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THE INVESTIGATION OF GRAIN ELEVATOR EXPLOSIONS

Report of
Panel on Causes and Prevention
of Grain Elevator Explosions

of the

Committee on Evaluation of Industrial Hazards

NATIONAL MATERIALS ADVISORY BOARD
Commission on Sociotechnical Systems
National Research Council
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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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ABSTRACT

Grain elevator explosions have become a problem of serious concern to a number of federal agencies and to the grain-handling industry. The explosiveness of grain dust when ignited in a confined space has been known for years. However, the conditions and sequence of events leading to an explosion, the point and cause of ignition, and the propagation of an explosion in actual occurrences have remained relatively unknown. Remedial action to reduce the number and severity of explosions must be based on determination of these factors. This report emphasizes that previous investigations following elevator explosions have yielded little information other than that an explosion occurred and that damage was of a certain degree. The investigation of an explosion to obtain a complete understanding of the event requires a team having specialized skills and capabilities. Such teams do not presently exist. The need for such a team and its qualifications and operation are outlined in this report.

PREFACE

Following a number of large explosions in grain elevators in December 1977 the National Materials Advisory Board held a symposium on grain elevator explosions in July 1978 at the request of the U.S. Department of Agriculture. To continue efforts in dealing with the problem of grain elevator explosions, the Occupational Safety and Health Administration requested the National Academy of Sciences to establish a panel, under the NMAB's Committee on the Evaluation of Industrial Hazards, to investigate causes and make recommendations for the prevention of such explosions. As part of the task OSHA requested the panel to examine a representative and specific sample of grain elevator explosion investigations made by the federal government for the purpose of making recommendations for improvement in the procedures. Members of the panel who are experts in explosion investigation and grain elevator operation examined the OSHA files and reports on five explosions. In addition they conducted their own independent on-site investigations of eight explosions that have occurred since the panel was formed in November 1978. The panel also thoroughly familiarized itself with grain elevator operation through discussions with representatives of various agencies and organizations involved in the grain-handling industry and by visits to a number of operating elevators. This report contains the panel's findings concerning the government explosion investigations* and offers recommendations for improvement in the government procedures. It is the first in a series; future reports will cover the causes and prevention of grain elevator explosions, grain dust collection systems and technology, and the causes and prevention of explosions in grain mills.

*The reports examined were made available to the panel on a privileged basis; their actual content is not cited herein.

PANEL ON
CAUSES AND PREVENTION OF GRAIN ELEVATOR EXPLOSIONS
of the
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THE INVESTIGATION OF GRAIN ELEVATOR EXPLOSIONS

SUMMARY AND RECOMMENDATIONS

The Panel on Causes and Prevention of Grain Elevator Explosions of the Committee on Evaluation of Industrial Hazards was constituted in November 1978 at the request of the Occupational Safety and Health Administration (OSHA). As part of its charge, the panel was asked to review the adequacy of OSHA's current procedures used to investigate grain elevator explosions and make recommendations for improvement.

The panel examined raw data and available reports of five investigations, one conducted by the Department of Agriculture and four by OSHA. The panel also conducted its own on-site investigations of eight recent grain elevator explosions. It found that, in general, OSHA's investigation of grain elevator explosions is performed mainly for determination of any and all code violations, with determination of cause of an explosion a secondary objective. The reports indicated that none of the investigating teams had been specifically trained to conduct explosion investigations for determination of cause. Each of the government investigations was unique--varying in expertise utilized, methodology, amounts of facts obtained, and their interpretation. In cases where subsequent litigation is a possibility, government files on the investigations are treated as privileged information, and even those files not involving litigation are not readily available to the public. The reports are, therefore, of little value as a basis for remedial action by industry other than for rectifying code violations that may have no relation whatsoever to the cause of the explosion.

The panel feels that the primary purpose of investigations should be to provide information that will lead to a reduction of the explosion hazard in grain elevators. The methods and expertise required for this type of investigation are outlined in this report.

The panel recommends the establishment of a program for investigating and reporting grain elevator explosions in a manner similar to that used by the National Transportation Safety Board, in which emphasis is placed on determining all factors bearing upon an accident. This is in contrast to investigations conducted by federal regulatory agencies in

which emphasis is placed on determining violations of codes and regulations for possible subsequent punitive action, even if the violation has no relationship to the explosion.

The requirements for such a program are as follows:

1. A federal agency or department should have the sole authority for investigation of grain elevator explosions. To maintain its objectivity, this organization should be an independent agency, i.e., not a rule-making or regulatory agency or one that has a special interest in the grain handling industry.
2. Investigations should be conducted in such a way as to elicit all facts relating to the explosion. The goals of the investigation should be to determine the circumstances and conditions leading to an explosion, the source of ignition, and the way the explosion propagated through the elevator. In recognition that an explosion can be a complex event with many contributing factors, identification of proximate or probable cause should not be absolutely required from an investigation. In the interest of obtaining unbiased information, the investigating team should use considerable care to avoid establishing an adversary relationship with witnesses, employees, and elevator operators and owners.
3. Investigations should be performed by a team consisting of experts in dust-explosion phenomena, mechanics of blast damage, electrical engineering, grain elevator operations, interviewing of witnesses, safety regulations and codes, and system analysis. Team members should be able to document their evidence by photographs. They should have at their disposal the services of qualified laboratories for those cases requiring laboratory analyses. Members should be able to proceed to an explosion site within two or three hours notice.

In order to obtain the most benefit from investigations all reports of this body should be available to the public.

As an interim measure and until the foregoing requirements can be met, an existing government agency that has an interest in reducing the incidence and severity of grain elevator explosions could be granted a coordinating role for the investigation of grain elevator explosions along the lines mentioned above.

In summary, all the factors involved in grain elevator explosions must be understood before the hazard can be reduced as far as possible. The examination of explosion sites to obtain data for this understanding requires specialized investigation methods and personnel. On the basis of its regulatory function, OSHA's present investigative procedures even if faultlessly applied and reported, will not satisfy this need.

INVESTIGATION OF GRAIN ELEVATOR EXPLOSIONS - CURRENT STATUS

At present, OSHA has the primary responsibility for the investigation of grain elevator explosions. On rare occasions the Department of Justice conducts an investigation if there is a suspicion or evidence of a criminal act. On equally rare occasions investigations may be conducted by the Department of Agriculture, particularly if there is an injury or fatality to an employee of the Federal Grain Inspection Service.

The situation with respect to current investigations has two serious faults. First, every explosion is not investigated; some are not even reported beyond the local news media. Elevator operators are required to report explosions only to OSHA and then only if a fatality occurs or there are at least five injuries requiring hospitalization. Second, explosions are usually investigated by OSHA only to determine a basis for legal action. Their purpose in investigating explosions is primarily to seek violations of safety regulations.* Investigations to determine the chain of events leading to and following the initial ignition of grain dust are rare occurrences and do not appear to be the responsibility of any organization.

At the request of OSHA a task group of the panel examined investigation records and raw data in OSHA's files of five grain elevator explosions to determine the adequacy of current techniques used by the federal government. Without identifying the individual investigations the task group found the following:

1. All five investigations were conducted without guidelines or a methodology for conducting an investigation. Each investigation was unique--varying in

*See Sections 8, 9, and 10 of 84 Statute 1593 (28 U.S.C. 655); Secretary of Labor's Order 8-76 (41 Federal Register 205029).

expertise utilized, amount of facts obtained, and subsequent interpretation of facts.

2. None of the five investigation files contained recommendations for preventive action.

3. The files of the five investigations are not open to the public because of pending litigation.

4. Only two of the investigations were quite thorough and complete, one particularly so. In the latter, the investigators drew a complete plan of the site, even though no drawings were available, and wrote a report. Thorough interviews of the witnesses by the investigators and a detailed examination of the entire site yielded a well-documented and quite believable sequence for the initiation and subsequent spread of the explosion. The only fault the task group could find with this report was that the explosion process was not described using current explosion investigation terminology. Nevertheless, the data were sufficiently clear so that an expert, reading the report, would have a clear understanding of what happened. The other well-documented report, which was not an OSHA investigation, contained sufficient information concerning the events leading to the explosion. In this case, the investigators repeatedly returned to the scene as portions of the elevator were uncovered by clean-up crews over a period of approximately three weeks. This persistence paid off because they discovered a likely source of ignition.

5. In the third incident, even though statements of the witnesses led to fairly obvious conclusions about the ignition source, the documentation was not sufficiently complete. A report was not prepared.

6. In the fourth incident legal action was required to obtain entry and the investigators were unable to obtain photographs or other evidence before critical portions of the site were disturbed. Thus, they were unable to document the damage patterns and could not ascertain the cause.

7. A fifth investigation file contained only witnesses' statements and field notes without a write-up or follow-up. The cause of this explosion will probably never be understood.

The task group that examined the above-mentioned files conducted its own independent on-site investigations of eight grain elevator explosions that occurred since the formation

of the panel in November 1978. In each case the physical cause of ignition as well as the course of the explosion were identified with a reasonable degree of certainty. The investigative team, drawn from members of the panel, consisted of an explosion expert, a grain elevator expert, a chemical engineer experienced in explosion investigation, and a systems analyst.

Based on the panel's experience in investigating explosions and the review of the government procedures, the panel concludes that, at present, the process of investigating and reporting grain elevator explosions is undisciplined and unsystematic. The responsibility for investigation is poorly designated and, by and large, qualified personnel are not used. Finally, the information concerning explosions is not available to the interested public. These conclusions are supported by observations made in the recent Department of Agriculture report on grain elevator explosions.*

INVESTIGATION OF GRAIN ELEVATOR EXPLOSIONS - PRESENT NEED

Although violations of safety codes and regulations represent a hazard in the working environment, it seems clear to the panel that investigations of grain elevator explosions based solely on determination of such violations are not sufficient. The panel feels that there is a need, at present, for investigations to determine the total chain of events in an explosion and thus provide a factual basis for recommending appropriate steps to reduce the frequency and severity of elevator explosions. Lack of knowledge obtained from this type of investigation has led in at least one instance to restrictive state legislation discouraging the use of effective control technology.** Identification of events leading to a known explosion will provide facts that would help in the selection of preventive measures directly related to real hazards and take into account the practical needs of elevator operation. Knowledge of these events will also serve to convince employees and employers of the hazardous conditions that can occur in grain elevators.

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*Prevention of Dust Explosions in Grain Elevators--An Achievable Goal, A task force report of the USDA, pages 46-47, January 1980.

**Laws of the Sixty-Eighth General Assembly (Iowa), 1979 Session; Chapter 12, Agriculture, Economic Development, Energy, Coal Research and Natural Resources (H.F. 734); pp 83; June 10, 1979.

The investigation of grain elevator explosions to determine all facts relating to an explosion can be a complicated task. Most explosions actually consist of a number of explosions--a primary explosion followed by one or more secondary explosions, depending on the distribution of dust throughout the elevator. Tracing the sequence of explosions is a difficult task. Factors and events leading to an explosion are often hidden or are not readily apparent. For example, it is common (unsafe) practice to "jog the leg" when an elevator belt is stuck. This is an attempt to free the belt by alternately stopping and starting the driving motor. Explosions have resulted from this practice when the belt parted and dropped down the leg. The question then arises as to whether the employee had been made aware of the hazard associated with this action. Facts such as these need to be known before recommendations can be made for remedial action.

TECHNICAL INVESTIGATIONS - PROCEDURES, REQUIREMENTS, and RESULTS

In order to discover all facts related to an explosion it is necessary to send a team of qualified observers to the site to make careful observations, record data, and interview witnesses. The team should analyze the information obtained, draw conclusions, and make recommendations for the prevention of similar occurrences in the future.

The first phase of the investigation--on--site observations, data collection, and interviewing witnesses--may continue for weeks or months. Primary emphasis is on seeking every conceivable clue to the initial and subsequent events. As will be noted later in this report, it is critical to avoid the adversary posture when interviewing witnesses for the obvious reason that willingness to expose every possible clue--especially by those most knowledgeable, i.e., those involved in the accident itself--will be restrained by possible or imagined punitive action.

The second phase should be the analyses of personal injuries, grain-handling hardware, elevator operations, combustion products, ignition sources, explosion debris, testimony of witnesses, and other evidence gathered in the first phase. In some cases physical analyses must be done in a controlled environment such as a laboratory.

The third phase of the investigation should extract the largest number of indisputable and unambiguous conclusions possible from the analysis of the physical evidence and witnesses' statements.

The objective of the total process is a recommended course of action that will reduce the frequency and severity of similar accidents.

The team conducting the investigation should be composed of trained professionals whose training consists of formal education, professional specialization, and on-site experience. The team's competences should include the following specialities:

Phenomena of dust explosions

Mechanics of blast damage

Mechanics of grain elevator operation

Interviewing of witnesses

Electrical engineering

Safety regulations and codes

Systems analysis

At least one and preferably all team members should be capable photographers.

One of the primary requirements for the investigative team is its availability to respond to a call and go immediately to the site of an explosion. Evidence of causative factors in an explosion disappears rapidly after the incident. Therefore, it is critical that the investigators arrive at the scene as soon as possible. They should be able to depart for the explosion site within two hours of notification. Return visits during salvage or demolition operations may be necessary.

Although OSHA, presently, has the responsibility for the investigation of grain elevator explosions, it has no authority to isolate the scene or restrict the activities of others having an interest in the explosion. As mentioned before, it has no designated authority or responsibility for determining a complete reconstruction of the event. In current practice numerous federal, state, and local officials, industry representatives, insurance investigators, etc., can and do appear on the scene of an explosion to extract only that evidence pertinent to their own special interests. Their findings rarely reach the public except through the news media.

The authority needed by an investigating group consists of four parts:

1. Authority at the accident scene to physically isolate the scene, collect evidence, interview witnesses, conduct salvage and demolition (great destroyers of evidence), and communicate with the news media;
2. Authority for subsequent analyses, simulation, and testing following the assembly of on-site evidence to resolve causative factors;
3. Authority to conduct public hearings for additional fact-finding as necessary; and
4. Authority to publish all findings related to the explosion in a public report made available to any interested party.

Any permanent federal agency that is given the authority to investigate grain elevator explosions for cause must be completely autonomous, as is the National Transportation Safety Board. Rule-making agencies that can take punitive action are primarily interested in discovering violations of codes and regulations. They are likely to seek out causes and details of an explosion only if they have some bearing on a violation. Since their mandate is to enforce rules, this immediately places them in an adversary position in the eyes of the people at the site of the explosion. Even if a rule-making agency re-directs the emphasis of its investigations along the lines recommended by this panel, this will not eliminate the adversary impression. Thus, even with the best of intentions, such a group would always work under a handicap that usually would be severe enough to obstruct its investigation.

The panel feels that, in order to obtain a thorough knowledge of the causes and prevention of grain elevator explosions, it is critical that investigations be conducted as much as possible in a non-adversary environment. The use of adversary procedures is likely to lead to serious errors in explosion investigations. The ideal way to eliminate the adversary relation would be to grant immunity from prosecution to individuals who testify on the explosion. This ideal may not be possible because the authority to grant immunity is generally quite limited. Further, there are occasions involving malicious behavior for which society demands punishment.

The reports of explosion investigations should be standardized so that commonalities among different explosions can be codified and effective preventive actions taken. The reports should be made public so that their findings can be used by the industry to prevent future explosions. The agency that is ultimately assigned the responsibility for investigation should publish the report. The reporting format evolved over the years within the National Transportation Safety Board could serve as a model for reporting the investigation. The recommended format is:

1. Investigation
    a. Operational history
    b. Injuries
    c. Damage to the elevator
    d. Other damage
    e. Personnel information
    f. Elevator information
    g. Meteorological information
    h. Standards in force
    i. Wreckage and explosion information
    j. Medical and pathological information
    k. Fire cause and damage
    l. Survival aspects
    m. Elevator instrumentation
    n. Tests and research
    o. Other information

2. Analysis

3. Conclusions.

ADMINISTRATIVE ISSUES TO BE RESOLVED

As noted in the previous section of this report, there are some actions to be taken and fundamental issues to be resolved before grain elevator explosions can be properly investigated. In summary they are as follows:

1. A federal department or agency should be given the authority and responsibility to conduct grain elevator explosion investigations in the manner recommended by the panel. This should not be a regulatory agency. The group making these investigations should have no authority to take or abet punitive action.

2. The question of witness immunity from prosecution should be resolved. The panel feels that the investigating team should have the authority to grant immunity if and only if it is needed to complete the investigation. Granting of this authority to the team would require legislative action.

3. Standards should be established to govern the resource allocation (budget) for any given magnitude of grain elevator explosion. While it is assumed that every catastrophic disaster will warrant investigation, there is a level of damage, lost time, etc., below which extensive investigation may not be economically justifiable. However, the investigation of smaller, less damaging explosions may be very informative with very little expenditure of time by an expert team and thus could warrant investigation on a selective basis. The decision for conducting an investigation should not be based solely on the occurrence of a minimum number of employee injuries or fatalities.

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