

DOCUMENT RESUME

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Report to Rep. Tom Bevill, Chairman, House Committee on Appropriations: Public Works Subcommittee; by Elmer B. Staats, Comptroller General.

Issue Area: Energy: Making Nuclear Fission a Substantial Energy Source (1C08).

Contact: Energy and Minerals Div.

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Organization Concerned: Nuclear Regulatory Commission.

Congressional Relevance: Rep. Tom Bevill.

Since 1971, about 50 gas explosions have been reported at boiling water nuclear powerplants. These explosions have caused degradation and failure of off-gas systems, radiation exposure and other injuries to personnel, physical damage to facilities, and lost revenues during reactor shutdowns for repair. An example of such an explosion was the one that occurred at the Millstone nuclear powerplant in Connecticut on December 31, 1977. In spite of the fact that the problems and actions which would minimize it have been known for some time, the Nuclear Regulatory Commission (NRC) has taken action on operating plants only after incidents have occurred. The explosion at Millstone might have been prevented by ventilation of the stack area. Recent actions by NRC, when implemented, will minimize the chances of gas explosion, but according to NRC's present plans, it will take up to 1 year before corrective actions are implemented at all facilities. The Chairman, NRC, should accelerate the process for requiring and implementing the actions aimed at minimizing gas explosions at nuclear powerplants. These actions should include ventilation of closed areas, assuring seal integrity, and protection of piping from ignition sources. (HTW)

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COMPTROLLER GENERAL OF THE UNITED STATES

WASHINGTON, D.C. 20548



B-164105

AUGUST 4, 1978

*Released LASC*

*8-11-78*

The Honorable Tom Bevill  
Chairman, Subcommittee on  
Public Works  
Committee on Appropriations  
House of Representatives

Dear Mr. Chairman:

In a June 21, 1978, letter you asked us to look into those gas explosions 1/ which have occurred at boiling water nuclear powerplants and to assess the actions of the Nuclear Regulatory Commission in connection with these explosions.

On December 13, 1977, a gas explosion at the Millstone nuclear powerplant in Connecticut became widely publicized. An employee at Millstone was injured and slightly contaminated with radioactive gases, a building was damaged extensively, and the powerplant was shut down for 10 days.

In our view, the explosion at Millstone, as well as other gas explosions might have been prevented if the Commission had acted decisively and aggressively to require licensees to take certain precautions. However, only recently has the Commission initiated actions which should minimize the possibility of these explosions.

We believe these actions, when implemented, will minimize the chances of explosions, but under the Commission's present plans these measures will not be implemented for at least 1 year. Because the measures are available, we believe the Commission should accelerate the process for requiring and implementing the actions aimed at minimizing gas explosions at nuclear powerplants.

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1/In the nuclear industry jargon, they are referred to as off-gas explosions.

As you requested, we did not obtain the Commission's formal comments on this report. However, we met with Commission officials and received informal comments which have been incorporated into the report.

The rest of this report discusses the details of gas explosions which led us to the above conclusion.

### WHAT ARE GAS EXPLOSIONS AND THEIR HAZARDS?

Gas explosions are potential hazards only to the 25 boiling water power reactors now licensed to operate in the United States. In a boiling water reactor, nuclear fuel converts water to steam to drive electric generating turbines. The steam then condenses and returns to the reactor to be reheated.

As it creates steam, the reactor also produces gas which cannot be condensed. Some of the gas is radioactive. An off-gas system is designed to remove this gas from the steam. Through a delaying and filtering process, the radioactivity is reduced and then released to the environment. The off-gas system consists of equipment located away from the reactor building, which separates the gas from the steam, and piping to carry the gas to a release stack. The stack usually houses fans and filters.

The delay time designed into the off-gas system is important because most of the radioactive gas loses its radioactive properties rapidly. Very small radioactive particles carried by the gas are collected by the system filters. After being delayed and filtered, the remaining gas, containing a limited amount of radiation, is diluted with air and released to the environment through the stack. The amount of radiation that can be released is limited by Federal regulations.

At present, 20 of the 25 operating boiling water reactors use a new off-gas system which releases much less radiation than the older system. <sup>1/</sup> Although the new system is not required by the Commission, nearly all of the remaining boiling water reactor licensees, according to the Commission, are committed to installing the system soon to meet new radiation standards.

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<sup>1/</sup>The older system is designed to release about 20 percent of the amount allowable by the Commission regulations. The newer system releases less than 1 percent of the allowable amount.

Over the past several years, about 50 gas explosions have been reported at nuclear powerplants. According to the Commission, none of the explosions resulted in offsite releases of radioactivity which exceeded the limits specified in the Federal regulations. But in some cases, these explosions have caused property damage and injuries to workers.

Explosions occur both internally and externally to the system. In internal explosions, gases contained within the system are ignited. Internal explosions are not viewed by the Commission as a problem because the systems are designed to withstand these explosions. Neither personal injury nor property damage is known to have resulted from an internal explosion.

External explosions are generally caused by equipment failure which permits gas leakage. They can follow an internal explosion which damages or weakens a part of the system. The failure of equipment or an internal explosion may permit combustible hydrogen, oxygen, and radioactive gas to escape from the contained system. If the gas escapes into a closed area, the buildup of hydrogen in the presence of an ignition source could result in an explosion.

The severity and consequences of a gas explosion depend on whether the explosion is internal or external. Of the approximately 50 explosions reported, 5 were external and all of these resulted in physical damage or personal injury. The following table shows the consequences of the five external explosions.

<u>Reactor facility and location</u>	<u>Date of explosion</u>	<u>Probable cause (note a)</u>	<u>Damage</u>
Dresden 2 Morris, Illinois	4/1973	Welding arc from welders working near an off-gas system filter.	Two workers received minor burns.
Cooper Brownville, Nebraska	11/1975	Improperly installed valve in a drain area allowed gas to escape. The gas was ignited by a spark from an air sampler.	One worker received major burns and five others received minor radiation exposure.
Cooper Brownville, Nebraska	1/1976	Ice blocked the top of system's release stack, backing up gas in the off-gas building. The gas was ignited by electrical equipment.	Off-gas building demolished, no injuries to people.
Brunswick 2 Southport, North Carolina	1/1976	Because of equipment failure, excessive moisture accumulated in a filter. It froze and blocked gas flow. Increased pressure drained loop seal allowing gas to escape.	Minor damage to equipment, no injuries to people.
Millstone 1 Waterford, Connecticut	12/1977	First explosion caused by welding arc. Loop seals were defeated allowing gas to escape into base of stack. Ignited by electrical equipment.	One worker suffered a concussion, multiple abrasions, and was slightly contaminated. Building sustained major damage.

a/The probable cause is determined and documented by the Commission, or its predecessor, the Atomic Energy Commission.

At the Millstone plant, an internal explosion weakened the system and resulted in a much more severe external explosion. The internal explosion weakened seals in the system and allowed the hydrogen gas to escape. The explosion was ignited by heat from a welding arc.

Attempts to replace all the seals in the system were unsuccessful. As a result, combustible gas escaped into an unventilated area at the base of the stack. According to the Commission, the probable ignition source of the second explosion, which occurred about 4 hours after the first explosion, was a spark from an electrical switch.

The second explosion blew a metal door from the stack base into a warehouse about 200 feet away. The impact of the door bent a 12-inch structural beam approximately 8 inches. The blast also removed two 2,000 pound shield plugs from the floor of the stack base and did extensive damage to the ceiling.

WHAT HAS THE COMMISSION DONE  
TO ELIMINATE OR REDUCE THE  
CHANCE OF GAS EXPLOSIONS?

The Commission and its predecessor, the Atomic Energy Commission, were aware of gas explosions as early as 1971 when the first one was reported. Since that time, about 49 more explosions have been reported.

In a 1974 report entitled "Review of Explosions in Boiling Water Reactor Off-Gas Systems," the Atomic Energy Commission discussed the causes of six explosions and the actions that could be taken to prevent future explosions. The report stated that because of the diverse causes of the explosions, they would continue at frequent intervals unless system modifications were made to minimize ignition sources. The report did not call for corrective actions to be required at all boiling water reactors. However, since 1974 the Commission has required all boiling water reactors in the design or construction stage to improve the integrity of seals in the off-gas system.

The General Electric Company, the prime vendor of boiling water reactor off-gas systems, as early as 1973 sent communications to all boiling water reactor owners emphasizing the potential hazard of the gas explosions and identifying operating and engineering actions which might be used to prevent them. In 1976 the General Electric Company recommended, among other things, that reactor owners (1) label pipes and equipment containing detonable mixtures of gas, (2) provide for adequate ventilation to prevent buildup of detonable mixtures,

and (3) assure the integrity of all seals. Commission officials could not tell us how many reactor owners may have taken these actions.

In the past, the Atomic Energy Commission and the Commission requested reactor owners who had reported external explosions to take steps aimed at preventing a similar explosion at the same powerplant. For example, an explosion occurred at the Cooper nuclear powerplant in early 1976, which completely demolished a 32-foot by 48-foot metal building. Immediately before the explosion occurred, plant personnel had entered the building to perform their duties but noticed an unusual odor and an abnormal reading of air monitoring equipment. These employees vacated the building which exploded shortly thereafter. During cleanup, a partially melted piece of ice was found and it was postulated that the ice had formed at the top of the stack through which the gas is released, thus causing the gas to backup in the stack building. Ignition was probably caused by a spark from one of the electrical devices in the building.

The Commission requested the owner of the Cooper powerplant to heat and insulate the upper 10-foot section of the stack pipe to prevent another ice buildup. Fan positioning and piping changes which may have prevented the explosion were also made. However, the Commission did not require any other plant owners to assess and correct the possibility of hydrogen gas buildups in stack areas.

The Millstone explosion is another example of the Commission's action in response to an external explosion. In this case, the Commission required the owner to improve seal integrity, identify and label pipes, and improve ventilation. This cost about \$10,000 and was completed in less than 10 days. Again, the Commission required these corrections only at Millstone and did not apply them to other plants.

The first action taken by the Commission that was directed at all operating boiling water reactor owners was to issue a bulletin on February 8, 1978. The bulletin instructed every owner to

--review measures taken to prevent actions which may cause ignition of gas in off-gas piping;

--review the adequacy of ventilation of spaces and areas through which pipes containing the explosive gas pass;

- describe actions to prevent accumulation of explosive gas, and describe monitoring equipment that will warn of the accumulation and disposal of such accumulations;
- describe procedures for assuring seal integrity; and
- review operating and emergency procedures to respond properly to gas explosions.

All owners have responded, and the Commission has begun its review of the responses. The Commission's review will first involve inspecting each reactor to verify the information in the response. Then the Commission will determine what additional steps, if any, are needed to assure that every reactor owner has taken or will take actions to minimize the possibility of external explosions. Commission officials told us that this inspection and review will take about 6 months, and that another 6 months will be given to the reactor owners to comply.

### CONCLUSIONS

Since 1971 about 50 gas explosions have been reported at boiling water reactors. These explosions have caused degradation and failure of off-gas systems, radiation exposure and other injuries to personnel, physical damage to facilities, and lost revenues during reactor shutdowns for repair.

The Commission and its predecessor, the Atomic Energy Commission, have known about the problem, its hazards, and actions which would minimize the problem for some time. The Commission has required some action on plants under design and construction, however, no action has been taken on operating plants except on an after-the-fact, case-by-case basis. Measures to eliminate or reduce explosions, such as ventilating closed areas, have been known for years by both industry and the Commission. In most cases, these measures appear to be relatively simple and are not as time-consuming as one might believe. At the Millstone facility, for example, the total cost was about \$10,000, and the work could have been completed during a normal shutdown. A direct cause of the Millstone explosion was lack of ventilation in a closed area. The explosion at Millstone may not have occurred if the stack area had been ventilated.

Although the Commission has failed to act promptly, we believe the recent actions, when implemented, will minimize the chances of gas explosions. However, according to the Commission's present plans, it will take up to a total of 1 year before corrective actions are implemented at all facilities. These corrective actions include such measures as providing



ventilation in closed areas where gas may accumulate, assuring seal integrity, and protection of piping from ignition sources. In the past, corrective actions have been taken at individual powerplants in relatively short time frames; therefore, the Commission should accelerate its process and promptly require all powerplants to take those measures necessary to provide a greater margin of safety.

In commenting on this report, the Commission stated that its efforts are timely and disagrees with accelerating the actions. Commission officials said that off-gas systems are not reactor-safety related and therefore present no danger to the public. However, the Commission did recognize that injuries to plant workers, property damage, and lost revenues due to reactor shutdown can occur. Further, although Commission officials recognize that gas explosions are an occupational safety issue that could be considered the responsibility of the Occupational Safety and Health Administration, the Commission believes it should be the lead agency on this problem because the Commission has the experience and expertise needed to deal with the problem.

RECOMMENDATION

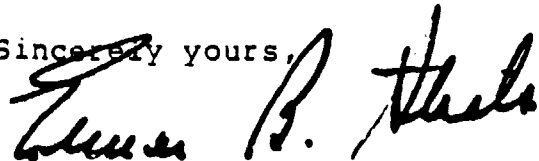
GAO recommends the Chairman, Nuclear Regulatory Commission:

- Accelerate the process for requiring and implementing the actions aimed at minimizing gas explosions at nuclear powerplants. These actions should include ventilation of closed areas where explosive gas may accumulate, assuring seal integrity, and protection of piping from ignition sources.

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As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 7 days from the date of the report. At that time we will send copies to interested parties and make copies available to others upon request.

Sincerely yours,



Comptroller General  
of the United States