Power Loss

The 1999 Ford Power Plant Explosion: A Study of Problems Encountered During Large-Loss Fire Investigations

By **Kim Mniszewski, Hal Lyson, and Crispin Hales**

ON MONDAY, FEBRUARY 1, 1999, an explosion and fire ripped through the aging power plant at Ford Motor Company's famous Rouge facility in Dearborn, Michigan, killing six civilians and injuring 38, 14 of them seriously. Resulting in about $1 billion in property damage, the fire was one of the most expensive industrial accidents in U.S. history. It was also the largest human-caused insurance loss of the year.

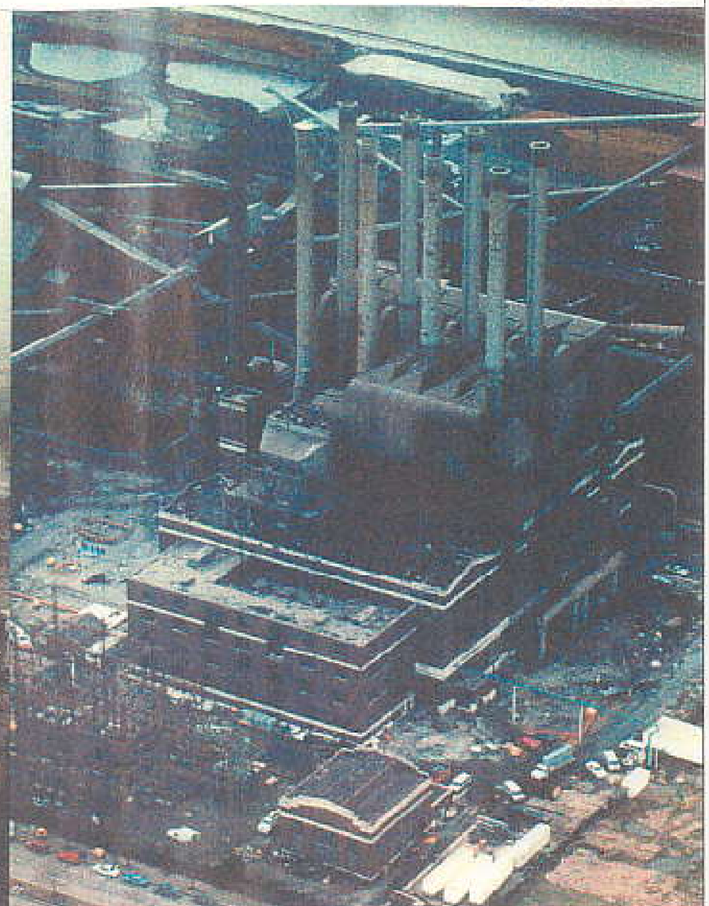
"The Rouge" was originally marshland that Henry Ford converted into what was once the largest private manufacturing complex in the world. Covering about 1,100 acres (445 hectares), the plant employed more than 100,000 people at its peak in the 1930s, when iron ore shipped up the Rouge River went into the facility at one end and came out the other end as cars. In the 1990s, however, Ford began planning a new assembly complex at the site, which today encompasses steel blast furnaces, steel rolling mills, the automobile assembly plant, an engine plant, a frame plant, and a tool-and-die plant, as well as the power plant.

In November 1998, the auto manufacturer announced that the facility's 78-year-old power plant would be replaced by a new 710-megawatt facility to be built and run by CMS Energy Corporation and DTE Energy Company. The original power plant, built in 1921, was being phased out.

The six-story power plant generated electrical power and pressurized air for the complex's blast furnaces. The unprotected, noncombustible structure covered a ground-floor area of 80,874 square feet (4,452 square meters), and included several distinct operational areas, separated by walls, creating smaller "buildings" within the overall structure (see Figure 1). Among these smaller buildings was the boiler house building, located in the center of the larger structure, and the turbo blower building to the west. The generator building was east of the boiler building, and the electrical building was to the east of the generator building.

The boiler building, parts of which were about seven stories high, had seven boilers, each topped by a smoke stack. An eighth boiler under an eighth smoke stack had been removed in the early 1960s. The boilers provided steam to power the turbo blowers, which produced high-volume compressed air for nearby blast furnaces and electric generators.

Connected to the fifth floor of the boiler house by an overhead conveyor bridge was the pulverizer building, containing 12 pulverizer mills, each of which sent pulverized coal to an associated cyclone and then to the fifth-level bridge, where the coal was augured to coal storage bunkers next to the boilers. Five of the boilers provided 1,250 pounds per square inch gauge (psig) (598 millibars) high-pressure steam, while the other two produced steam at about 300 psig (143 millibars). The high-pressure boilers, each with its own firebox, could be powered by either blast furnace gas, natural gas, or pulverized coal. All the boilers had natural gas-fired ignition



Several views of the Rouge complex of the Ford Motor Company in Dearborn, Michigan, including a view from the explosion site (top left) as two firefighters on a ladder truck pour water into the huge power plant on Monday, February 1, 1999.

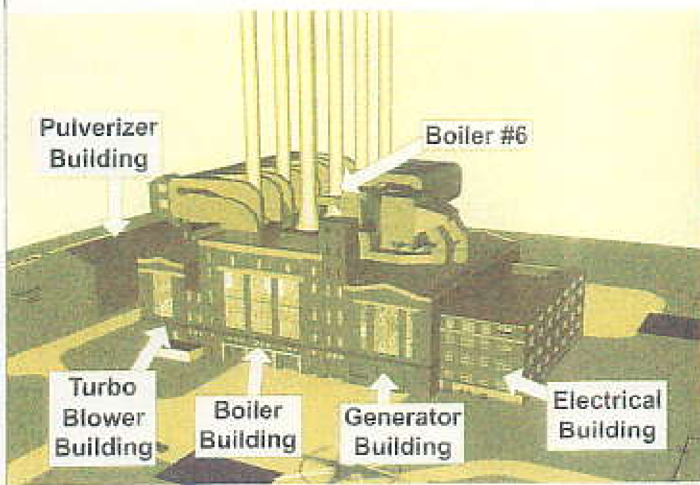


Figure 1: Ford Power Plant Facility

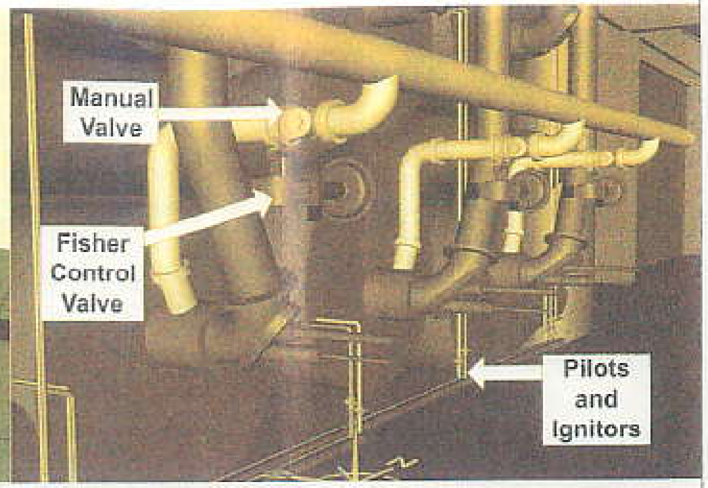


Figure 2: Three natural gas burners on each side of Boiler 6

and pilots at each burner, as well as roof-mounted electrostatic precipitators and recuperative air heaters. They were manually controlled with pneumatic controllers.

Boiler 6

Boiler 6, the power plant's newest unit, was the unit involved in the explosion. Installed in 1964–1965, the Stirling two-drum, bent tube unit had the largest capacity of all seven boilers in the complex, with a design pressure of 1,525 psig (730 millibars) and a maximum continuous high-pressure steam output of 500,000 pounds/hour (226,792 kilograms/hour).

Essentially, it was a rectangular box about 136 feet (41 meters) high, hanging from an overhead steel structure supported by four columns, one on each outside corner of the boiler. Combustion in the enclosed space created by the water walls heated the water that flowed through the tubes with natural circulation.

To control the heating effect of the combustion gases and use them as efficiently as possible, the water walls on the rear side of Boiler 6 curved inward to form a "bull nose" that divided the unit into an upper and a lower chamber into which heated air for combustion was forced. After hot flue gases wove their way up through the boiler and its regenerative components, they passed through the electrostatic precipitator, which imparted an electrostatic charge to the dust particles in the flue gases allowing the dust and fly ash to precipitate out to provide clean emissions to the chimney (see Figure 5).

Originally, Boiler 6 was designed to use pulverized coal, coke oven gas, and blast furnace gas, with six burners in two tiers on the front and six burners in two tiers on the rear. The coal, which was about the size of fine sawdust, was fed to the boiler from the bottom of the coal bunkers through 12 coal feeders. All 12 burners were used for blast furnace gas and coal, and coke oven gas was supplied to the lower 3 burners on each side of the boiler. All three types of fuel could be used alone or in combination. The ignitors and pilots were fueled with natural gas, which was manually lit using an alcohol-soaked rag.

The operator monitored the boiler, watching charts and gauges, making control adjustments by opening and closing the fuel control valves or other valves at a control panel in a control room. Manual control interlocks were not used.

Inspections were typically conducted once every two years, and the unit was brought down for maintenance about every year. Boiler 6 was last inspected in May 1998 and was issued a license.

Natural gas trains

Around 1987, the fuel and fuel control systems of Boiler 6 were modified so that 6 of its 12 burners could be fired with natural gas, which the gas company supplied at about 25 psig from a meter house southeast of the facility through two ground-floor risers, one at the southwest corner of the boiler and one at the southeast corner (see Figure 4). The two risers had mirrored valve arrangements.

Both risers were 10 inches (25 centimeters) in diameter at the ground floor. They rose to the manual valves and blanking flanges on the second floor, narrowing to 8 inches (20 centimeters) in diameter as they extended to a manual valve on the third floor. From there, the risers narrowed to 6 inches (15 centimeters) in diameter as they ran to the burners on the east and west sides of the firebox.

The risers had 10-inch (25-centimeter) manual valves on the second floor, above which "blanks" were located for a positive gas shut-off during maintenance. On the third floor, there was an 8-inch (20-centimeter) manual valve, next to which was a flame-sensing valve that had been manually wired in the open position. Crossovers from the east and west risers were connected to the igniter system below the third floor.

Each riser led to three burners on opposite sides of

ILLUSTRATIONS: CHAD AMBORN

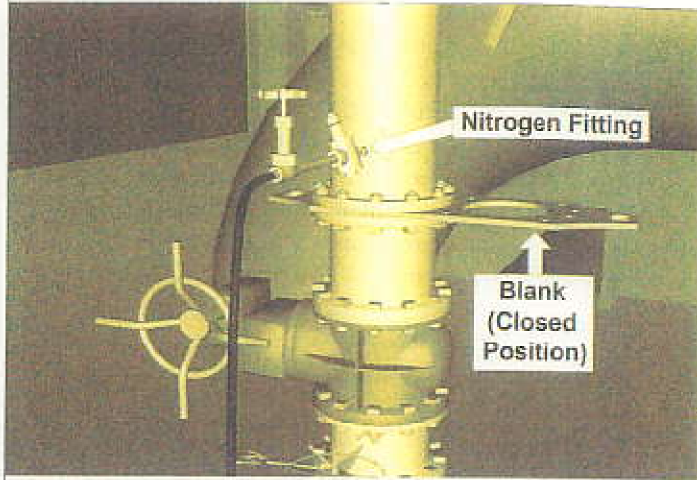


Figure 3: Valving and blanking hardware on natural gas piping

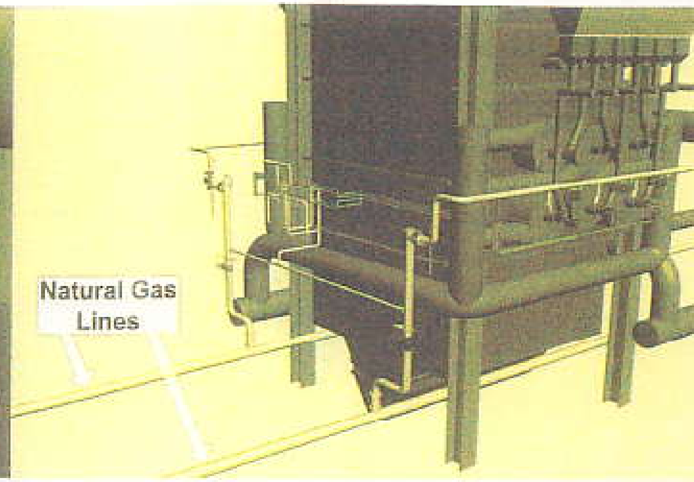


Figure 4: Two natural gas feed lines supplying Boiler 6

the boiler (see Figure 2). These six feed lines each had a manual plug valve and a pneumatically controlled butterfly valve, the actuators for which were regulated by two controllers. The controllers, designated as the east and the west, regulated the three burners on one side of the boiler and were situated in the Boiler 6 control room on the third floor. They used a 30-psig (14-millibar) air supply to control the three 6-inch (15-centimeter) feed lines on the east and west sides of the burner as groups. Each burner was also fed from a blast furnace gas line 30 inches (76 centimeters) in diameter and a coal primary air line 12 inches (30 centimeters) in diameter.

Anatomy of the incident

At about 1 p.m. on February 1, Boiler 6 erupted, sending a fireball a quarter mile (0.4 kilometers) into the sky above the powerhouse. The explosion showered debris over a large area, blowing out windows in cars parked nearby and cutting power to the entire facility. The blast also ignited fires on five floors, some of which burned for more than four hours, and blew out virtually all the power plant's windows, several doors, and some areas of the composite brick walls. Heavy concrete-roof panels blown into the air did extensive damage to trailers parked in the area, and the cinderblock wall of a locker room at the southwest corner of the facility collapsed.

Most of the glass windows in the electrical area, which housed offices and electrical switchgear, shattered, and concrete ceiling panels from the engine room landed on the electrical building's roof, as well as the ground.

The explosion also blew all the windows and metal ventilation louvers out of the north side of the powerhouse and destroyed a 20-by-20-foot (6-by-6-meter) section of brick wall on the fifth-floor. Fire and smoke were showing in this area when the fire marshal arrived.

Fire also vented through internal windows into the generator building and ignited the combustible roofing material and generator lube oil systems, spreading to the northeast corner of the precipitator on the roof of the building. The metal panels of the bridge to the pulverizer building at the northwest corner of the powerhouse blew off at approximately the sixth floor, and a fire there and in several areas inside the pulverizer building activated the building's sprinklers.

In the turbo boiler building, internal overpressure broke most of the glass windows and distorted their metal frames.

The investigation process

Once the fires had been extinguished and the search and rescue teams finished scouring the facility for victims, the investigation into the blast, following the guidelines of NFPA 921, *Guide for Fire and Explosion Investigations,* began.

Given the complexity of the incident and the size of damaged area, a joint investigative team representing all interests was formed with the intent to give them an equal opportunity to examine the evidence while avoiding concurrent investigations. Participating firms included Exponent, RKMC (Robins, Kaplan, Miller & Ciresi), Wilford Baker Engineering, Triodyne, Inc., Crawford and Company, and Rimkus Engineering. Public sector participants included the police and fire departments and the Michigan Department of Consumer Industry Protection. The United Auto Workers (UAW) was also represented.

A memorandum of understanding (MOU) was drafted, stating that a protocol would be developed for the fact-finding process and that handling and removal physical evidence from the site had to have permission of the chair, in consultation with government agencies, particularly the Dearborn Fire Marshal. The MOU also prohibited investigators from disassembling physical evidence except in compliance with the committee's protocols. These protocols, developed for each aspect of the investigation, allowed the investigators to reach independent conclusions based on their personal observations.

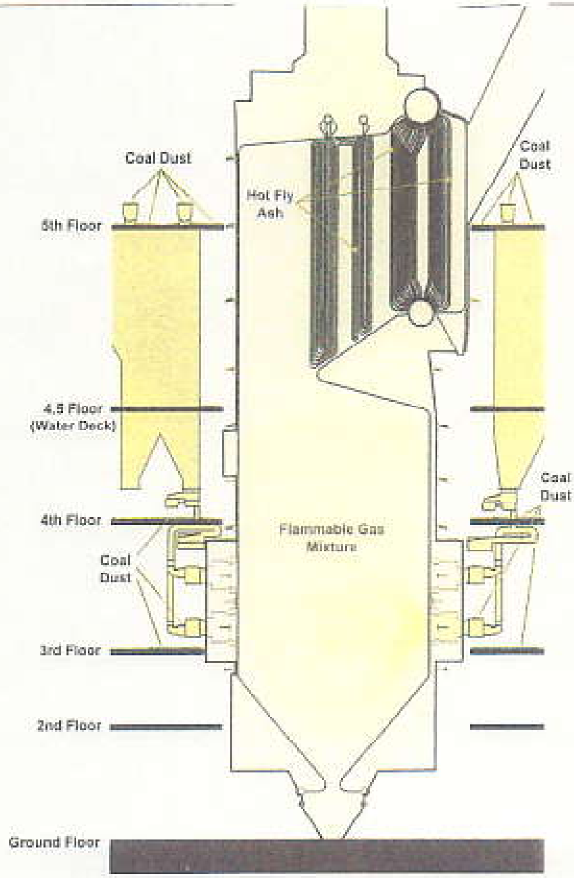


Figure 5: Cross-section of Boiler 6

The investigative team held weekly meetings to discuss the progress of the work and plan for the next week.

Given the enormous quantity of evidence anticipated, an independent evidence custodian was hired to identify, mark, store, decontaminate, and transport the evidence, which was kept in a secure Ford warehouse near the complex.

Of immediate concern was the fact that the power plant was a hazmat-mat site, given that its pipes were wrapped with asbestos, which had also been sprayed on beams and attached to walls as insulation and fire blocking. Other physical hazards included missing floor grates, collapsed walls and ceilings, overhead debris, and damaged equipment.

As part of the investigators' procedures, participants had to register their entry and exit with the site control officer. They had to enter in teams of at least two, carrying a portable radio and portable gas monitor, and each team was escorted by a member of the Ford safety staff.

Their personal protective equipment was essentially equivalent to level-two protection. All entrants were required to wear substantial footwear, eye protection, hard hats, harnesses, half-mask respirators with HEPA cartridges, Tyvek coveralls, latex and cotton gloves, and water-resistant boots. The boots and gloves had to be sealed to the coveralls with duct tape. Miners' lamps were attached to the hard hats of most of the investigators because visibility in the soot-stained and coal-dust-covered buildings was so poor.

A data collection team (DCT) was formed to systematically document the entire powerhouse with detailed photographs, diagrams, videotape, and notes, using a grid based on the facility's columns to define each area of inspection. This activity took about four months using a shift approach to ease the teams' burden.

In the end, however, investigators found that such exhaustive documentation was only necessary in areas of specific interest. The amount of evidence quickly became unmanageable as the count grew to more than 30,000 photographs, 75 hours of videotape, and 500,000 pages of notes. Distributing those items to all the parties involved became unmanageable, and much of the preliminary evidence wasn't shared equally among the groups. Statements from boiler house employees were not released to everyone until the investigation was well underway, and many of the groups were not allowed to participate in or monitor the interview process.

To correct these deficiencies, several teams went back through the facility and conducted their own supplementary scene documentation, which proved to be more fruitful than the months of work the DCT did earlier.

Fortunately, other joint investigative tasks proved more efficient and worthwhile. These included gathering miscellaneous evidence and dust samples, measuring the ruptured boiler from top to bottom, testing various controls, and jointly examining specific equipment.

Results of the investigation

The examination of Boiler 6 showed evidence of an internal explosion, all four corners of the boiler having been ruptured at various levels. There was overpressure damage from the first floor through the flue gas ducts to the precipitator on the roof, and the damage patterns showed that the fire had vented at different areas of the boiler, projecting flames into the generator building's engine room, the electrical building, the turbo blower building, the conveyor area, and the pulverizer building.

Interviews with workers and an examination of the physical evidence showed that there was more than one explosion. An analysis of particulates in various areas throughout the boiler house by Michigan OSHA (MIOSHA) and other investigators revealed that combustible coal dust accumulations in the building were a factor in these secondary explosions and fires.

Although partial wet-pipe sprinkler systems in some areas activated during the incident, the widespread explosion damage negated their effect. The most severe fire damage was at the south end of Boiler 6 on the first and second floors. The interior of the boiler house also showed severe blast and fire damage. The least damaged area was the turbo blower building.

ILLUSTRATION: CHAD AMBORN

Cause and contributing factors

The explosion occurred as maintenance workers and welders shut the boiler down so that it could be serviced. The boiler operators had turned the burners off from the control room so that a blank could be installed in the west gas line to start a nitrogen purge flow between the second-floor manual valve and the boiler. In the process, the main valves on the natural gas lines are normally turned off. The operator then opens the burner valves to allow the purged gas to pass through the boiler.

Employees in the final stages of inserting the blank opened the gas valves to the west burners and to the east natural gas burners. However, the manual natural gas valve on one of the main gas lines on the second and third floors had not been closed, and gas flowed into the boiler through the three east natural gas burners mixing with air from an operating forced-draft fan for 90 to 120 seconds before the flammable mixture was ignited, probably by hot fly ash residue or the discharge of the electrostatic precipitator. Moments before the explosion, an employee in the control room noticed the mistake and tried to alert the crew, but it was too late.

The resulting explosion vented flames and hot gases that raised dense coal dust clouds from the accumulated layers in the building. These dust clouds ignited, causing secondary explosions to propagate through the boiler house to remote areas such as the pulverizer building.

The MIOSHA report concluded that several factors contributed to the incident. Among these were the lack of operating igniter and flame-sensing interlocks that would have prevented natural gas flow into the furnace without any flame or igniter and the lack of specific written procedures for shutting down and blanking the natural gas lines. Communication among the boiler operators and the crew performing the gas line blanking procedure was also inadequate.

The dense layers of coal dust throughout the powerhouse also contributed. The workers tending to the boilers said they had not been promised jobs in the aftermath of the closing, and maintenance during this period was cut back. As a result, housekeeping suffered, contributing to the coal dust accumulations.

Implications for NFPA 921

Since NFPA 921 guidelines for major investigations had been in effect for only four years when the Rouge explosion and fire occurred, its use in the investigation may be considered a trial learning process. Overall, investigators found the guidelines extremely useful, especially in terms of organization, but they felt that certain topics should be expanded.

In particular, all participating organizations need access to preliminary information. Some teams examined the scene before they received preliminary information and felt they were walking blindly through the process. If new information is not shared equally and on a timely basis, the investigation process becomes inefficient.

All organizations involved should also be allowed to participate in, or monitor, interviews of key witnesses. Interviews are a critical part of any investigation, and participants must be given this information as it is developed, even if it is proprietary.

In addition, key members of each organization's team must have access to the scene as soon as possible. This is critical for organizational planning, and lack of such access can lead to rumors and frustration.

The use of data collection teams only appears to work well for highly defined and specialized tasks. For months, investigators combed through the entire Rouge facility, systematically documenting every nook and cranny, but this level of documentation had little value in the end except in key areas. And each organization had to reinvestigate those areas as needed to distill quality data.

Multi-organizational teams should spend time on preliminary scene inspections to develop an overall awareness of the damage and condition of the structures and equipment, and this information should be integrated with interviews before the data are analyzed. Then each specific team should be given time to conduct its own preliminary investigation of the scene. After that, the teams can cooperatively document and photograph the scene, remove debris, and examine artifacts as necessary. Since each organization has its own agenda, it's natural that they will be interested in particular areas or equipment.

If public agencies understand the method and principles of this type of investigation, they can more smoothly integrate their roles into the overall process, thus protecting the public's interest.

References

NFPA Journal®, November/December 2000; National Fire Protection Association, NFPA 921, *Fire and Explosion Investigations*, 1998, 2001 editions; Polcyn, R., "Ford Rouge Powerhouse Explosion, Monday, February 1, 1999," Dearborn Fire Department; Zalosh, R., "February 1, 1999 Explosion at Ford Motor Company Rouge River Plant Powerhouse," September 1999; MISOHA Report, Ford/Rouge Powerhouse, February 1999; NFPA 850, *Fire Protection for Electric Generating Plants*, 1996 edition; various articles and reports obtained from newspapers and Internet news services, and UAW/Ford Joint Report.

KIM MNISZEWSKI is a fire protection engineer with FX Engineering, Inc., Hinsdale, Illinois, and is a former member of the NFPA 921 technical committee.

HAL LYSON is an investigator for Robins, Kaplan, Miller & Ciresi and is a long-time member of the NFPA 921 committee.

CRISPIN HALES, Ph.D., is an engineer with Triodyne, Inc., in Northbrook, Illinois.

ILLUSTRATION: CHAD AMTKERN