. 11); small open vats of flammable liquid (N.F.P.A.-N.B.F.U. No. 11); chemical process buildings or structures (N.B.F.U. No. 16); loading and unloading facilities (N.B.F.U. No. 16); flammable-liquid storage creating exposure (N.B.F.U. No. 16); solvent-extraction plants (N.B.F.U. No. 16); airplane hangars (3, 4); and fuel and solvent pumps (N.B.F.U. No. 16).

Evaluation of Economic Aspect of the Use of Airfoam Systems (N.B.F.U. No. 16). Analyzing the economics of airfoam fire-protection requires the weighing of all facts relating to drainage costs, building costs, safety, saving in area, etc. Many times savings in such items far outweigh insurance rate considerations. A study of this type should involve consulta-

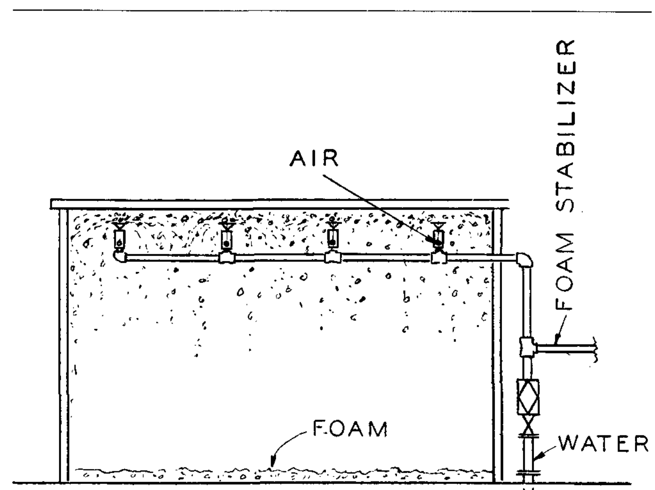

FIG. 3. Foam is discharged overhead and falls to blanket the liquid surface. This type of system allows the same action with water as does the standard, deluge-sprinkler system.

[2] This method is not applicable to flammable liquids easily soluble in water.

tions with personnel thoroughly familiar with the usage and adaptability of the airfoams.

The term "equivalent isolation" best describes the use of airfoam in such studies. The automatic discharge of a sealing airfoam blanket over flammable liquids to isolate this hazard from affecting equipment and property has already been accepted in lieu of relocation of flammable storage.

For example, a paint manufacturer in New York state was faced with a relocation of his solvent storage to qualify for adequate insurance. Because of his peculiarly cramped position such relocation was estimated to cost in excess of $100,000. The installation of an airfoam system costing $25,000 achieved the desired recognition with a savings of $75,000.

A naval stores manufacturer, who had built his plant over a period of years, finally faced the fact that any fire in his plant could easily become a catastrophe. The only solution to this problem was the relocation and diking of flammable liquid storage and a re-design of building; the estimate for this work was well over $2,000,000. The board of directors of this firm appropriated $500,000 to cover the hazardous areas with airfoam. One of these systems laid a blanket of foam 40,000 sq. ft. in area and 6 in. deep in two minutes.

Conclusion

The application of airfoam as described herein gives promise of a sound improvement in fire safety where flammable liquids are used.

REFERENCES

1. Perri, J. M., *et al.*, "Foams, Theory, and Application," p. 189.
2. Standards of the National Board of Fire Underwriters for Foam Extinguishing Systems as Recommended by the National Fire Protection Association.
3. Standard of the National Board of Fire Underwriters for Combined Foam and Water Spray-Systems, No. 16.
4. Standard on Aircraft Hangars, No. 409, National Fire Protection Association.

[Received May 9, 1957]

Some Aspects of Laboratory Safety

HAROLD H. SCHULTZ, S. C. Johnson and Son Inc., Racine, Wisconsin

It was decided at the fall meeting of the American Oil Chemists' Society to increase the activities of the Technical Safety Committee by forming a general plant subcommittee and a laboratory subcommittee. The activity of these committees is getting under way, and this paper is presented as a general introduction to laboratory safety. It is hoped that, in the future, papers on laboratory safety will be given on specific problems in safety which face the industry and laboratory today.

The subject of laboratory safety is not new. However it is a subject which is overlooked by many chemists and laboratory workers. I would like to discuss briefly my convictions concerning the need for a laboratory safety program, some of the ideas which are generally acceptable in the organization of a safety program, and the part played by executive management, first-line supervision, laboratory personnel, and the safety representative in the functioning of such a program.

Owing to the very nature of the work the chemist or laboratory technician is exposed to the hazards of a wide variety of compounds which are toxic, flammable, and explosive and may cause severe burns or dermatitis if they come in contact with the skin. Howard Fawcett of the General Electric Research Laboratories stated that there are five specific hazards connected with most chemical laboratories: toxicity, chemical burns, fire, electric shock, and glass cuts (7).

Toxicity is the hazard which is least appreciated since it is not as apparent or easily recognized as a chemical burn or dermatitis. For many years the toxicity of common materials such as carbon tetrachloride, benzene, and hydrogen sulfide were not recognized and are still not fully appreciated.

Dr. Van Atta, who is staff representative of the Chemical Section of the National Safety Council, stressed the importance of training plant and laboratory people so they are well aware of the hazards connected with their work (13). He cited several case histories concerning poisoning from hydrogen sulfide. One concerned a freshman chemistry laboratory where, over a period of time, two students and a stockroom attendant were overcome by the fumes and had to be carried out.

Looking back on my freshman chemistry course in college, it is a miracle that some of us were not overcome by hydrogen sulfide poisoning. When one considers the stench which permeated the chemistry building, it is a wonder that any of us continued on in chemistry. In all probability some students may have deserted the field of chemistry for this very reason. This could easily have been remedied if adequate hood space had been provided and the students thoroughly briefed on the toxicity of hydrogen sulfide.

The interest in safety in university laboratories is increasing because of the efforts of the National Safety Council Chemical Section and Alpha Chi Sigma chemical fraternity. In some instances this interest has been catalyzed by a serious accident. In the March 25, 1957, issue of Chemical and Engineering News the safety programs at Ohio State University and Purdue were outlined.

Statistics on laboratory injuries, according to Dr. Van Atta, are rather hard to obtain. Based on a handful of laboratories, the latest frequency rate was two accidents per million man-hours, and the severity was 260 days charged per million man-hours. The chemical industry had a frequency of 3.9 and a severity of 640 compared to frequency of seven and a severity of 800 for all industries.

Chemical and Engineering News periodically publishes frequency rates for the chemical industry, which are compiled by the Bureau of Labor. This information was broken down for different chemical industries, and it was a surprise to me that the vegetable and animal oils and fats industry was consistently high, ranging in frequency rate from 19 to 23 injuries per million man-hours. According to these statistics, it appears that laboratories are relatively safe. However chemists should not be complacent be-