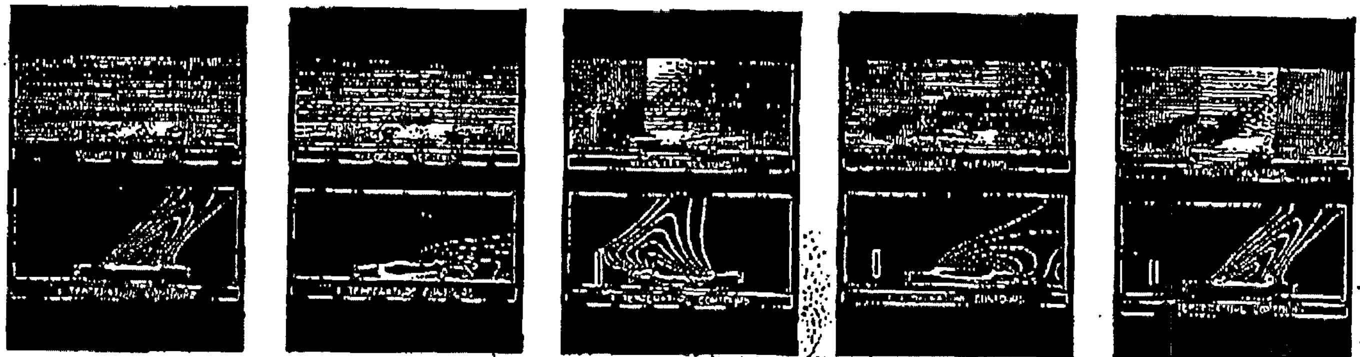
CASE STUDY

Safer Firefighter Training Aboard Aircraft Carriers

Computer simulation helped the Navy eliminate a wind hazard that was endangering equipment and personnel.



BY WILLIAM D. DAVIS AND ROBERT S. LEVINE

Computer simulation helped solve a problem with devices used by the U.S. Navy to train personnel in fighting fires on board aircraft carriers. The 19F4 firefighting trainer consists of an elevated platform or deck with a central region consisting of steel grating below which are located propane burners. The problem was that high wind could push the flames below the grating, causing a hazard to equipment and personnel.

Simulating the trainer with computational fluid dynamics (CFD) helped National Institute of Standards and

Technology scientists identify the problem—a low pressure zone below the grating. These calculational techniques were used to evaluate the effectiveness of a variety of proposed solutions. The solution developed during the simulation process, a combination of a wind-breaking fence and fans to pressurize the space below the deck, worked.

An agency of the U.S. Department of Commerce's Technology Administration, NIST's primary mission is to help American industry strengthen its international competitiveness. NIST's Building and Fire Research Laboratory (BFRL) enhances the competitiveness of industry and public safety through performance prediction, measurement technologies, and technical advances that improve the life cycle quality of constructed facilities. Its products are used by those who own, design, construct, supply, and provide for safety or environmental quality of constructed facilities. BFRL works closely with its customers to identify needs for improved practices, conduct the needed research and development, and transfer research results to practice.

The firefighting trainer where the original problem occurred was at the Treasure Island naval base located in San Francisco Bay in California. Wind blowing into the bay caused the flames to go beneath the deck of the trainer, where they created an unrealistic training scenario. The flames had the potential to damage instruments and cabling below the deck and sometimes stretched all the way to the stairs used by personnel to climb up on the deck.

The Navy had tried several experiments in an effort to solve the problem. These all involved putting steel skirts around the trainer that rose up to the level of the deck in an effort to block wind from blowing under the deck. This change actually made the problem worse. Because of this failure, the Navy was thinking of constructing a building to enclose the trainer. This would have been a very costly solution.

So the Navy asked the Fire Modeling and Applications Group of NIST if there was anything they could suggest to solve the problem. This group develops and applies mathematical models for fire growth and smoke spread. It uses three modeling approaches to predict the course of a fire. The models can be characterized by simple models, zone models, and computational fluid dynamics models. The *zone model* concept is embodied in the CFAST/HAZARD I model. CFAST is a zone model capable of predicting the time evolving distribution of smoke and fire gases and the temperature throughout a building during a user-specified fire. HAZARD I combines CFAST with additional capabilities to perform hazard analyses for a variety of applications.

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CFD models are typically applied in cases, like that of the Navy trainer, where more detailed knowledge of the flow of gases is required. CFD involves the solution of the governing equations for fluid flow, heat transfer, and chemistry at several thousand discrete points on a computational grid in the flow domain. The use of CFD enables engineers to obtain solutions for problems with complex geometries and boundary conditions. The CFD

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analysis yields values for fluid velocity and fluid temperature throughout the solution domain.

One of the CFD models used by the Fire Modeling and Applications Group is a commercial code called CFX from AEA Technology of Pittsburgh, Pa., to model fire growth and smoke spread. Previously, this code had been successfully used to simulate the fire at the King's Cross underground station in London, England. In that application, it predicted an unexpected flow pattern—along the base of the escalator rather than vertical flow toward the ceiling. This flow pattern was subsequently verified with 1/3 scale fire experiments.

The physical setups for the analysis of the firefighting trainer were as follows:[1] It was assumed that the fluid was air and that it was fully compressible. Turbulence was modeled using the k- model and included the default treatment of the boundary layer near the ground, fence, and trainer platform. The platform and fence were assumed not to be heated by the fire. Radiation effects were not included in the calculations. A rectangular, non-uniform, two dimensional grid was used to model each iteration. A grid with 87 x 32 x 3 cells was used to model the trainer and the fence. The cells near the fire were 0.3 m by 0.3 m, since this was the most important region in the simulation.

The fire was modeled as a heater. Approximately 106 Watts/cell was released in grid cells located below the platform. These cells correspond to the location of the propane burners. The fences were modeled by using an inlet boundary condition. This boundary condition allows the quantity of a material absorbed or emitted at a boundary to be specified. The permeability of the fence was modeled by allowing a portion of the wind velocity to pass through it. The fence was specified to be 6.1 m (20 feet) tall with the bottom 2.4 m (8 feet) open. Fans were also added to the model as prospective solutions by prescribing the volume flow rate at the boundary below the trainer platform. The velocity of flow was set so that the volume flow produced by the fans was 15 m^3/s (32,000 cfm) in one case and 60 m^3/s (130,000 cfm) in the other.

The first analysis scenario was designed to duplicate the base case without any fence or fan. The CFD model predicted the presence of flame blowdown under windy conditions. The second case added steel skirts around the perimeter of the deck at a height that was equal to the deck. This model showed that the flames were driven below the deck even more forcefully than in the base model. This prediction matched the results of the experiments that had been performed earlier by the Navy. The analysis showed that the steel skirt in the presence of the wind formed a low pressure zone under the deck. The fact that these first two analysis cases matched physical reality helped to build the confidence of NIST scientists and the Navy in the accuracy of the CFX software.

Four different scenarios were evaluated in an attempt to find a solution to the problem. The first two cases involved the presence of a permeable fence. This was designed to simulate a tall fence covered with slats or some type of mesh screening. The fence in the first of these four scenarios extended all the way to the ground, while the second fence was open at the bottom up to the level of the deck. The third and fourth cases provided a fan in addition to the two fence cases mentioned earlier.

The analysis results showed the importance of having a fence that is open near the ground. The fence extending all the way to the ground did not prevent flame blow-down. The analysis showed that the solid blockage near the ground forces all the air to go over the top of the fence, resulting in a low pressure zone. As a consequence, the flame is drawn toward the fence.

The case where the fence is open near the ground, on the other hand, showed the absence of downward velocity in the area where the propane burners are located. This case showed that flame blow-down was nearly eliminated. The addition of the fan improved the situation. In each case, the temperature contours were located further above the deck than in the case without the fan present. The best case of all was with the fence open below the surface of the deck and the fan present. The analysis results for this case predicted that flame blow-down would be totally eliminated.

This $12,000 approach totally eliminated the flame blow-down problem.

Based on the results of the analysis, the Navy built a fence that was open in the bottom and added the fan as described in the ideal analysis case. The cost of this solution, $12,000, was minimal compared to the alternative of constructing a building around the trainer. Yet, this approach totally eliminated the flame blow-down problem.

The Navy built as many as five more 19F4 trainers. Each of these trainers was built with the post holes in place for the fence, but the wind speeds never reached high enough velocities to warrant the fence. OHS

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Reference

1. G. P. Forney and W. D. Davis, Analyzing Strategies for Eliminating Flame Blow-down Occurring in the Navy's 19F4 Fire Fighter Trainer. NISTIR 4825, National Institute of Standards and Technology, 1992.

Halon Ban Prompts Study of Navy's Use

Following the Jan. 1, 1994, ban on domestic production of halons as a way of protecting the Earth's ozone layer, the [illegible] Naval Studies Board established a [illegible] committee to study the Navy's extensive use of halons for suppressing fires and explosions. The committee worked for eight months on the questions of whether the Navy should aggressively research halon substitutes and whether a "drop-in replacement" for halon could be found.

The committee released its report, "Fire Suppression Substitutes and Alternatives to Halon for U.S. Navy Applications," in early 1997. One of its key findings: It is "unlikely that a drop-in replacement agent will be discovered that will exhibit all of the beneficial properties of halon 1301 and not also exhibit a significant environmental impact." Halon 1301 is a total flooding agent; it and halon 1211 (a streaming agent) are widely used on Navy ships, aircraft, and shore facilities, as they are in civilian facilities, according to the report.

The Navy now has 1.4 million pounds of halon 1301 installed on 228 ships, representing an investment of $665 million. Another 441,170 pounds are scheduled to be installed on new vessels, although the Navy has chosen non-halon systems—heptafluoropropane (HFC-227ea) and a high-pressure water mist system—for an upcoming amphibious ship class, an aircraft carrier, and a new surface combatant class. [illegible] In all, the committee found, the Navy has invested $1 billion in halon-based firefighting systems since 1978. The service's total halon 1301 reserve in 1985 was approximately 4 million pounds. That total is projected to fall to 2 million pounds in the year 2010 and to 1 million pounds in 2030.

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The committee weighed three options for the Navy: continue its present course of selecting alternatives for newly designed ships; retrofit engineering plans so halon could quickly be replaced if the Navy's use of its reserve is restricted; or seek a drop-in replacement. The committee has recommended the first option, advising that the Navy should not "underwrite a major new program to seek the ultimate halon 1301 replacement agent." OHS