

**TYPE A ACCIDENT  
INVESTIGATION BOARD REPORT  
OF THE JULY 28, 1998  
FATALITY AND MULTIPLE INJURIES  
RESULTING FROM RELEASE OF  
CARBON DIOXIDE  
AT  
BUILDING 648, TEST REACTOR AREA  
IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL  
LABORATORY**

**September 1998**

**Office of Oversight  
Environment, Safety and Health  
U.S. Department of Energy**

This report is an independent product of the Type A Accident Investigation Board appointed by Peter N. Brush, Acting Assistant Secretary for Environment, Safety and Health (EH-1).

The Board was appointed to perform a Type A Investigation of this accident and to prepare an investigation report in accordance with DOE 225.1A, *Accident Investigations*.

The discussion of facts, as determined by the Board, and the views expressed in the report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.

On July 29, 1998, I established a Type A Accident Investigation Board to investigate the July 28, 1998, fatality and multiple injuries resulting from release of carbon dioxide at Building 648, Test Reactor Area, Idaho National Engineering and Environmental Laboratory. The Board's responsibilities have been completed with respect to this investigation. The analysis, identification of contributing and root causes, and judgments of need reached during the investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations*.

I accept the findings of the Board and authorize the release of this report for general distribution.



Peter N. Brush  
Acting Assistant Secretary  
Environment, Safety and Health

9/10/98

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Date

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## ACRONYMS AND INITIALISMS

AC	Alternating Current
CFR	Code of Federal Regulations
CO <sub>2</sub>	Carbon Dioxide
CFR	Code of Federal Regulations
CPR	Cardiopulmonary Resuscitation
DC	Direct Current
DOE	U.S. Department of Energy
ES&H	Environment, Safety, and Health
ETR	Engineering Test Reactor
ID	DOE Idaho Operations Office
INEEL	Idaho National Engineering and Environmental Laboratory
kV	Kilovolts
LMITCO	Lockheed Martin Idaho Technologies Company
NFPA	National Fire Protection Association
OSHA	U.S. Occupational Safety and Health Administration
psi	Pounds per Square Inch
SAR	Safety Analysis Report
TRA	Test Reactor Area

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## EXECUTIVE SUMMARY

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On July 28, 1998, an unexpected activation of the high pressure carbon dioxide (CO<sub>2</sub>) fire suppression system occurred in Building 648 at the Test Reactor Area of Idaho National Engineering and Environmental Laboratory (INEEL). The accident resulted in one fatality, several life-threatening injuries, and significant risk to the safety of initial rescuers. On the following day, the Department of Energy (DOE) Acting Assistant Secretary for Environment, Safety and Health appointed a Type A Accident Investigation Board to conduct an independent investigation of the accident. This report presents the results of that investigation.

At approximately 6:00 p.m., on Tuesday, July 28, 1998, workers were engaged in de-energizing electrical circuit breakers in preparation for preventive maintenance activity on the electrical system in Building 648. Thirteen people were in the building, including foremen, operators, electricians, and fire protection personnel. As the last electrical circuit breaker was opened, the CO<sub>2</sub> fire suppression system unexpectedly discharged without an evacuation warning alarm. Within seconds, the workers found themselves struggling to escape the potentially lethal atmosphere under near zero visibility and the disorienting effects of CO<sub>2</sub>.

The Accident Investigation Board determined that this accident was avoidable. Since March 1996, INEEL has experienced several precursor accidents, including two accidents resulting in Type A investigations. These previous accidents indicated a need to significantly improve work planning and controls, perform hazard evaluations, and develop work packages to assure that appropriate safety requirements are integrated into work control documents and performance of work in the field. Initiatives by INEEL to implement enhanced work planning and the Voluntary Protective Program have not been consistently applied to resolve previous Type A accident investigation judgments of need in work and hazard controls and were not effective in preventing or mitigating the accident. The DOE Idaho Operations Office (ID) and Lockheed Martin Idaho Technologies Company (LMITCO), the site operating contractor, have also not been timely in the implementation of the Department's integrated safety management policy to resolve these chronic work control problems and to improve safety performance. These serious accidents and level of safety performance, in fact, indicate continuing acceptance of an informal, expert-based approach to the control of work and the associated hazards.

LMITCO has not been effective in managing the flowdown of requirements and standards applicable to CO<sub>2</sub> fire suppression systems and worker safety, and institutionalizing these requirements. Not institutionalizing requirements into corporate safety manuals, design control processes, procedures, and training programs contributed to less than adequate knowledge and competencies in dealing with the hazard, an inconsistent and deficient application to design, work planning and control and procedures, and inadequate resource prioritization and allocation. The physical lockout of the CO<sub>2</sub> system to protect these workers, for instance, is a requirement and could have prevented this accident. This barrier, however, has been inconsistently applied, and the procedure which requires it has not been updated and was not used for this work. There are clear requirements for training workers on the hazards of emergency response to CO<sub>2</sub> discharges, but the CO<sub>2</sub> hazard had not been incorporated into LMITCO training programs and, on the day of the accident, workers were not sufficiently aware of the hazard, emergency



response measures, or the significant limitations of the protection provided. LMITCO placed excessive reliance on the pre-discharge warning alarm, which was never received, and on electronic impairment of the fire panel to protect the workers.

Once the CO<sub>2</sub> system discharged, instantly flooding the room and creating whiteout conditions, the workers were not provided the necessary means to safely escape, including clear exit pathways, breathing apparatus, emergency exit training, exit pathway lighting, or emergency ventilation. The immediate rescue attempts were impeded by the lethal concentration of CO<sub>2</sub>, pathway obstacles, low visibility, and absence of self-contained breathing apparatus. Initial rescuers made heroic but life-threatening entries to rescue fellow workers.

The circumstances that would culminate in this tragic accident began to develop years ago. The CO<sub>2</sub> system design, as installed in 1971 and as modified in 1997, did not include required monitoring of system status to ensure at least a 25-second warning alarm regardless of the source of activation.<sup>1</sup> Failure to re-evaluate the need for this system as the risks changed, the absence of a corporate policy and procedures to mitigate risks posed by CO<sub>2</sub>, and incremental cost cutting in the site support infrastructure that reduced the availability of self-contained breathing apparatus and search and rescue training also played a role. Most importantly, despite the previous serious accidents at INEEL, LMITCO and ID leadership has not been effective in institutionalizing and implementing requirements, ensuring timely and effective corrective actions to address work planning and control weaknesses, achieving rigor and discipline in the workplace, or implementing the Department's integrated safety management policy in a timely manner.

The Board concludes that ID has not been aggressive or effective in monitoring contractor performance or adherence to requirements, or in ensuring that corrective actions and improvements in hazard and work controls are completed and consistently applied. The Board also finds that LMITCO did not fulfill its contractual obligation to protect workers from a toxic and potentially lethal hazard by establishing requisite design, policies, procedures, hazard analysis, work controls, communications, personal protective equipment, positive system lockout, and training. The contractor failed to prevent actuation of the CO<sub>2</sub> system in occupied space or, alternatively, to ensure adequate warning and escape time and the ability to accomplish immediate search and rescue without risking additional lives. In the words of one of the seriously injured workers, "It's taken one life. We're lucky it didn't take more."

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<sup>1</sup> If properly designed, two separate and independent signals should have initiated a warning alarm. The first signal was a 30-second pre-discharge warning alarm that did not function. The second signal was a 25-second warning alarm that should have indicated the system was going to discharge. This signal was not functional because it was not installed, although it was specified in the design.

**Table ES-1. Causal Factors and Judgments of Need**

Root Causes	Judgments of Need
<p>LMITCO did not have a systematic method for identifying, institutionalizing or implementing requirements for the design, installation, and work conducted or affected by the CO<sub>2</sub> fire suppression system</p>	<p>LMITCO needs to establish and implement a program that complies with and incorporates all applicable worker protection requirements contained in Occupational Safety and Health Administration regulations, National Fire Protection Association codes and standards, and DOE Orders for CO<sub>2</sub> fire suppression systems and other systems with hazardous gases into applicable manuals, safety analysis reports, procedures, and work planning and control processes to ensure that employees are protected from releases of toxic agents from energized systems.</p> <p>ID and LMITCO need to assure effective quality assurance practices are in place to independently verify that system design modifications are accomplished in accordance with all applicable codes and requirements.</p> <p>ID, in its capacity as the "Authority Having Jurisdiction" with respect to fire protection, needs to strengthen its review of fire protection design and design modifications to ensure compliance with applicable requirements, codes, and standards.</p> <p>LMITCO needs to verify the qualifications of its fire protection design personnel, ensure that all fire protection contracts address required contractor submittals, ensure that those submittals receive qualified review prior to acceptance, re-evaluate acceptance testing procedures, and ensure that all required re-acceptance testing is in fact performed.</p> <p>LMITCO needs to assure that safety basis documentation and procedures for inactive facilities are updated, maintained, and appropriately used.</p>
<p>ID and LMITCO management has accepted unstructured work controls at INEEL, which contribute to increased industrial safety risks to workers.</p>	<p>ID and LMITCO management need to expedite the implementation of integrated safety management policy including the need for organizational behavior change, increased leadership and management presence, and accelerated application of core functions to all work activities on site.</p> <p>LMITCO needs to strengthen the contribution of procedures to safety management and the consistent implementation of safety requirements and policies through accelerated updating and quality improvement, field validation, and a deliberate approach to assure consistent use and application.</p>

**Table ES-1. Causal Factors and Judgments of Need (continued)**

Contributing Causes	Judgments of Need
<p>Faulty design and installation of the fire suppression system, due to failure to implement the appropriate requirements and procedures, and failure to install a monitoring or feedback circuit for the CO<sub>2</sub> discharge header or solenoid valve position to the discharge alarm.</p>	<p>LMITCO needs to verify that all gaseous agent fire extinguishing systems (i.e., CO<sub>2</sub>, Halon, FM200, Inergen, etc.) are monitored for discharge in accordance with NFPA Standard 72, <i>National Fire Alarm Code</i>. This monitoring should be configured to assure positive notification to building occupants in sufficient time to allow evacuation of the protected area prior to system discharge. With respect to total flooding CO<sub>2</sub> systems, the combination of a discharge pressure switch and a mechanical discharge delay should be considered.</p> <p>LMITCO needs to update fire protection systems drawings and keep them updated to reflect modifications for the as-built plant.</p> <p>LMITCO needs to determine the specific mechanism by which the CO<sub>2</sub> system in Building 648 discharged on July 28, 1998, and take actions as appropriate to avoid a recurrence in the future. Until this is done, the CO<sub>2</sub> system in Building 648 should remain out of service and compensatory fire protective measures implemented, as appropriate.</p>
<p>Failure to use physical (lockout/tagout) and administrative barriers (current procedures and work planning and control processes) that implemented regulatory requirements.</p>	<p>DOE needs to actively campaign to improve consensus standards and in the interim should consider strengthening Orders and policies related to fire protection and worker safety to clearly define lockout, to limit occupancy in CO<sub>2</sub> flood areas, and to prevent use of fire system impairments as a means of personnel protection.</p> <p>LMITCO needs to ensure that all total flooding gaseous fire suppression systems at INEEL are equipped with an OSHA complaint positive lockout mechanism that is electrically supervised by the releasing system. DOE needs to consider implementing a similar policy across the complex.</p> <p>LMITCO needs to improve the work control system by providing additional guidance on the performance of hazard evaluations to include the importance of capturing all potential and credible hazards associated with the work or workspace and the significance of risks created by the hazards; requiring utilization of the Job Requirements Checklist process for applicable preventive maintenance tasks that have not yet been through the process; and expediting the training and qualification program for work planners (in the interim, ensure only qualified personnel are used for this function.)</p> <p>LMITCO needs to provide additional management attention to assure the effectiveness of the work control system. This includes direct involvement of knowledgeable managers in reviewing work and coaching individuals on implementation of the system.</p> <p>LMITCO needs to provide additional guidance in the outage request procedure to assure documentation of any controls associated with outages that may impact safety and to provide additional guidance to assure that appropriate personnel such as the fire protection engineer are included in the outage planning process when appropriate.</p>
<p>Competency of staff at all levels to deal with CO<sub>2</sub> hazards was not assured by LMITCO. Those involved with the CO<sub>2</sub> fire suppression system failed to understand the necessary requirements and procedures at the design, work planning and control, and implementation stages at the sitewide, facility, and activity levels.</p>	<p>LMITCO needs to institutionalize training and incorporate information about CO<sub>2</sub> hazards into INEEL training programs. This should include:</p> <ul style="list-style-type: none"> <li>- CO<sub>2</sub> hazard recognition (including pre-discharge alarm recognition)</li> <li>- Emergency preparedness and immediate response and rescue to CO<sub>2</sub> discharges</li> <li>- Egress requirements and CO<sub>2</sub> evacuation drills for all personnel performing work in buildings protected with CO<sub>2</sub> flood systems</li> <li>- Clarification on the limitations of system impairments for personnel protection, and the use of lockout/tagout.</li> </ul> <p>LMITCO needs to provide training for work planners, fire protection engineers and safety engineers in industry requirements related to CO<sub>2</sub> including personal protection, warning signs, clear exit pathways and preparations for immediate rescue.</p>

**Table ES-1. Causal Factors and Judgments of Need (continued)**

Contributing Causes	Judgments of Need
<p>Failure of LMITCO to take corrective actions and apply lessons learned from previous accident investigations, particularly in work planning and control; and failure of ID and LMITCO to exercise sufficient monitoring and feedback of this process to ensure correction of major safety deficiencies that are impacting worker safety.</p>	<p>LMITCO needs to conduct sitewide lessons learned training on the root causes and corrective actions associated with this accident, including those related to the level of hazard, protective lockout, emergency preparedness and immediate response.</p> <p>ID and LMITCO need to strengthen the INEEL issues management process to assure effective prioritization and tracking of issues, identification and resolution of management system weaknesses, and field follow-up, performance-based validation, and closure of corrective actions.</p>
<p>Failure to identify, institutionalize, and implement requirements for immediate emergency rescue and response to planned and unplanned CO<sub>2</sub> discharges.</p>	<p>LMITCO needs to assure the ability to accomplish immediate rescue and response to planned and unplanned CO<sub>2</sub> discharges, including the capability to deal with mass casualties having insufficient oxygen.</p>
<p>Failure on the part of ID and LMITCO to adequately evaluate the impact of incremental cost cutting and infrastructure reductions on worker safety.</p>	<p>ID and LMITCO need to improve analysis and control of incremental reductions in funding for safety infrastructure, including individual as well as cumulative impacts on safety management and emergency preparedness.</p> <p>LMITCO needs to conduct a risk benefit analysis on the continued need for CO<sub>2</sub> fire suppression systems at INEEL and to evaluate the necessity of using total flooding CO<sub>2</sub> for fire suppression in occupied spaces. Where alternatives are not practical for cost or other reasons, facilities should comply with NFPA 101, <i>Life Safety Code</i>, requirements for high hazard industrial occupancies and all safety-related requirements of NFPA 12, <i>CO<sub>2</sub> Extinguishing Systems</i>, should be strictly enforced. DOE needs to consider implementing a similar policy across the complex, including re-evaluation on a risk-benefit basis as the mission or status of facilities change.</p>