

Assessment of the Effects of Air Movement Created by High Volume/Low Speed Ceiling Fans on Fire Sprinkler Operations

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Abstract

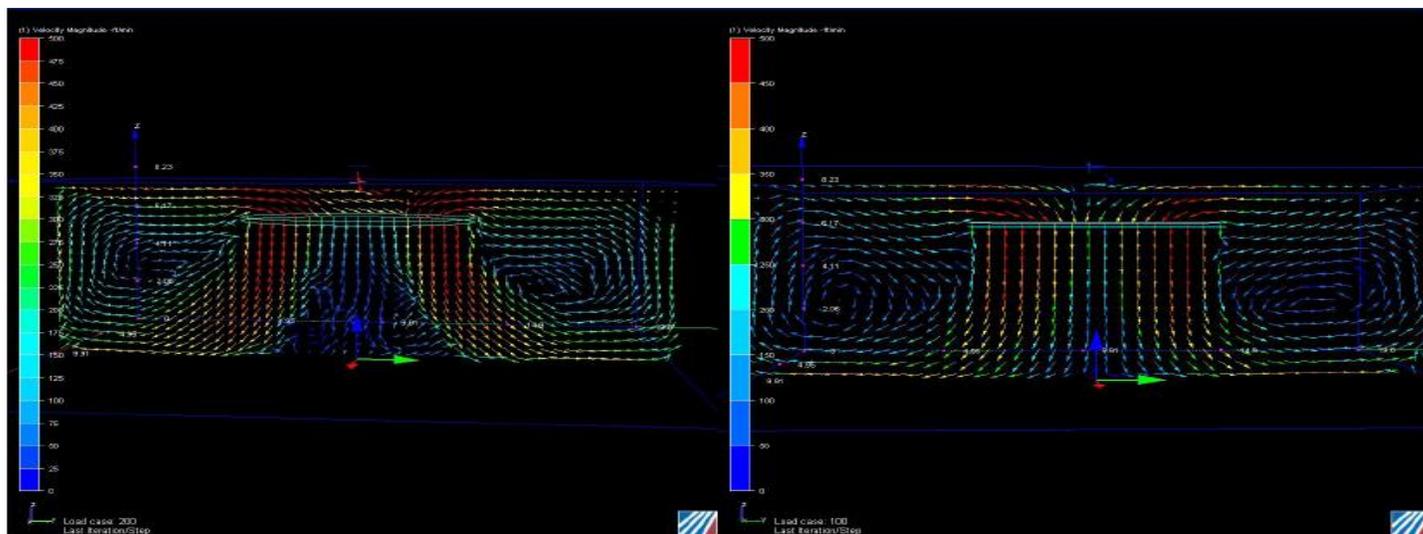
High volume/low speed ceiling fans were developed to keep the cows cool on dairy farms so there would be an increase in milk production. In today's environment of keeping the cost down and to use less energy, these fans are being installed in manufacturing and warehousing facilities to aid with the heating, ventilation, and cooling of the building. These fans are also used to provide some de-stratification of the air to keep temperature sensitive stock at a constant temperature.

Questions were raised regarding the effects these large fans have on the performance of wet pipe automatic sprinkler systems. How does the air movement created by these fan effect fire sprinkler activation, operation, and effectiveness? These questions prompted Global Asset Protection Services, LLC to initiate the research work presented in this paper. Work conducted by the Fire Protection Research Foundation will also be discussed.

In order to find some answers, series of large-scale fire tests were conducted to collect data related to fires starting under a ceiling fitted with an operating large diameter fan and a wet pipe automatic sprinkler system. Data was obtained to evaluate the effects of mechanically forced air circulation created the fan on fire growth, sprinkler operation, and the water spray obstruction effects caused by the rotating fan blades. The large-scale fire tests were conducted at Underwriters Laboratories using both palletized storage arrangements of plastic and cardboard test commodity on wooden pallets in October 2007 and using racked storage arrangements of plastic test commodity on wooden pallets in October 2008 and in June 2009.

Introduction

In 1995 Mr. Walter Boyd of MacroAir developed a fan to be used in dairy barns to keep the cows cool and comfortable so the cows can produce more milk. These fans can be up to 24 ft (7.3 m) in diameter and rotate at low speeds, 60 to 125 rpm. The fans can have between 4 and 10 blades. The blades can be either a straight airfoil that is approximately 12 in. (304 mm) wide or a tapered airfoil from 2 ft (0.61 m) at the hub to 6 in. (152 mm) at the tip. The airfoils can be fixed onto the to the hub or arranged to have a variable pitch. These fans can move approximately 428,000 cfm¹ (12,120 m³/min) of air over a space of over 30,000 ft² (2787 m²) and create an air velocity of 500 fmp (153 m/m).² In early 2000 these fans were introduced into the manufacturing and warehousing environment for cost savings and comfort. According to Marco-Air's website "In environments where air conditioning is not feasible or possible, Macro-Air HVLS fans provide an efficient and cost-effective alternative. When used in conjunction with air conditioning systems, HVLS fans can significantly reduce cooling costs. Under moderate heat conditions, the industrial fans can be run without any air conditioning, cutting operating costs as much as 90% versus air conditioning. On hot days, the industrial fans can be run with the air conditioning thermostat set 10 to 15 degrees warmer while still achieving an equivalent cooling effect. HVLS commercial fans can also substantially cut operating costs during winter months by mixing air to eliminate varying temperatures at different levels in a building. They also offer efficient ventilation, minimizing the loss of warm or cool air, as well."³ The HVLS fans are now being used in lieu of smaller, high speed fans due to the cost savings. Depending on the fan, the air flow created can create a dead space below the hub. In the presentation by Dr. Aynsley of Big Ass Fans, he showed how the air movement was below a fan with 10 straight blades vs. a fan with 4 tapered, twisted blades.⁴



Air Movement Was Below A Fan With 10 Straight Blades Vs. A Fan With 4 Tapered, Twisted Blades

For years fire testing has been conducted on rack and palletized storage in a static environment, the only air movement was that created by the fire. When the XL Global Asset Protection Services (XL GAPS) field people started seeing these fans being installed and brought it to the attention of the XL GAPS Research Department to determine if there was an issue with sprinkler obstruction or sprinkler operation. A series of full scale fire tests were conducted starting October 2007. After the initial series of tests were conducted, XL GAPS asked the Fire Protection Research Foundation (FPRF) to get a group together to determine the severity of the problem.

Fire Tests

To determine the effects of the airflow on fire growth, XL GAPS conducted two series of full scale fire tests and the Fire Protection Research Foundation conducted two tests. The first XL GAPS test series consisted of three palletized storage tests. The first test was conducted on 15 ft (4.6 m) high palletized storage of a Group A plastic commodity positioned so that the ignition was located between four ceiling sprinklers with the movable ceiling located 25 ft (7.6 m) above the floor. The piles of commodity were stacked to create a 6 in. (152 mm) flue space. The sprinklers were 286°F (141°C) rated, K-11.2 (K-161) with a standard response operating link, on a 8 ft x 10 ft (2.44 m x 3.05 m) spacing. The sprinklers were arranged to operate at a flowing pressure of 18.4 psi (1.3 bar) upon activation creating a density of 0.60 gpm/ft² (24.42 L/min/m²). Ignition was accomplished while the fan was moving air in the downward direction at the 50% power setting. The first sprinkler operated at 3:26 after ignition and the fan power was shut off and the fan was allowed to coast to a stop. A total of 73 ceiling sprinklers operated between 3:26 and 7:35. The test was terminated 8 minutes after ignition. The posttest observation and analysis of the test array indicates that the fire spread to the extremities of the test array. The baseline tests for this test were the results of the sprinkler manufacturers' listings tests as outlined in UL 199 *Standard for Automatic Sprinklers for Fire Protection Service*, Section 61 from the 11th Edition. This is the test all K-11.2 (K-161) sprinklers must pass to be listed by Underwriters Laboratories. A review of the baseline tests results showed between 4 and 7 sprinklers operating, between 45 seconds and 70 seconds, and created minimal damage.

The second and third tests were conducted on 12 ft (3.7 m) high palletized storage of a Class II commodity positioned so that the ignition was located between four ceiling sprinklers with the movable ceiling located 22 ft (6.7 m) above the floor. The sprinklers were 155°F (68°C) rating, K-5.6 (K-80) with a standard response operating link, on a 10 ft x 12 ft (3.05 m x 3.7 m) spacing. The sprinklers were arranged to operate at a flowing pressure of 18.4 psi (1.3 bar) upon activation creating a density of 0.20 gpm/ft² (8.14 L/min/m²). These tests were to simulate an Ordinary Hazard occupancy.

The second test was a baseline test and the fan was not used. Ignition was accomplished and the first sprinkler operated at 1:14 after ignition. A total of 21 ceiling sprinklers operated between 1:14 and 3:40. The test was terminated 30 minutes after ignition. The posttest observation and analysis of the test array indicates that the fire did not spread to the extremities of the test array.

The third test had the fan in operation. Ignition was accomplished while the fan was moving air in the downward direction at the 50% power setting. The first sprinkler operated at 1:57 after ignition and the fan power was secured at that time. A total of 26 ceiling sprinklers operated between 1:57 and 3:51. The test was terminated 30 minutes after ignition. The posttest observation and analysis of the test array indicates that the fire spread to the extremities of the test array.

The second XL GAPS test series consisted of two rack storage tests. Both tests were conducted on Group A plastics stored in racks to 15 ft (4.6 m) under a 25 ft (7.6 m) ceiling. The sprinklers were arranged to operate at a flowing pressure of 18.4 psi (1.3 bar) upon activation creating a density of 0.60 gpm/ft² (24.42 L/min/m²). These tests used the same sprinkler type, 286°F (141°C) rated K-11.2 (K-161), standard response link that was used for test 1. For the first test, the fan was on the side of the rack with the ignition in the flue of the rack directly below the tip of the fan blade. For the second test, the fan was over the longitudinal flue with the ignition in the flue directly below the tip of the fan blade.

In the first rack test, the fire was to the top of the array in approximately 1 minute and the first sprinkler activated at 1:56. A total of 9 sprinklers operated between 1:56 and 5:34. The test lasted the full 30 minutes. Flames did come to the face of the array quickly, but they reached the top of the array in about the same amount of time as the base tests for the K-11.2 (K-161) acceptance test using palletized storage.

In the second rack test, the fire was to the top of the array in approximately 1 minute and the first sprinkler activated at 1:53. A total of 10 sprinklers operated between 1:53 and 3:31. The test lasted the full 30 minutes. Flames did come to the face of the array quickly, but they reached the top of the array in about the same amount of time as the base tests for the K-11.2 (K-161) acceptance test using palletized storage.

These tests showed the effects the fan had on the fire growth. It pushed the flames deeper into the flues and inhibited the vertical growth of the fire. In the first test, the flames broke through the top of the storage array approximately 8 ft (2.4 m) horizontally from the ignition spot.

The FPRF conducted two large-scale fire tests in October 2008, on 20 ft (6.1 m) rack storage of a Group A plastic under a 30 ft (9.1 m) ceiling. The fan was a 6 blade fan mounted 50 in. (1270 mm) below the ceiling. The fan was left running during the tests. Sprinklers were 165°F (74°C) rated, K-14.0 (K-201) pendent ESFR ceiling sprinklers, on a 10 ft x 10 ft (3.05 m x 3.05 m) spacing. The sprinklers were arranged to operate at a flowing pressure of 50 psi (3.45 bar). The base test for these tests was Test 10 of the National Quick Response Sprinkler Research Project. The pass/fail criteria used for

the National Quick Response Sprinkler Research Project testing was not more than four sprinklers activate when the sprinklers open in the proper sequence.

The first test was conducted with the main rack ignition located between two sprinklers, and the center of the fan located offset from the main array 15 ft (4.5 m) south of the ignition location. The first sprinkler operated at 1:00 after ignition and the second operated at 1:04. The test was terminated after 32 min, and a total of 2 ceiling sprinklers operated during the test period. The fire in test was centered around the center bay above the ignition location and did not spread to either end of the main array or to the adjacent target arrays.

The second test was conducted with the main rack ignition scenario located between four sprinklers, and the center of the fan positioned above ignition. The first sprinkler operated at 0:49 after ignition and the last operated at 4:48 after ignition, a total of 8 sprinklers operated during the test period. Although more that the pass/fail criteria, the 4th and 5th sprinklers to operate were on the second ring from the ignition. The test was terminated after 31 min. The fire in test was generally centered around the center two bays above the ignition location and did not spread to either end of the main array or to the adjacent target arrays.

Discussion and Conclusion

The flue spacing in the palletized storage array was only 6 in. (152 mm) horizontal between stack of product and no flue spacing vertical while the flue spacing in the rack arrangement was loaded so that there were 6 in. (152 mm) flues horizontally and vertically. The flue spacing in the racks created a larger open area which allowed the air to flow around the pallet loads of product at a lower velocity. The palletized arrangement had minimal openings which funneled the air at a higher velocity in the open space. The air flowing at the higher velocity fanned the fire, pushing the fire horizontally further into the storage array before it had a chance to break through the top of the array. This can be seen in the videos. The video from the north balcony showed the smoke being pushed out the end of the ignition flue while none of the other flue spaces showed this. The video from the south balcony showed the fire breaking through the top of the array approximately 8 ft (2.4 m) from the ignition source. The timing of the first operation also indicates the effect the fan has on the fire, in the base line tests the first sprinkler operated between 45 and 70 seconds while in this test the first sprinkler operated at 3:26, almost 3 time longer as in the base tests.

The increase wind velocity created by narrow openings in large masses is well know by the civil engineers. Civil engineers designing buildings in large cities such as New York, Chicago, and Boston must now use a wind tunnel to determine the effect the wind creates on the structure since ASCE 7⁵ mandated this since they dropped Exposure A as an option.

The videos and results of the racked storage tests showed only minor influence on the fire development and sprinkler operation. Sprinklers operated less than a minute longer than the base test and the initial fire spread was minimal.

The fan did have a strong influence on palletized storage of product while having minimal impact on rack storage. Palletized storage of Class II commodity to 12 ft (3.6 m) high operated 23% more sprinklers than the based test and was uncontrolled with the 15 ft (4.6 m) high palletized Group A plastic storage. Further testing is needed to determine the break point of the influence of the fan and palletized storage height.

¹ Rite Hite's The Revolution® fan literature

² Minnesota/Wisconsin Engineering Notes August 2001, *HVLS Fans for Free Stall Barns*, David W. Kammel, Wisconsin Extension Engineer

³ <http://www.macro-air.com/1552>

⁴ Aynsley NFPA HVLS Concepts & Fire Tests presentation Jan 15, 2008

⁵ ASCE 7 2005 Edition *Minimum Design Loads For Buildings and Other Structures*, American Society of Civil Engineers