Performance Entry from "Saving the City: An Encyclopedia of Calamity-mollifying Devices for the Modern Metropolis"

Aside from keeping the rain out and producing some usable space, architecture is nothing but a special effects machine.

—Elizabeth Diller, *The Blur Building and Other Tech-empowered Architecture*, 2007

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INTRODUCTION

In 1752, the year Benjamin Franklin invented the lightning rod, he also established the first American fire insurance company. That these innovations share a common source is notable not only for the fact that Franklin's impact on American architecture may be greater than is customarily assumed, but also because this parallel development prefigures the interwoven relationships between invention, building insurance, and legislation that underlie the production of architecture today. Industrialization brought new threats to the city (electricity, speed, explosives) while also dramatically increasing the scale of historical perils (flood, fire, theft). In turn, these threats gave rise to a field of new products, accessory to conventional building. Negotiating the thresholds between the developing infrastructures of the city and its private spaces (as insured and legally defined), these emergency devices can be understood collectively as a crumple zone intended not to prevent urban disaster but to absorb, limit, and contain its effects. In their early forms, the automatic sprinkler, exterior fire escape, panic bar, emergency light, and theft alarm were, like Franklin's original lightning rod, ready for production and deployment on a large scale, without definitive spatial identity, and suitable for use in new or existing construction. Culminating in their current ubiquity, the integration of these devices into the spatial and psychological landscape of the city is the story of the Encyclopedia

MEASURING PERFORMANCE

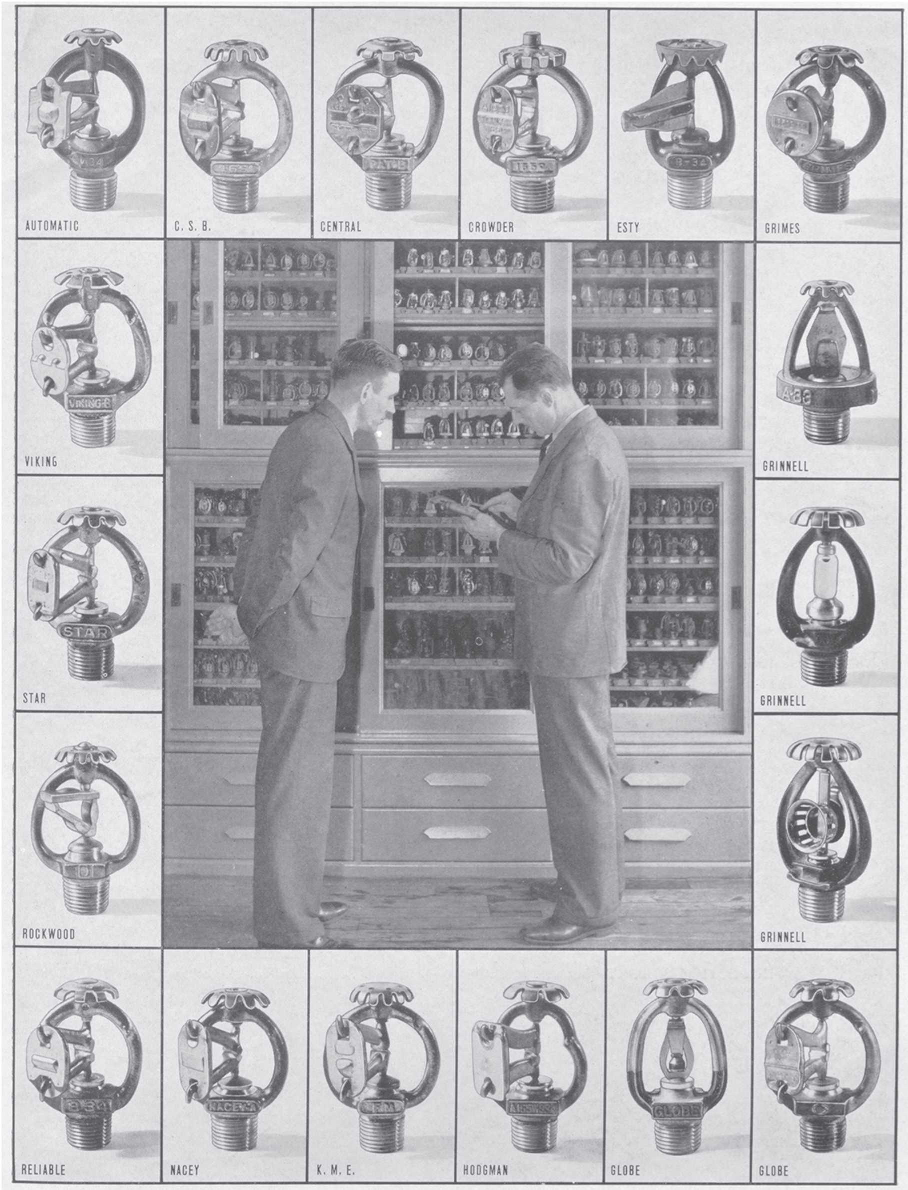
The history of building research is, perhaps self-evidently, intertwined with the history of building failure—with architectural underperformance. While architecture's own origin myths may cast fire in the benevolent role of hearth, giving "rise to the coming together of men, to the deliberative assembly, and to social intercourse,"[1] it was the combustibility of material architecturally arranged that kindled the flames of systematic building research during the latter half of the 19th century in the United States. Specifically, the science of fire protection may be traced to the records of the Factory Mutual insurance companies, the first of which was founded 1835, and their coverage of mills engaged in the manufacture of cotton.

For several decades through the mid nineteenth century, Factory Mutual insured timber-frame mill buildings in New England provided a valuable concurrence of typological consistency, requisite inspections to assess risks, and the methodical recording of failures. Drawing largely on these records, and his own experience as an engineer and Factory Mutual insurance inspector, Charles J. H. Woodbury released *The Fire Protection of Mills; and Construction of Mill-Floors: Containing Tests of Full Size Wood Mill Columns* in 1882. Noting that "a fire-proof mill is a commercial impossibility,"[2] Woodbury focuses instead on fire prevention and mitigation—on absorbing, limiting, and containing its effects. The means of extinguishing a fire once started is a topic of particular interest—as are the performance records of available "apparatus" for fire-mitigation. In closing his preface, itself an apology for the development of applied building research on the effects of fire, Woodbury finds the pith of his pragmatist argument in excerpting a metaphorical passage on governance found in Macaulay's History of England. "It is most important that the architect who has to fix an obelisk on its pedestal, or to hang a tubular bridge over an estuary, should be versed in the philosophy of equilibrium and motion. But he who has actually to build must bear in mind many things never noticed by D'Alembert and Euler."[3]

Following the publication of The Fire Protection of Mills, Woodbury was enlisted by the Factory Mutual Fire Insurance Companies to carry out a performance evaluation of automatic sprinkler devices, in 1884. In the decade since the invention and first commercial installation of Parmalee's revolutionary "Improvement to Fire-Extinguishers,"[4] in 1873, the number and variety of products advertised as automatic sprinklers had increased dramatically. Individual manufacturers, for whom proof of effectiveness held market value, frequently showcased product performance by means of staged, dramatic performance. In fact, the demonstration of architectural emergency equipment as public spectacle has a substantial history—from Benjamin Franklin's "sentry-box" lighting rod assembly outside Paris, in 1852, to Elisha Otis's dramatic demonstrations of elevator cable cutting, "an invention in urban theatricality: the anticlimax as denouement, the non-event as triumph."[5] However, the Factory Mutual sponsored testing would be the first recorded, systematic, comparative study of an architectural emergency device, testing 19 commercially available automatic sprinkler heads.[6]

Working with two collaborators (one from MIT, of which Woodbury was a graduate, the other an inspector from the Boston Board of Fire Underwriters, Factory Mutual's insurance market competitor), Woodbury established and undertook tests for "sensitiveness," "bursting strength," "distribution," "discharge," and "sprinkler solder." The research "indicated standards of performance to which automatic sprinkler equipment should be manufactured and installed, which influenced sprinkler practice, not only in the United States and Canada, but in England as well."[7] It also led to the establishment of the Factory Mutual Laboratories, in 1886. In the same year, Woodbury undertook more elaborate tests for sprinkler head "sensitiveness" "by placing the heads in a building 20 by 30 by 10 feet high. Six sprinklers were installed on piping near the roof, under pressure of 35 to 40 pounds. They were subjected to heat from a fire consisting of ½ barrel of shavings to which excelsior was added if necessary."[8] The time necessary for each of the various sprinkler models to automatically open and discharge was recorded. The carefully dimensioned room, the distribution pattern of the sprinklers, and the standardization of a fuel source, marked the birth of an architecture designed for the systematic staging of contained catastrophe, facilitated by scaffolds, walls, and spatial delineation against which the effectiveness of emergency devices could be measured. (Figure 1)

Today, the FM Global Laboratories sprawl across a 1600 acre campus that "includes four laboratories focused on property loss prevention research and product testing. These facilities include the worlds largest Fire Technology Laboratory, as well as a natural hazards laboratory, an electrical hazards laboratory and hydraulics laboratory."[9] Architecturally, the laboratories



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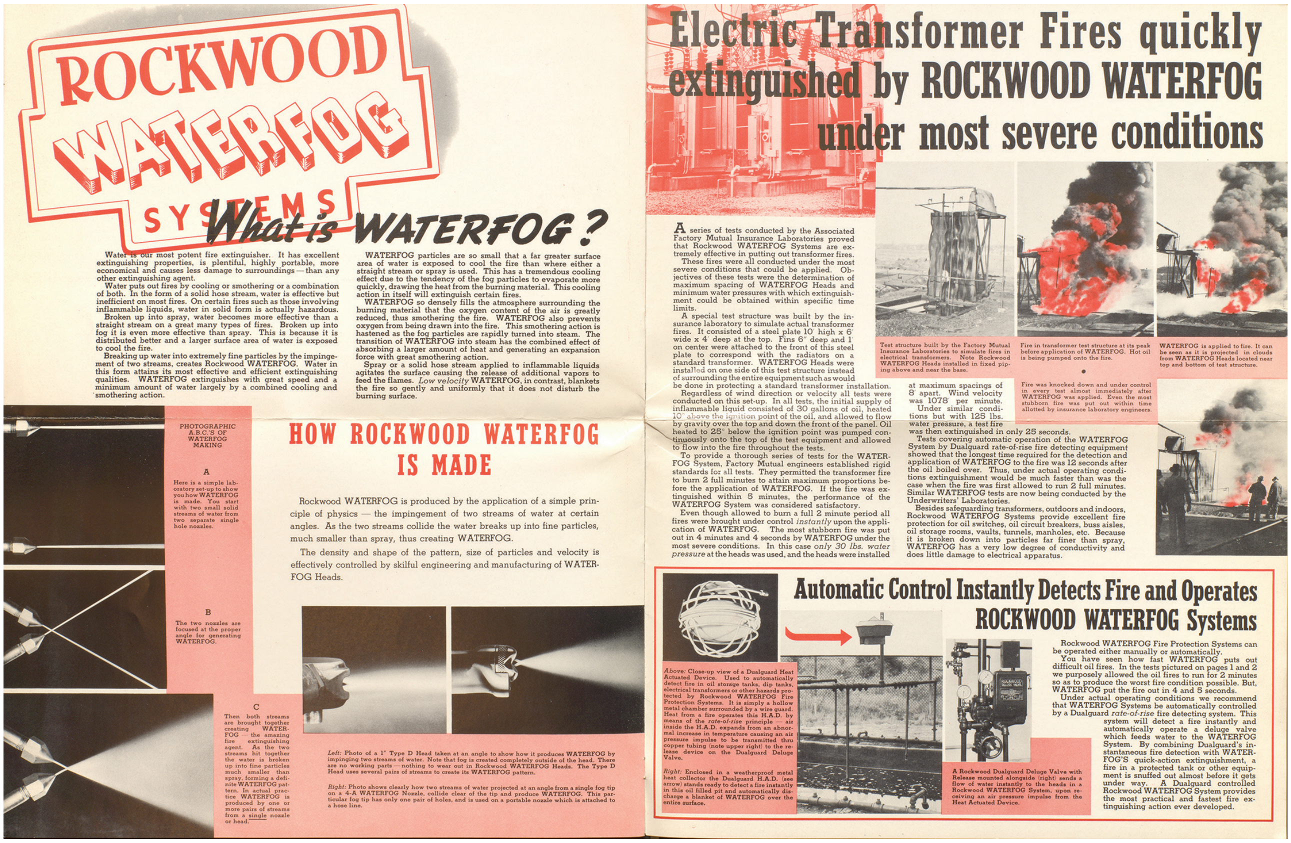
are essentially over-scaled and over-structured spatial containers, some with customizable ceiling heights, capable of sheltering full-scale, multi-story buildings and other architectural assemblies from exterior weather conditions while exposing them to most known natural and manmade disaster scenarios (from shake table earthquakes to pneumatic canon hail storms).

LET'S TRY FOG

While the Factory Mutual laboratory was the first such testing facility, it was hardly singular. Another that bears specific mention is the Underwriters Laboratories (UL), founded in 1900 under the sponsorship of the National Board of Fire Underwriters (NBFU) and the National Fire Protection Association (NFPA), the latter having been formed in the 1890s "as a result of discussion which followed this standardization research on sprinkler equipments."[10] In the years following the turn of the century, the number of facilities conducting research on fire mitigation would grow dramatically. With the development of new technologies came new flammabilities (petroleum fires, electrical fires, engine room fires…), new devices for overcoming these new hazards and, in turn, new techniques for testing them. New alternatives for the suppression of unconventional fires were sought, and it was discovered that as an

Figure 1: *Cabinet of Automatic Fire Extinguishers, Factory Mutual Laboratories, with images of FM approved devices*. From "What is the Best Way to Extinguish a Fire? How Automatic Sprinklers have Controlled Fire Waste." American Factory Mutual Fire Insurance Company (1943)



ROCKWOOD WATERFOG SYSTEMS

What is WATERFOG?

Water is our most potent fire extinguisher. It has excellent extinguishing properties, is plentiful, highly portable, more economical and causes less damage to surroundings — than any other extinguishing agent.

Water puts out fires by cooling or smothering or a combination of both. In the form of a solid hose stream, water is effective but inefficient on most fires. On certain fires such as those involving inflammable liquids, water in solid form is actually hazardous.

Broken up into spray, water becomes more effective than a straight stream on a great many types of fires. Broken up into fog it is even more effective than spray. This is because it is distributed better and a larger surface area of water is exposed to cool the fire.

Breaking up water into extremely fine particles by the impingement of two streams, creates Rockwood WATERFOG. Water in this form attains its most effective and efficient extinguishing qualities. WATERFOG extinguishes with great speed and a minimum amount of water largely by a combined cooling and smothering action.

WATERFOG particles are so small that a far greater surface area of water is exposed to cool the fire than where either a straight stream or spray is used. This has a tremendous cooling effect due to the tendency of the fog particles to evaporate more quickly, drawing the heat from the burning material. This cooling action in itself will extinguish certain fires.

WATERFOG so densely fills the atmosphere surrounding the burning material that the oxygen content of the air is greatly reduced, thus smothering the fire. WATERFOG also prevents oxygen from being drawn into the fire. This smothering action is hastened as the fog particles are rapidly turned into steam. The transition of WATERFOG into steam has the combined effect of absorbing a larger amount of heat and generating an expansion force with great smothering action.

Spray or a solid hose stream applied to inflammable liquids agitates the surface causing the release of additional vapors to feed the flames. *Low velocity* WATERFOG, in contrast, blankets the fire so gently and uniformly that it does not disturb the burning surface.

PHOTOGRAPHIC A.B.C.'S OF WATERFOG MAKING

A

Here is a simple laboratory set-up to show you how WATERFOG is made. You start with two small solid streams of water from two separate single hole nozzles.

B

The two nozzles are focused at the proper angle for generating WATERFOG.

C

Then both streams are brought together creating WATERFOG — the amazing fire extinguishing agent. As the two streams hit together the water is broken up into fine particles much smaller than spray, forming a definite WATERFOG pattern. In actual practice WATERFOG is produced by one or more pairs of streams from a single nozzle or head.

HOW ROCKWOOD WATERFOG IS MADE

Rockwood WATERFOG is produced by the application of a simple principle of physics — the impingement of two streams of water at certain angles. As the two streams collide the water breaks up into fine particles, much smaller than spray, thus creating WATERFOG.

The density and shape of the pattern, size of particles and velocity is effectively controlled by skilful engineering and manufacturing of WATERFOG Heads.

Left: Photo of a 1" Type D Head taken at an angle to show how it produces WATERFOG by impinging two streams of water. Note that fog is created completely outside of the head. There are no working parts — nothing to wear out in Rockwood WATERFOG Heads. The Type D Head uses several pairs of streams to create its WATERFOG pattern.

Right: Photo shows clearly how two streams of water projected at an angle from a single fog tip on a 4-A WATERFOG Nozzle, collide clear of the tip and produce WATERFOG. This particular fog tip has only one pair of holes, and is used on a portable nozzle which is attached to a hose line.

Electric Transformer Fires quickly extinguished by ROCKWOOD WATERFOG under most severe conditions

A series of tests conducted by the Associated Factory Mutual Insurance Laboratories proved that Rockwood WATERFOG Systems are extremely effective in putting out transformer fires.

These fires were all conducted under the most severe conditions that could be applied. Objectives of these tests were the determination of maximum spacing of WATERFOG Heads and minimum water pressures with which extinguishment could be obtained within specific time limits.

A special test structure was built by the insurance laboratory to simulate actual transformer fires. It consisted of a steel plate 10′ high x 6′ wide x 4′ deep at the top. Fins 6″ deep and 1′ on center were attached to the front of this steel plate to correspond with the radiators on a standard transformer. WATERFOG Heads were installed on one side of this test structure instead of surrounding the entire equipment such as would be done in protecting a standard transformer installation.

Regardless of wind direction or velocity all tests were conducted on this set-up. In all tests, the initial supply of inflammable liquid consisted of 30 gallons of oil, heated 10° above the ignition point of the oil, and allowed to flow by gravity over the top and down the front of the panel. Oil heated to 25° below the ignition point was pumped continuously onto the top of the test equipment and allowed to flow into the fire throughout the tests.

To provide a thorough series of tests for the WATERFOG System, Factory Mutual engineers established rigid standards for all tests. They permitted the transformer fire to burn 2 full minutes to attain maximum proportions before the application of WATERFOG. If the fire was extinguished within 5 minutes, the performance of the WATERFOG System was considered satisfactory.

Even though allowed to burn a full 2 minute period all fires were brought under control *instantly* upon the application of WATERFOG. The most stubborn fire was put out in 4 minutes and 4 seconds by WATERFOG under the most severe conditions. In this case *only 30 lbs. water pressure* at the heads was used, and the heads were installed at maximum spacings of 8′ apart. Wind velocity was 1078′ per minute.

Under similar conditions but with 125 lbs. water pressure, a test fire was then extinguished in only 25 seconds.

Tests covering automatic operation of the WATERFOG System by Dualguard rate-of-rise fire detecting equipment showed that the longest time required for the detection and application of WATERFOG to the fire was 12 seconds after the oil boiled over. Thus, under actual operating conditions extinguishment would be much faster than was the case when the fire was first allowed to run 2 full minutes. Similar WATERFOG tests are now being conducted by the Underwriters' Laboratories.

Besides safeguarding transformers, outdoors and indoors, Rockwood WATERFOG Systems provide excellent fire protection for oil switches, oil circuit breakers, buss aisles, oil storage rooms, vaults, tunnels, manholes, etc. Because it is broken down into particles far finer than spray, WATERFOG has a very low degree of conductivity and does little damage to electrical apparatus.

Test structure built by the Factory Mutual Insurance Laboratories to simulate fires in electrical transformers. Note Rockwood WATERFOG Heads installed in fixed piping above and near the base.

Fire in transformer test structure at its peak before application of WATERFOG. Hot oil is being pumped onto the fire.

WATERFOG is applied to fire. It can be seen as it is projected in clouds from WATERFOG Heads located near top and bottom of test structure.

Fire was knocked down and under control in every test almost immediately after WATERFOG was applied. Even the most stubborn fire was put out within time allotted by insurance laboratory engineers.

Automatic Control Instantly Detects Fire and Operates ROCKWOOD WATERFOG Systems

Above: Close-up view of a Dualguard Heat Actuated Device. Used to automatically detect fire in oil storage tanks, dip tanks, electrical transformers or other hazards protected by Rockwood WATERFOG Fire Protection Systems. It is simply a hollow metal chamber surrounded by a wire guard. Heat from a fire operates this H.A.D. by means of the *rate-of-rise* principle — air inside the H.A.D. expands from an abnormal increase in temperature causing an air pressure impulse to be transmitted thru copper tubing (note upper right) to the release device on the Dualguard Deluge Valve.

Right: Enclosed in a weatherproof metal heat collector the Dualguard H.A.D. (see arrow) stands ready to detect a fire instantly in this oil filled pit and automatically discharge a blanket of WATERFOG over the entire surface.

A Rockwood Dualguard Deluge Valve with Release mounted alongside (right) sends a flow of water instantly to the heads in a Rockwood WATERFOG System, upon receiving an air pressure impulse from the Heat Actuated Device.

Rockwood WATERFOG Fire Protection Systems can be operated either manually or automatically.

You have seen how fast WATERFOG puts out difficult oil fires. In the tests pictured on pages 1 and 2 we purposely allowed the oil fires to run for 2 minutes so as to produce the worst fire condition possible. But, WATERFOG put the fire out in 4 and 5 seconds.

Under actual operating conditions we recommend that WATERFOG Systems be automatically controlled by a Dualguard *rate-of-rise* fire detecting system. This system will detect a fire instantly and automatically operate a deluge valve which feeds water to the WATERFOG System. By combining Dualguard's instantaneous fire detection with WATERFOG'S quick-action extinguishment, a fire in a protected tank or other equipment is snuffed out almost before it gets under way. A Dualguard controlled Rockwood WATERFOG System provides the most practical and fastest fire extinguishing action ever developed.

HIGH SPEED EXTINGUISHMENT of FIERCE OIL FIRE

1 2

TIME 4 SECONDS

EXTINGUISHING AGENT 15 GALLONS ROCKWOOOD WATERFOG

INSTALLATION SIX ROCKWOOD TYPE D WATERFOG HEADS ON SIDEWALL INSTALLATION OF FIXED PIPING

3 4 5 6 7

8 9 10 11 12 13 14

ROCKWOOD WATERFOG SYSTEMS

Robot Camera catches vivid split-second pictures of remarkable extinguishing action of Rockwood WATERFOG -- only 4 seconds elapsed between pictures 5 and 10.

1 Four men pour 20 gallons high test gasoline on 150 gallons of #4 fuel oil in concrete test pit (12′ x 18′ x 18″) on testing grounds which adjoin Rockwood's outstanding fire protection laboratory at Worcester, Mass.

2 Test engineer ignites gasoline on surface of concrete test pit. Note blaze flashing up in left center of pit as engineer jumps back to safety. Also observe six one-inch Type D Rockwood WATERFOG Heads installed on pipe line around tank. Pipe line running from lower right corner of photo to tank in center feeds water to WATERFOG Heads.

3, 4 Show fire building up to full intensity. Heavy clouds of black smoke and raging flames indicate fierceness of fire.

5, 6 and 7 Rockwood WATERFOG starts! Observe closely its application thru two Rockwood Type D Heads on side of tank nearest the camera, as WATERFOG gets underway.

8 and 9 Smoke and flames throttled off as if by a touch of magic as application of Rockwood WATERFOG reaches its full strength. Study carefully the remarkable extinguishing power of WATERFOG as it cuts off the intense flames with knife-like action.

10, 11, 12, 13 and 14 All out! It took but 4 seconds and 15 gallons of Rockwood WATERFOG to knock down and completely extinguish this tough oil fire — a result that can be matched in performance and economy by no other existing fire extinguishing agent. So effective is the extinguishing and cooling action of WATERFOG that test engineers can approach tank and handle WATERFOG Heads and piping with their bare hands, 5 seconds after WATERFOG is first applied. WATERFOG can be seen as moderate wind drifts it upward and away from tank.

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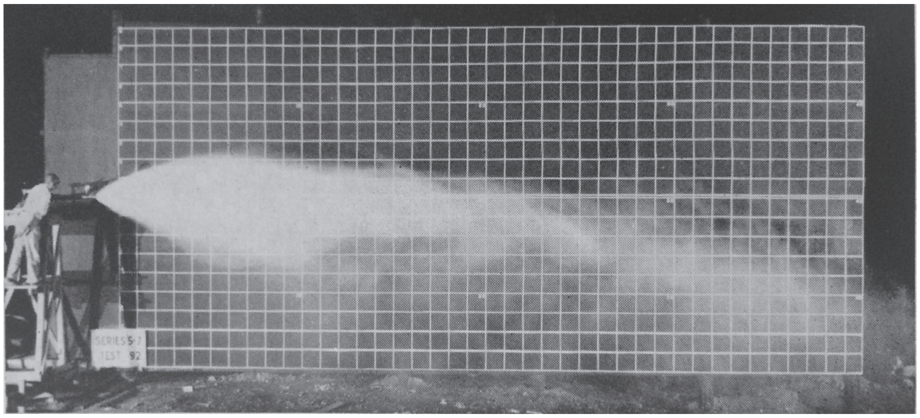

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alternative to chemical extinguishing agents, fine mist, or fog, was highly effective in a range of circumstances where conventional water streams were not.

Nozzles for producing mist or fog had been patented in the 1860s and commercially produced for fighting fires as early as the 1890s. However, it wasn't until the first half of the 20th century that spray nozzles for hose and sprinkler applications designed to "atomize" a stream of water would become the subject of more extensive research, testing, and design refinement. The primary reason for the renewed interest in fog nozzle technology was the rise of novel combustion threats, particularly the widespread use of petroleum products and electricity. While the problematic effects of adding water to electric or oil-based fires may be readily observed, it was some collection of anonymous, empirical fire-fighting scenarios which led to the discovery that "finely divided" water, or fog, was effective in combatting these unconventionally fueled fires. Elaborate testing of fog nozzles for fire suppression was carried out by the Fire Service Extension at the University of Maryland, the Factory Mutual Laboratories, and by the Exploratory Committee on Application of Water to Fires (a committee of the NFPA). Among the products to evolve during this period was the Waterfog™ nozzle by Rockwell Sprinkler. Developed for use by the Navy in the early years of World War II the Waterfog™ nozzle was designed by Rockwell's in-house research engineer, Howard G. Freeman, through several distinct iterations (Freeman accrued over twenty patents during his time with Rockwell). The nozzles could be fitted to hoses for individual use, or to a variety of piping systems for automatic, in situ, applications (Figure 2).

In the years following the Second World War, fog continued to be studied for its effects on fire, even as chemical agents, halon in particular, gained in popularity. In addition to Rockwell, Bete and Grinell (the latter holding a dominant share of the market for automatic sprinklers since the 1880s) were among the concerns engaged in the development of fog nozzles for fire suppression. In 1955, NFBU and NFPA funded research at the University of Maryland studied the discharge of commercially available fog and spray nozzles. Photographs of the fog issuing from each nozzle were taken at night, using stroboscopic light (Figure 3). The subsequent report, titled T*he Mechanism of Extinguishment of Fire by Finely Divided Water*, noted that the photographs were taken with the same camera, from the same position, with the same exposure, against the same measured background, to facilitate comparison. Roughly contemporaneously with these efforts, the NFPA's Exploratory Committee on Application of Water to Fires was experimenting with fog nozzles on staged burns of full-scale structures. Documentation of these studies led to a series of films, including "Fog Against Fire" and "Let's Try Fog," both produced in 1957. With halon production banned in the United States in 1994, there has been a resurgence of interest in fog nozzles as an alternative to chemical extinguishing sprays. Currently there are multiple lines of nozzles commercially available designed specifically for fire-suppression applications, including Fogtec™, Automist™, Ultrafog™, Microdrop™, and Aquamist™.

Figure 2: Excerpts from "Rockwood Sprinkler-ings" trade catalog featuring Waterfog™ nozzles in demonstrative testing conditions, including a staged generator fire at the Factory Mutual Laboratories, (1940)

Figure 3: Photograph from 1955 fog nozzle discharge studies undertaken by Fire Service Extension at the University of Maryland (1955)

SPECIAL EFFECTS

That the potential applications for fog nozzles extended well beyond their use as emergency equipment may be quickly recognized. The alternative applications drawing on the body of testing and research undertaken in the first half of the 20th century included special effects for film and theatre, and protection not from fire, but from frost for agricultural concerns. Artists also discovered the technology's own performative potential. In the late 1960s, Robert Rauschenberg introduced artist Fujiko Nakaya (a fellow member of the Experiments in Arts and Technology group) and Thomas Mee (a cloud physicist and former Cornell University research scientist where, perhaps ironically, he was a lead investigator for Project Whiteout, a Department of Defense funded study of cloud-seeding techniques for the dissipation of cloud coverage causing whiteout conditions in the arctic).[11] The two would collaborate on Nakaya's contribution to Expo '70 in Osaka, a fog sculpture that would envelope the exterior of the Pepsi Pavilion (figure 4). "The collaboration between Mee and Nakaya proved highly successful. With the help of extremely precise water sprayers and a completely new guidance mechanism, they succeeded in generating the largest 'natural' cloud ever created."[12] Mee would subsequently patent the fog nozzle developed (citing a range of earlier nozzle patents dating back to the late 1800s) marketing them to clients ranging from California citrus growers to the Walt Disney Company under the label MeeFog™, while Nakaya would continue to produce fog sculptures using MeeFog™ nozzles, including recent installations at Philip Johnson's Glass House and the Exploratorium in San Francisco.[13]

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Figure 4: Fujiko Nakaya, Expo '70 Pepsi Pavilion fog test with Mee nozzles (1970)

In 2002, architects Elizabeth Diller and Ricardo Scofidio arrayed over 30,000 MeeFog™ nozzles with supply piping on a tensegrity frame to produce an "artificial cloud" on Lake Geneva for the Expo.02 in Neuchatel, Switzerland. Describing the ambition of the project, titled *Blur*, Diller proposed "to use the water not only as a context, but also as a primary building material. We wanted to create an architecture of atmosphere…just a mass of atomized water.”[14] To achieve the desired effect, on-site testing would be required. As presented in the office’s official documentation of the project, published in the form of a book titled *Blur: The Making of Nothing*, a central ambition for the use of Mee’s fog nozzles was visual white-out. That is, the performance objectives of the project hinged on the use of a technology developed largely for use as a safety device for fire suppression (the fog nozzle) to simulate architectural emergency conditions frequently associated with fire (loss of visibility).

ENDNOTES

1. E Vitruvius Pollio, *The Ten Books on Architecture*, Morris H. Morgan, Trans., (Cambridge: Harvard University Press, 1914): 38.

2. Horatio Bond, Ed., *Research on Fire: A description of the facilities, personnel and management of agencies engaged in research on fire*, (Boston: National Fire Protection Association, 1957): 3.

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In initial testing, the fog system failed to perform to expectations (Figure 5). Nozzle coverage was insufficient. The supporting metal scaffold remained visually dominant—the literal structure and its implied spatial delineation were not adequately shrouded in the atmospheric ambiguity of the fog. The nozzle deployment pattern would need to be made denser to achieve the desired visual effect. Through subsequent rounds of mockup testing, an effective arrangement for nozzle density was developed which would be used successfully in the final project.

SAFETY FIRST

However, the measurement of performance in architecture has many different metrics. Even a “building” lacking the trappings of conventional enclosure would not escape life safety review. In a fax to Diller and Scofidio following a meeting with the Human Safety Division of the Building Department, project architect Dirk Hebel recounts the day’s events before arriving at an important announcement.

Figure 5: “Fog test 1” photographs from *Blur: The Making of Nothing* (2002)

But now listen to this:

They actually requested a sprinkler system for Blur!

After explaining that we are making the largest sprinkler system in the world, the authorities finally classified the steel as F30, considering the cooling effect of the fog. That means, however, that we have to make sure that the fog is kept running as long as people are in the structure.[15]

Calculations were solicited from Ove Arup, Engineers in London and spreadsheets were produced, favorably comparing the potential for fire mitigation performance by the "Blur Mist System" with both a "'Traditional' Sprinkler System" (NFPA13 classification) and the "Range of Current Mist Fire Suppression Systems."[16] That code officials failed to initially recognize the project as an atypical arrangement of fire suppression equipment, rather than a "building," is perhaps to the architects' credit. While there is a substantial history in the development of theatre technology of using steam, vapor, and fog for visual effects—perhaps most notably Wagner's use of steam for the staging of the Ring Cycle in Bayreuth in the mid 1870s —in *Blur*, the effect itself is rendered as an architectural space.[17] The relative invisibility of the sprinklers is given spatial, material presence by the fog. By contrast, most emergency devices are intentionally hidden, their operation automatically triggered and presence fully revealed by emergency conditions. However, Blur's performance as both an architectural atmosphere and a "safe," legally occupiable space are contingent on the continual presence of its nozzle-produced fog.

For special effects, success hinges on the concealment of the apparatus producing the effect, just as camouflage and concealment are usually the favored strategies, ornament and trompe l'oeil the favored techniques for integrating emergency devices into architecture, which may count "safety" and "stability" among its presumed effects. Since their introduction into architecture in the late 1800s, automatic sprinklers have by turns been decorated, customized as design objects, and made "invisible," buried in drop ceilings behind white circular caps that both hide and hint at their persistent presence and ever expanding coverage. The historical migration of many of these inventions—from experimental "plug-ins" to integral and legally mandated components—has allowed them to acquire surrogate spatial identities, redrawing architecture's limits around their inclusion. From egress stairs to alarm systems, it is not that architecture has become unimaginable without them; rather, their omission has become an impossibility for architecture. While architectural emergency devices are typically slow to be adapted for design applications, the fog nozzle is exceptional. In its ongoing technical refinement it has created the potential for an alternative architectural materiality while its performance as a fire-mitigating device continues to expand.

3. Charles J. H. Woodbury, *The Fire Protection of Mills; and Construction of Mill-Floors: Containing Tests of Full Size Wood Mill Columns*, (New York: John Wiley & Sons, 1882): vi.
4. This was the first automatic sprinkler to be both patented and put into commercial production. Henry S. Parmelee, 1874. Improvement in Fire-Extinguishers. US Patent 154,076, filed June 24, 1874, and issued August 11, 1874.
5. Rem Koolhaas, *Delirious New York: A Retroactive Manifesto for Manhattan*, (New York: Oxford University Press, 1978): 27.
6. Charles J. H. Woodbury, "Report on Automatic Sprinklers. May 15, 1884," (Boston: Ripley, 1884).
7. Horatio Bond, Ed., *Research on Fire: A description of the facilities, personnel and management of agencies engaged in research on fire*, (Boston: National Fire Protection Association, 1957): 2.
8. Gorham Dana, *Automatic Sprinkler Protection, Second Edition*, (New York: John Wiley & Sons, 1919): 74.
9. David Odeh, "FM Global Test Center," Structure magazine, August 2006: 43.
10. Horatio Bond, Ed., *Research on Fire: A description of the facilities, personnel and management of agencies engaged in research on fire*, (Boston: National Fire Protection Association, 1957): 3.
11. See James E. Jiusto and Thomas R. Mee, Jr., "Project Whiteout; an investigation of Whiteout dissipation techniques. Final report." Prepared for U.S. Army Cold Regions Research and U. S. Army Material Command, Hanover, N. H. Contract no. DA-11-190-Eng-100.
12. Saskia van der Kroef, "Patenting Art: Lessons from Experiments in Art and Technology," Metropolis Magazine, 4, 2011: http://metropolism.com/magazine/2011-no4/lessen-van-e.a.t.
13. See Bruce Keppel, "Cools, Humidifies: Tom Mee's Fog Machine Winning Place on the Farm," Los Angeles Times, Business Section, May 02, 1985.
14. Elizabeth Diller, "The Blur Building and other tech-empowered architecture," https://www.ted.com/talks/liz_diller_plays_with_architecture, (TED Talk, Filmed Dec 2007, Posted Oct 2008): 0:11.
15. Elizabeth Diller and Ricardo Scofidio, *Blur: The Making of Nothing*, (New York: Harry N. Abrams, 2002): 274.
16. Ibid., 275.
17. For Wagner's use of steam, see esp. Gundula Kreuzer, "Wagner-Dampf: Steam in Der Ring des Nibelungen and Operatic Production," The Opera Quarterly 09/2011; 27(2): 179-218. For the use of special effects in Wagner's theatre in Bayreuth, see Carl-Friedrich Baumann, *Bühnentechnik im Festspielhaus Bayreuth* (Munich: Prestel, 1980). For the use of steam and fog for theatrical special effects, see George C. Izenour, *Theater Technology, 2nd Edition*, (New Haven and London: Yale University Press, 1996).