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GAO

Report to Congressional Addressees

May 2007

# NUCLEAR SAFETY

# DOE's Investigation of Phosgene Gas Contamination Was Inadequate, but Experts Conclude That Worker Safety and Facilities Are Not Threatened


GAO-07-712

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# DOE's Investigation of Phosgene Gas Contamination Was Inadequate, but Experts Conclude That Worker Safety and Facilities Are Not Threatened

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Highlights

Highlights of GAO-07-712, a report to congressional addressees

## Why GAO Did This Study

More than 700,000 tons of uranium are stored at two Department of Energy (DOE) sites where uranium enrichment took place and where two facilities are being constructed to treat depleted uranium. Some of the storage cylinders for uranium came from the Army more than 50 years ago and may originally have contained phosgene, a toxic gas used as a chemical weapon in World War I. In September 2005, DOE's Inspector General issued an alert warning that residual phosgene, if present, could threaten the safety of people and the treatment facilities.

GAO was directed to review DOE's investigation of possible phosgene contamination of uranium storage cylinders. GAO consulted a panel of experts to assess the adequacy of DOE's investigation and whether possible phosgene contamination could threaten the new treatment facilities under construction.

## What GAO Recommends

GAO recommends that the Secretary of Energy strengthen DOE's review process for safety investigations to include reviewers who are independent of the investigations being done and can provide objective evaluations of the methods used and the findings and conclusions reached.

DOE agreed that workers and the public were not at risk but did not believe that its investigation had flaws. DOE did not comment on our recommendations.

www.gao.gov/cgi-bin/getrpt?GAO-07-712.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Gene Aloise at (202) 512-3841 or AloiseE@gao.gov.

## What GAO Found

According to members of GAO's expert panel, although DOE adequately demonstrated that the public would not be harmed if small amounts of phosgene escaped from the storage cylinders, it neglected to explicitly document its analysis of worker safety in its investigation of possible phosgene contamination. DOE's regulations and guidance call for thorough safety analyses of newly identified hazards, such as possible phosgene contamination, to protect workers and the public. Yet DOE assumed, without explicitly documenting, that existing worker safety procedures were adequate to protect workers from the possible presence of phosgene. After GAO identified the need for DOE to support this key assumption, DOE provided supplemental information on worker safety; GAO's panel agreed that this supplement sufficiently supported DOE's position. In addition, although DOE's guidance calls for independent review of investigation results, DOE officials supervising the phosgene investigation also served as reviewers. This lack of independent review may have contributed to weaknesses in the investigation.

The experts GAO consulted agreed that, for two reasons, the facilities under construction in Ohio and Kentucky would not be threatened by possible phosgene contamination of uranium storage cylinders. First, at the start of treatment operations, cylinders containing depleted uranium will be placed inside pressure vessels designed to withstand and contain any leak from a cylinder. If phosgene were present, it would not affect either the pressure vessels or the treatment facilities. Second, during subsequent steps, any phosgene that may be processed with the depleted uranium would be destroyed by the extreme heat and water vapor applied during the treatment process.

**Uranium Storage Cylinders at Paducah, Kentucky**

Source: Uranium Disposition Services.

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## Abbreviations

| | |
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| DOE | Department of Energy |
| UDS | Uranium Disposition Services |
| USEC | U.S. Enrichment Corporation |

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**United States Government Accountability Office**
**Washington, DC 20548**

May 31, 2007

The Honorable Byron L. Dorgan
Chairman
The Honorable Pete V. Domenici
Ranking Minority Member
Subcommittee on Energy and Water
Committee on Appropriations
United States Senate

The Honorable Peter J. Visclosky
Chairman
The Honorable David L. Hobson
Ranking Minority Member
Subcommittee on Energy and Water Development
Committee on Appropriations
House of Representatives

The Honorable Mitch McConnell
United States Senate

From the 1940s, one of the missions of the Department of Energy (DOE) and its predecessors was to enrich uranium as a source of nuclear material for defense and commercial purposes. Before it can be enriched, uranium is combined with fluorine to form uranium hexafluoride, a substance dangerous to human health and the environment because it is radioactive and forms potentially lethal compounds if it comes in contact with water. The enrichment process results in two principal products: (1) enriched uranium hexafluoride, which can be further processed for specific uses, such as nuclear fuel or weapons, and (2) depleted uranium hexafluoride, a material that can be converted into a more stable form for storage and other applications. Both processes—uranium enrichment and depleted uranium conversion—involve hazardous materials and processes that can harm the public, workers, and the environment. DOE therefore requires specific safety procedures to be in place at uranium-processing sites. Uranium-processing activities took place at three sites near Paducah,

Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee,[1] where over 700,000 tons of uranium hexafluoride is currently stored. At the Paducah and Portsmouth sites, DOE is constructing two new facilities to convert depleted uranium hexafluoride into a more stable compound, uranium oxide, for long-term storage.

Between 1945 and the mid-1950s, the Atomic Energy Commission, a DOE predecessor, acquired from the U.S. Army Chemical Warfare Service more than 2,500 of the approximately 63,000 steel cylinders in which it now stores uranium hexafluoride. The Army previously stored other chemicals in these 2,500 cylinders, including a toxic gas called phosgene, which was used as a chemical weapon during World Wars I and II. Phosgene can immediately endanger health or life, even in quantities as small as 2 parts per million. If inhaled, the gas damages the lungs, causing them to fill with fluid and potentially leading to death by suffocation or heart failure. DOE's records from 1946 indicate that some of the storage cylinders it received from the Army tested positive for phosgene; the records do not indicate, however, which cylinders tested positive, how much phosgene was present, or whether DOE removed the phosgene before using the cylinders to store uranium hexafluoride.

In September 2005, DOE's Inspector General issued an urgent letter, called a management alert, to DOE regarding the possible presence of phosgene in the cylinders received from the Army. The alert warned that the possible presence of phosgene in uranium storage cylinders had significant implications for the safety and health of workers and the public. In response to the Inspector General's alert, DOE identified 2,509[2] cylinders suspected of containing phosgene, immediately suspended regular maintenance activities around these cylinders, implemented precautions to protect workers from the potential phosgene hazard, and began an investigation of phosgene contamination of the 2,509 cylinders.

[1]DOE processed uranium at the site near Oak Ridge, Tennessee until 1985. This site is now being decontaminated and decommissioned, and storage cylinders have been moved to other sites, such as Portsmouth. Since 1992, uranium enrichment activities have been performed by U.S. Enrichment Corporation (USEC), a private company that was created in 1992 as a wholly owned government corporation and then privatized in 1998.

[2]DOE's *Phosgene Characterization Study* reported 2,544 cylinders that were suspected of containing phosgene. Thirty-five of those cylinders were removed from consideration because they were not relevant; for example, some were not the type of cylinder in question. We chose not to report on these 35 cylinders, reporting instead on the 2,509 relevant cylinders.

This investigation was conducted collaboratively by DOE and a contractor, Uranium Disposition Services (UDS), which was tasked with analyzing and reporting on possible phosgene contamination and also with maintaining the storage cylinders and constructing the facilities to convert depleted uranium.[3] In April 2006, DOE completed its investigation,[4] concluding that phosgene, if present, would not react with uranium hexafluoride and that the uranium storage cylinders would not contain enough residual phosgene to harm the public outside site boundaries, that is, no closer than 200 meters from the cylinders.[5] DOE also concluded that the small quantity of residual phosgene it deemed safe for the public would also pose no harm to workers, who would be protected under existing safety procedures, and not threaten the depleted uranium conversion facilities at Portsmouth, Ohio, and Paducah, Kentucky.

Given the potential safety risks, the Conference Report accompanying the Fiscal Year 2006 Energy and Water Development Appropriations Act[6] directed us to provide an independent review of possible phosgene contamination of DOE's uranium storage cylinders. This report discusses (1) the adequacy of DOE's investigation of potential harm to workers and the public from phosgene contamination of the storage cylinders and (2) whether possible phosgene contamination of storage cylinders could threaten the depleted uranium treatment facilities after conversion operations begin at the Portsmouth and Paducah sites.

## Scope and Methodology

To determine the adequacy of DOE and UDS's investigation of potential harm to workers and the public from possible phosgene contamination of uranium storage cylinders, we reviewed the DOE Inspector General's workpapers and interviewed officials to understand their preliminary findings. We also interviewed officials at the Defense Nuclear Facilities Safety Board and U.S. Enrichment Corporation (USEC). To identify what actions DOE and UDS were required to take to address worker and public

[3]In addition to DOE and UDS officials, officials from Bechtel Jacobs Corporation were involved in investigating possible phosgene contamination of uranium storage cylinders formerly stored at DOE's Oak Ridge site.

[4]Department of Energy, Depleted Uranium Conversion Project, *Phosgene Characterization Study*, DUF6-G-RGN-008, rev. 1 (Washington, D.C.: April 2006).

[5]DOE and UDS determined that, should a cylinder rupture, 1.2 grams or less of residual phosgene present in a cylinder would not harm people standing 200 meters or more from the ruptured cylinder.

[6]H.R. Rep. No. 109-275, at 150 (2005).

safety in light of the possible presence of phosgene, we reviewed federal safety requirements set out in the *Code of Federal Regulations*[7] and DOE guidance.[8] In addition, we spoke with senior DOE safety officers to clarify the requirements and expectations of DOE safety investigations. To learn what actions DOE and UDS took to address the potential presence of phosgene, we reviewed DOE's *Phosgene Characterization Study* and supporting documents and interviewed DOE and UDS officials who conducted the investigation. To determine the reliability of the data DOE and UDS used in determining whether cylinders posed harm to workers or the public, we reviewed a stratified random sample of 250 cylinders from the 2,509 cylinders in question and reviewed all the available records for each cylinder. We visited the cylinder storage yards at the Paducah and Portsmouth sites to view some of the cylinders in our sample and to examine cylinder records. We found that DOE and UDS had generally interpreted the cylinder record information correctly and consistently and that their data were sufficiently reliable.

To assess DOE and UDS's scientific assumptions and conclusions in their investigation of possible phosgene contamination, we assembled a panel of experts from outside DOE to review DOE's final report and supporting documents. To select experts, we used an iterative process (often referred to as the "snowball sampling" technique) to identify scientists outside DOE who had experience or expertise in phosgene, nuclear material, or both. Through recommendations by knowledgeable government agency officials, we first identified a small number of experts. We asked these experts to participate in the panel and to provide names of other experts with knowledge of phosgene or nuclear material. We continued soliciting names until we determined that we had appropriate coverage of the topic areas. We did not limit our search to government agencies but solicited recommendations for experts from government, private, academic, and international organizations. The scientists we identified with the necessary expertise were all government scientists. Table 1 lists the resulting panel of seven experts.

[7]10 C.F.R. part 830, subpart B: Safety Basis Requirements.

[8]Department of Energy, *DOE Standard: Review and Approval of Nuclear Facility Safety Basis Documents (Documented Safety Analyses and Technical Safety Requirements)*, DOE-STD-1104-96, Change Notice No. 1, May 2002; *Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements*, DOE G 424.1-1, October 2001; and *Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 C.F.R. 830*, DOE G 421.1-2, October 2001.

**Table 1: GAO's Expert Panelists, Titles, and Affiliations**

| Name | Title | Affiliation |
|---|---|---|
| Dr. Frederic Berg | Supervisory Research Chemist | U.S. Army Edgewood Chemical and Biological Center |
| Dr. John F. Kalinich | Principal Investigator, Research Biochemist | Armed Forces Radiobiology Research Institute |
| Dr. Tadeusz Kleindienst | Research Physical Scientist | U.S. Environmental Protection Agency, National Exposure Research Laboratory |
| Dr. Urmila Kodavanti | Research Biologist | U.S. Environmental Protection Agency, Experimental Toxicology Division, Pulmonary Toxicology Branch |
| Dr. David McClain | Research Biochemist | Armed Forces Radiobiology Research Institute |
| Dr. Alfred Sciuto | Research Physiologist, Branch Chief | U.S. Army Medical Research Institute of Chemical Defense |
| Mr. William Troskoski | Senior Chemical Engineer | Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards |

Source: GAO.

Panelists were given DOE and UDS's final report on the investigation and the report's attached supporting documents, in addition to information we collected on uranium enrichment from scientists at USEC who work directly with the uranium enrichment process. DOE and UDS officials reviewed these documents for completeness and accuracy. The panelists met to discuss their own analyses and conclusions and continued discussions via e-mail and telephone calls.

To determine whether possible phosgene contamination of uranium storage cylinders could threaten the depleted uranium treatment facilities, we assessed documentation on the facilities' operations and interviewed officials at UDS and the Nuclear Regulatory Commission. The expert panel we assembled reviewed the conversion process and discussed whether the facilities would be threatened by phosgene and how the conversion process would affect phosgene. Finally, to corroborate the information we gathered, we interviewed officials at UDS and the Nuclear Regulatory Commission who are familiar with the conversion facilities and the equipment used to process the uranium storage cylinders. We performed our work in accordance with generally accepted government auditing standards from March 2006 through April 2007.

## Results in Brief

The experts we consulted confirmed that DOE and UDS's investigation of possible phosgene contamination was flawed because, among other things, it did not explicitly document that phosgene would not harm workers near the storage cylinders. It was not until February 2007, after we brought this weakness to DOE and UDS's attention that they provided

supplemental information that addressed worker safety. Until then, DOE and UDS believed, but did not explicitly document, that existing worker safety procedures were adequate to protect workers from the possible presence of phosgene. Regulations governing how DOE and its contractors should conduct operations involving hazardous materials explicitly call for the contractor to prepare documented safety analyses that establish hazard controls necessary to ensure adequate protection of workers, the public, and the environment. The regulations require DOE to take appropriate action to address a newly identified hazard, such as possible phosgene contamination. Our panelists agreed that DOE and UDS's investigation demonstrated that phosgene would not be present in quantities that could harm members of the public passing by or living near the DOE sites—at a distance of 200 meters or more from the cylinders—where uranium is stored or treated.

The experts also agreed, however, that DOE and UDS failed to document that the same quantities of phosgene that would not harm the public would also not harm workers directly involved in handling and maintaining the cylinders. Although DOE and UDS officials stated that they systematically analyzed the potential consequences to workers of phosgene in uranium storage cylinders, they did not explicitly document their analysis or conclusions, creating a weakness in their investigation. In particular, we found no record of their assumptions, analysis, or results. DOE and UDS officials reasoned that because the uranium hexafluoride in the cylinders was more dangerous than the possible presence of phosgene, the existing safety procedure—known as "see and flee"—was adequate to protect workers from phosgene. Specifically, "see and flee" directs workers to evacuate the area when they see any sign of a cylinder rupture. DOE guidance instructs DOE and its contractors to document all support for safety investigations to allow independent reviewers to assess the adequacy of analyses and conclusions. DOE's guidance also calls for independent review of investigation results by officials who are not directly involved in the investigation. In this case, however, reviewers may have been too familiar with the investigation to provide a review that was sufficiently independent to identify and correct this weakness. In February 2007, DOE and UDS issued a supplement to the original investigation report, which supported their earlier assertion that existing safety procedures would protect workers near the uranium storage cylinders from residual phosgene, and our expert panel concurred. In our view, DOE and UDS were fortunate that their undocumented assumptions proved correct and existing safety procedures had been sufficient to protect workers throughout the investigation.

The experts with whom we spoke agreed that any phosgene present in uranium storage cylinders would not threaten the depleted uranium conversion facilities under construction at Portsmouth and Paducah, for two reasons. First, at the start of the conversion process, cylinders containing depleted uranium hexafluoride will be placed inside pressure vessels, where their contents will be heated and liquefied. According to our expert panel and officials from DOE and UDS, the pressure vessels are designed to withstand and contain any leak from a cylinder, so that if phosgene were present, it would not affect either the pressure vessels or the facilities. Second, during subsequent steps in the conversion process, any phosgene that was processed with the depleted uranium hexafluoride would be destroyed. Specifically, our expert panel and DOE and UDS officials all agreed that the extreme heat would destroy phosgene. In addition, the water vapor added during the process would react with any phosgene present to form compounds, including carbon dioxide, that would not threaten the facilities.

We recommend that DOE better ensure that its safety investigations follow agency guidelines and are technically adequate, in particular, by making use of reviewers who are independent of the investigations being done and who will provide objective evaluations of the investigations' methods and resulting findings and conclusions.

DOE commented on a draft of this report and generally agreed with our conclusions that neither workers nor the public would have been at risk from potential phosgene contamination. DOE did not comment on our recommendations. DOE took exception to our findings that its assessments of worker safety and of the fate of phosgene in the enrichment process were inadequately documented, stating that explicit documentation was unnecessary. Our panel of technical experts, however, concluded that without explicit documentation of these critically important analyses, DOE could not adequately demonstrate that workers would not be harmed by the potential presence of phosgene. DOE also took issue with our finding that its review of the investigation was not sufficiently independent, stating that its investigation was reviewed by four officials who had no direct connection to the investigation. Nevertheless, according to documents previously provided to us by DOE, we believe that two of these officials, who had approved investigation plans and provided direction to the investigation, were not sufficiently independent to provide an objective review of the quality or results of that investigation.

## Background

Created in 1977 from diverse agencies, DOE manages the nation's nuclear weapons production complex, cleans up the environmental legacy of nuclear weapons development, and conducts research in both energy and basic science. DOE carries out its work at numerous sites and facilities around the country, primarily through organizations that manage the facilities and implement program and project activities under contract to DOE. The department has established an extensive network of field offices to directly oversee the work of these contractors. DOE's Portsmouth/Paducah Project Office, under the Office of Environmental Management, is responsible for cleanup and depleted uranium conversion at the Portsmouth and Paducah sites.

The United States began processing uranium—a radioactive heavy metal that is mined and extracted from ore—before the Manhattan Project gave rise to the first atomic bomb in the 1940s. Subsequently, DOE and its predecessor agencies continued to process uranium as fuel for commercial nuclear reactors. A key step in this process is uranium enrichment, which increases the concentration of uranium-235, the form of uranium that undergoes fission to release enormous amounts of energy.[9] Uranium enrichment involves combining uranium with the chemical fluorine to form uranium hexafluoride. Radioactive and extremely corrosive, uranium hexafluoride reacts with water and can burn the skin, eyes, and internal organs.

Uranium hexafluoride and depleted uranium hexafluoride (the material left over after uranium enrichment) are currently stored in steel cylinders. In all, approximately 700,000 tons of uranium hexafluoride is stored in about 63,000 cylinders at storage yards on the Paducah and Portsmouth sites (see fig. 1). A cylinder surveillance and maintenance program includes regular inspections to check the integrity of cylinder walls, valves, and plugs; replacement or reattachment of nameplates (which are vital for cylinder identification and tracking); and repair of any defective valves or plugs.

[9]Natural uranium, the raw material required for the uranium enrichment process, comprises several isotopes—forms of the same element with different atomic weights. Uranium ore consists mostly of uranium-238 and less than 1 percent uranium-235, the fissile isotope used in nuclear reactors and nuclear weapons. To be usable as reactor fuel, uranium must be enriched so that the proportion of uranium-235 exceeds 1 percent; commercial nuclear fuel is typically enriched to 3 to 5 percent.

**Figure 1: Uranium Storage Cylinders at DOE's Paducah Site**

Source: DOE Inspector General.

Ultimately, DOE plans to convert the stored depleted uranium hexafluoride into uranium oxide, a more stable chemical form for long-term storage. UDS is constructing two depleted uranium hexafluoride conversion facilities, one each at Paducah and Portsmouth. Scheduled to begin operating in 2008, the facilities together will be able to process a total of about eight cylinders of depleted uranium hexafluoride per day. DOE estimates that once the conversion facilities begin operating, it will take approximately 25 years to convert its existing stockpile of depleted uranium hexafluoride.

Historically, because of national security concerns, DOE and its predecessors have not been externally regulated for worker or nuclear facility safety; rather, DOE relies on its own internal system of oversight and controls to hold its contractors accountable. DOE's primary approach to regulating its contractors to ensure public health and safety and the safety of workers at nuclear facilities is to incorporate the requirements of DOE regulations and directives, including policies, orders, and standards, into contracts. Among other requirements, DOE regulations require

nuclear facilities to maintain a master document, called a documented safety analysis, that analyzes hazards and describes the controls necessary to ensure that workers, the public, and the environment are adequately protected. The documented safety analysis and hazard controls are referred to as a safety basis. The contractor must submit a safety basis to DOE for review and approval; update the safety basis to keep it current and reflect changes in the facility itself, its work, or the hazards present; and submit the updated document (or a letter stating that there have been no changes) to DOE once a year thereafter. If a new hazard is discovered, the regulations direct contractors to take immediate steps to ensure the facility's safety and to notify DOE. In addition, the contractor must conduct and submit to DOE a safety evaluation of the new hazard.

An October 2000 report by DOE's Office of Environment, Safety, and Health informed DOE that some 30-inch diameter cylinders acquired from the Army, now used to store uranium hexafluoride, previously contained phosgene. A chemical not found in nature, phosgene, or carbonyl chloride ($COCl_2$), was used as a chemical weapon in World War I and stockpiled by the U.S. Army Chemical Warfare Service in World War II; at present, it is used to make plastics, pesticides, and even pharmaceuticals. At room temperature, phosgene is a colorless gas heavier than air, with an odor of musty hay; in the presence of moisture, it may form a white cloud. According to the National Institute for Occupational Safety and Health, phosgene presents an immediate threat to life and health at a concentration of about 2 parts per million. When the chemical comes in contact with moisture on the skin or in the respiratory tract, it reacts to form hydrochloric acid, which, like uranium hexafluoride, burns human tissues.[10] With uranium storage cylinders used in the conversion process, DOE's Inspector General raised a concern that some 30-inch cylinders could possibly contain phosgene and could enter the depleted uranium conversion facilities for processing.

After DOE's Inspector General issued its warning about possible cylinder contamination from phosgene, DOE and UDS conducted an investigation to determine the extent to which the cylinders received from the Army

[10]The severity of a chemical's toxic effect depends on a person's total exposure to that chemical, that is, the concentration of the chemical multiplied by the duration of exposure. For phosgene, exposure to a concentration of 30 parts per million for 1 minute (or 3 parts per million for 10 minutes) damages the lungs, exposure to 150 parts per million for 1 minute causes the lungs to fill with fluid, and exposure to 300 parts per million for 1 minute or more can kill.

were contaminated. For each cylinder, they applied one of three criteria to establish that the cylinder could contain no more than a trace amount of phosgene. First, they found that if past practices to prepare storage cylinders for use in the uranium enrichment process had been consistently followed, these practices should have eliminated any phosgene that might have been present. These practices included cleaning the cylinders—washing their interiors with corrosive chemicals and rinsing them with water—and pressure testing them to ensure they were structurally sound. DOE had documents demonstrating that 176 of the 2,509 cylinders had been cleaned or pressure tested after DOE received them from the Army. DOE was therefore able to clear these 176 cylinders of suspicion on the basis of this first criterion. Second, DOE and UDS calculated that if the storage cylinders had been filled with and emptied of uranium hexafluoride at least once, any residual phosgene in the cylinders should have been reduced to quantities too small to harm the public. DOE cleared 2,296 cylinders on the basis of this second criterion.[11] Third, DOE and UDS determined that if a cylinder had a hole in it—for example, where a valve was removed from the cylinder and the resulting hole was left uncovered—residual phosgene would have dissipated completely from the cylinder. DOE cleared another 12 cylinders with open holes, on the basis of this third criterion. Finally, DOE and UDS sampled and analyzed the contents of the last 25 cylinders and did not detect phosgene at or above the residual quantity they deemed safe for the public.

## DOE's Investigation of Possible Phosgene Contamination Did Not Adequately Document Analysis of Worker Safety

DOE and UDS's investigation of possible phosgene contamination was flawed because, among other things, it did not explicitly document that phosgene would not harm workers near the uranium storage cylinders. Under federal regulations and DOE guidance, DOE and its contractors are to assess safety risks to workers and the public. Although DOE considered worker safety, it did not explicitly document its analysis or conclusions. It did adequately assess and document its conclusions for public safety. In response to our review, DOE and UDS provided supplemental information that the experts we consulted found sufficient to support DOE's initial assertion that existing safety procedures had protected workers from harm throughout the investigation.

[11]DOE and UDS originally identified 182 cylinders that met the first criterion and 2,290 cylinders that met the second criterion. During our review, however, 6 cylinders were found to not meet the first criterion; they were subsequently cleared of suspicion by DOE under the second criterion. As a result, 176 cylinders met the first criterion, and 2,296 met the second. The next section discusses this difference in more detail.

## DOE Did Not Explicitly Document Its Analysis of the Safety Risk to Workers from Possible Exposure to Phosgene

According to the experts we consulted, the original investigation was flawed because DOE and UDS did not explicitly document that workers would face no harm from small quantities of phosgene that could be present in uranium storage cylinders. Federal regulations and DOE guidance direct DOE and its contractors to analyze safety risks to workers, the public, and the environment to ensure that they are adequately protected from hazardous materials and conditions. To do so, each DOE facility must maintain a comprehensive documented safety analysis that details potential hazards and appropriate safety procedures to mitigate those hazards. If a new hazard is discovered that is not addressed in the existing documented safety analysis, federal regulations direct DOE and its contractors to take action to place or maintain the facility in a safe condition until a safety analysis is completed and submitted to DOE for approval.

According to DOE guidance and senior regulatory officials, a safety analysis conducted in response to a new hazard must analyze appropriate accident conditions, derive or identify procedures sufficient to ensure the safety of workers, and demonstrate the adequacy of those procedures to maintain the work environment at an acceptably low level of risk. In addition, guidance specifies that safety analyses should be well documented to allow independent reviewers to assess the adequacy of the analysis and its conclusions. The officials stated that the analysis should be rigorous, include quantitative and qualitative reasoning, and identify and defend assumptions.

In this case, DOE and UDS conducted an investigation of the possible presence of phosgene contamination in uranium storage cylinders because they recognized the possibility that workers and the public might be in danger if phosgene were present in the cylinders. For example, if an accident occurred in the uranium storage cylinder yard and a cylinder containing phosgene ruptured, workers and the public could suffer serious harm if they inhaled phosgene gas.[12] Through their investigation, DOE and UDS demonstrated that only small amounts of phosgene could be present in the uranium storage cylinders. All members of our expert panel reviewed and concurred with this finding. Nevertheless, the expert panel raised concerns that DOE did not specify whether or how workers

[12]The uranium hexafluoride stored in the cylinders is also very dangerous to workers, but safety procedures are in place to protect workers from uranium hexafluoride if a cylinder were to rupture.

conducting operations directly adjacent to the cylinders would be protected from harm if phosgene accidentally escaped from a cylinder.

When we related our expert panelists' concerns about the possible effects of phosgene on workers, DOE and UDS officials stated that they had assessed worker safety during the investigation and decided that workers would not be harmed by the possible presence of small amounts of phosgene. DOE and UDS officials stated that the first-response safety procedure to protect workers from uranium stored in the cylinders—termed "see and flee"—calls for immediate evacuation of the area around a ruptured cylinder. They reasoned that since this procedure was sufficient to protect workers against large quantities of uranium hexafluoride if a cylinder ruptured and the contents escaped, it would also be sufficient to protect workers from small amounts of phosgene.

DOE and UDS did not, however, explicitly document or support their inference that workers would be protected by the "see and flee" safety procedure. During their investigation, DOE and UDS considered worker safety and inferred that "see and flee" would protect workers from the possible presence of phosgene. Contrary to guidelines, however, they did not document a thorough analysis demonstrating that "see and flee" was adequate to protect workers until we brought the matter to their attention. Although DOE and UDS officials stated that they had systematically analyzed the potential consequences of the presence of phosgene in uranium storage cylinders to worker safety, they were unable to provide any documentation of their analysis, such as assumptions, reasoning, or results. The phosgene investigation did undergo review, but the lack of documentation of DOE and UDS's consideration of worker safety made it impossible for reviewers to assess the adequacy of this consideration and thus allowed a key element of the investigation to pass without inspection.

In addition, DOE's review of the phosgene investigation may not have been sufficiently independent. Senior DOE regulatory officials stated that reviewers should not be involved in the investigation under review; in this case, however, officials involved in the investigation also served as reviewers. DOE reviewers may have been too familiar with the project to provide a sufficiently independent assessment of the investigation. DOE's review allowed a weakness—the unsupported inference that existing safety procedures would protect workers—to persist in DOE's investigation of possible phosgene contamination. Thus DOE and UDS believed, without explicitly documenting, that existing worker safety procedures were adequate to protect workers from the possible presence of phosgene.

Ultimately, in February 2007, DOE and UDS issued a supplement to the original investigation report, which documented the assumptions, reasoning, and calculations used to reach the conclusion that existing safety procedures would protect workers from the possible presence of phosgene. All members of our expert panel agreed with the conclusions presented in the supplement. Therefore, the supplemental information showed that, throughout the investigation, workers were protected from harmful phosgene exposure by existing safety procedures.

In addition, we identified two other weaknesses in DOE and UDS's investigation of possible phosgene contamination, which they addressed during our review. Specifically:

- DOE and UDS assumed, but did not explicitly document, that any phosgene introduced into the uranium enrichment process would be destroyed. DOE and UDS did not identify this assumption or support it with evidence or analysis during the investigation. This is a key assumption because if the uranium enrichment process did not destroy phosgene, the gas could have passed through the process and into hundreds of thousands of cylinders containing enriched uranium hexafluoride and could still be present today. Scientists knowledgeable about the uranium enrichment process and the experts we consulted all confirmed that DOE and UDS's undocumented assumption was correct—phosgene, if introduced into the uranium enrichment process, would have reacted with other chemicals in the process and been destroyed, or it would have been purged from the process with other waste gases. After we discussed this weakness with DOE and UDS, they provided supplemental information demonstrating that phosgene would not survive the uranium enrichment process. We reviewed the supplemental information and found that it adequately supports DOE and UDS's assumption.

- DOE and UDS used records to determine that 181 cylinders had been pressure tested, which would have eliminated any phosgene that may have been present, but records for 6 cylinders lacked sufficient information to meet this criterion. According to DOE and UDS's definition of the pressure-test criterion, a cylinder must have information showing that (1) it underwent a pressure test and (2) the cylinder was under DOE's control at the time of the test. If a test had been performed while the cylinder was still in the Army's possession, it could have subsequently been used to store phosgene. During our review, we identified one cylinder that did not have sufficient information to prove that DOE had performed the pressure test. After discussing this weakness with DOE and UDS officials, UDS conducted its own review of all 181 cylinders and

found 5 additional cylinders that also had insufficient information to meet the pressure-test criterion. The available information for all 6 cylinders, however, did meet the definition of another criterion, and as a result, DOE and UDS concluded that the cylinders posed no harm.

These two weaknesses created potential vulnerabilities in DOE and UDS's investigation of possible phosgene contamination because if phosgene had survived the enrichment process, or if the six cylinders could not have passed a different criterion, many cylinders could still contain unknown amounts of phosgene today.

## DOE Did Document Its Analysis of the Safety Risk to the Public

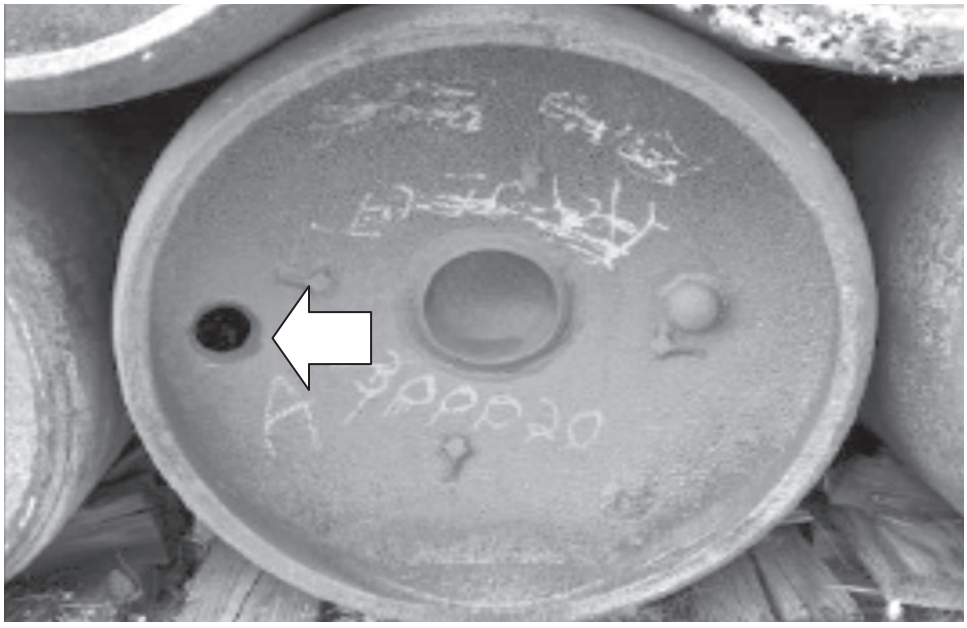
According to the experts we consulted, DOE and UDS conclusively demonstrated that the presence of small amounts of phosgene in storage cylinders would not harm the public. DOE and UDS followed federal regulations and agency guidelines by identifying possible accident conditions and applying and documenting a qualitative and quantitative analysis consisting of three main steps. First, DOE and UDS determined that the closest the public would be to cylinders possibly containing phosgene was 200 meters—the shortest distance between the storage site boundary and the cylinders. Second, DOE and UDS calculated the maximum amount of phosgene that could be released from a cylinder without harming a person standing 200 meters away. To do this, DOE and UDS used emergency-response planning guidelines that specify the maximum airborne concentration of phosgene that nearly all individuals could be exposed to for up to 1 hour without experiencing more than mild, transient health effects (such as coughing and eye irritation) and perceiving only an objectionable odor.[13] They then applied a computer model to predict the dispersion of phosgene gas from a ruptured cylinder and determined that 1.2 grams was the maximum amount of phosgene that could be present in a cylinder without harming a member of the public 200 meters away. Third, DOE and UDS determined that none of the cylinders could contain phosgene in excess of this 1.2 gram amount. Specifically, DOE and UDS reviewed cylinder records to document that the cylinders:

[13]These emergency response planning guidelines were developed by the American Industrial Hygiene Association, a nonprofit organization founded in 1939 that serves the needs of environmental health professionals practicing industrial hygiene in industry, government, labor, academic institutions, and independent organizations.

- had been washed or pressure tested after DOE acquired them;
- had been filled and emptied of uranium hexafluoride at least once, which would have removed enough phosgene that only a residual amount (less than 1.2 grams) could remain; or
- had open holes (for example, where a valve had been removed; see fig. 2), which would have allowed any phosgene to diffuse harmlessly over time.

DOE and UDS determined that if any one of these criteria were met, the amount of phosgene that could remain in a cylinder was 1.2 grams or less. For cylinders that did not meet these criteria, DOE and UDS sampled the contents to test for phosgene. On the basis of these procedures, DOE and UDS determined that phosgene could not be present in quantities that would harm the public.

**Figure 2: Cylinder with an Open Hole**



Source: Uranium Disposition Services.

DOE and UDS documented their assumptions, reasoning, calculations, and results from this analysis and reported them in their April 2006 investigation report. According to the experts we consulted, DOE and UDS's analysis conclusively demonstrated that the public would not be

harmed from any phosgene that could be present in uranium storage cylinders.

## Possible Phosgene Contamination of Uranium Storage Cylinders Does Not Threaten Depleted Uranium Conversion Facilities

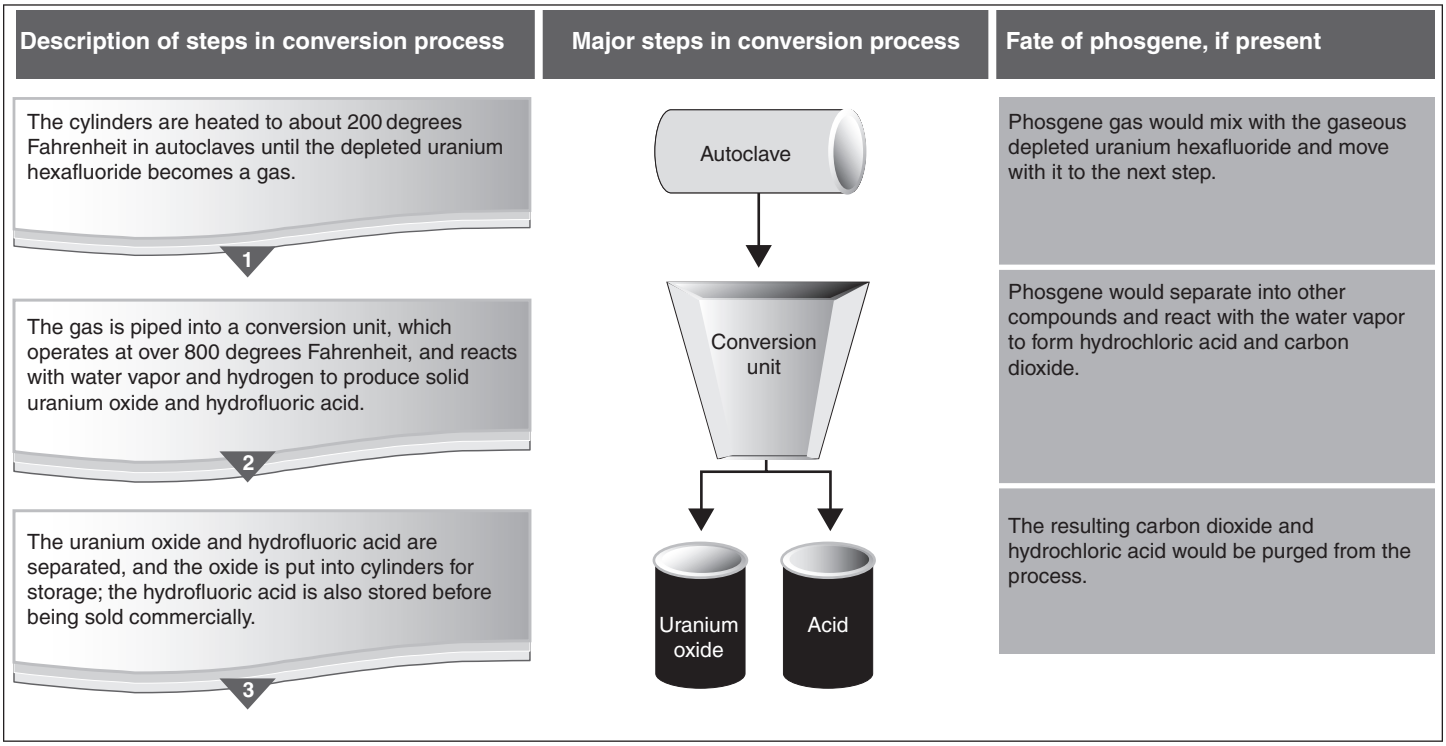
In September 2005, DOE's Inspector General warned that the introduction of phosgene into the conversion process could possibly have catastrophic safety consequences. At that time, neither the Inspector General nor DOE and UDS knew how much phosgene could be in a cylinder. In the investigation prompted by the warning, however, DOE and UDS demonstrated that no more than 1.2 grams of phosgene could be present in a cylinder. DOE and UDS determined that this small quantity of phosgene, if introduced into the conversion facilities, would not cause a safety concern, and the experts we consulted concurred.

The experts, as well as DOE and UDS officials, cited two main reasons for concluding that the conversion facilities would not be threatened if 1.2 grams or less of phosgene were present in the uranium storage cylinders. First, during the conversion process, the cylinders will be placed in pressure vessels (called autoclaves) that will heat their contents to approximately 200 degrees Fahrenheit. (Fig. 3 summarizes the conversion process and what would happen to any phosgene present.) According to UDS officials and experts we consulted, these autoclaves are designed to withstand any cylinder ruptures and to contain the contents of the cylinders, regardless of whether phosgene is present. Specifically, the autoclaves are designed to withstand pressures up to 200 pounds per square inch and temperatures exceeding 200 degrees Fahrenheit, and their interiors are treated with a protective coating that resists heat and corrosive chemicals. They would therefore withstand any depleted uranium hexafluoride or phosgene that might leak from a ruptured cylinder into the interior of the autoclave. Furthermore, if a cylinder did rupture, according to UDS officials, sensors in the autoclave would detect any depleted uranium hexafluoride released. These sensors would alert workers, who could then shut down the autoclave and follow safety procedures for cleaning it out.

Second, once the gaseous depleted uranium hexafluoride and phosgene, if present, left the autoclave and entered the conversion unit, high temperatures and water vapor applied during conversion would destroy any phosgene, in addition to converting the uranium hexafluoride to uranium oxide and hydrofluoric acid. According to UDS officials, the conversion unit will heat the depleted uranium hexafluoride and phosgene to temperatures exceeding 800 degrees Fahrenheit as water vapor is added. Because phosgene reacts with water and begins to dissociate into

carbon monoxide and chlorine gases below 800 degrees Fahrenheit, any phosgene would separate and react with the water vapor, forming carbon dioxide and hydrochloric acid, neither of which would threaten the conversion equipment. According to UDS officials, the carbon dioxide would be vented from the conversion system with other gases through exhaust stacks. The hydrochloric acid would also react with the water vapor and be purged from the system. Thus, any residual amounts of phosgene that may be introduced into the depleted uranium conversion process would be destroyed and would not threaten any part of the conversion facilities.

**Figure 3: Steps to Convert Depleted Uranium Hexafluoride to Uranium Oxide, with Impact on Phosgene, If Present**




Sources: GAO and DOE.

# Conclusions

In view of DOE's long history of processing highly radioactive and other dangerous materials for use in defense and civilian endeavors, protecting workers, the public, and the environment is an integral part of accomplishing DOE's missions. In doing so, DOE has guidelines for addressing potential hazards to workers and the public, which include an independent review of safety analyses. Nevertheless, DOE and UDS's

investigation of possible phosgene contamination of uranium storage cylinders did not follow guidelines for adequately documenting a safety analysis of the potential harm to workers that phosgene contamination might present. Furthermore, we do not believe that DOE had an adequate internal review process for assessing this investigation, a process that should have but did not identify weaknesses. Specifically, the review should have been conducted by reviewers who were independent of the investigation and who could have provided an objective evaluation of the investigation's methodology, findings, and conclusions. Although the assumptions DOE used in reaching its judgment on possible phosgene contamination turned out to be reasonable in this case, DOE may not be so fortunate the next time. The same process weaknesses, if undetected in other situations, could have dangerous consequences. The discovery of the possible presence of a potentially hazardous or lethal safety condition, such as phosgene contamination, demands a better planned and managed review process and assurance that guidelines are followed.

## Recommendations for Executive Action

To ensure the comprehensiveness and technical adequacy of investigations of potentially unsafe situations at DOE's nuclear facilities, we recommend that the Secretary of Energy ensure that safety investigations benefit from a review process that (1) includes reviewers who are sufficiently independent of the investigations being done and (2) provides objective evaluations of the methodologies being used and the findings and conclusions reached.

## Agency Comments and Our Evaluation

We provided a draft of this report to DOE for review and comment. In a written response, DOE's Chief Operating Officer for Environmental Management agreed with our conclusion that neither workers nor the public would have been at risk from potential phosgene contamination of depleted uranium cylinders but took exception to our findings of inadequacies in DOE's investigation. DOE did not comment on our recommendations. DOE's comments on our draft report are included in appendix I. DOE also provided the February 2007 supplement to its investigation that was previously provided to us. We did not, however, reproduce the supplement because our draft report already discussed its contents.

In its written comments, DOE expressed the view that three basic assertions in our draft report were incorrect, inaccurate, or misleading. Specifically, DOE took issue with our findings that DOE's assessment of worker safety was flawed, DOE's reviewers of the investigation were not

sufficiently independent, and explicit information on the fate of phosgene in the enrichment process was not included in the investigation.

Regarding worker safety, DOE agreed that its investigation did not specifically document that potential phosgene contamination would not increase health consequences to workers. Nevertheless, DOE argued that explicit documentation was unwarranted because it was so obvious to those involved in the investigation that the existing safety management plan fully protected workers, and the investigation was written by technical experts for review and approval by technical experts. We disagree. Our expert panel, which consisted of nationally recognized technical experts on phosgene or nuclear material, was unable to independently draw the same conclusions as DOE because of the lack of explicit documentation in DOE's investigation regarding the effects on worker safety of potential phosgene contamination. In our view, this fact calls into question DOE's contention that it was "obvious" that the existing safety management plan fully protected workers.

Furthermore, we are concerned about the seemingly lax attitude portrayed in DOE's comments about the need for adequate documentation of important safety analyses. DOE asserted that the absence of explicit documentation of the analysis and results of its investigation does not jeopardize worker safety, just as the presence of explicit documentation would not ensure worker safety. Nevertheless, DOE's own standard for reviewing and approving safety documents states that hazards analyses should be both "clearly characterized" and "understandable."[14] Our expert panel found DOE's analyses to be neither clearly characterized nor understandable until DOE issued a February 2007 supplement to its original report. DOE stated in its comments that such a supplement would have been unnecessary had DOE officials been allowed to communicate directly with our expert panel. GAO's standards of evidence, however, require that the experts we rely on be independent and objective. To help ensure their independence and objectivity, the experts on our panel did not interact directly with DOE or UDS officials, but the experts did review information provided by those officials about the investigation's details. We worked closely with DOE and UDS officials to ensure that the information provided to the expert panel fairly, accurately, and sufficiently described the steps DOE and UDS had taken. We also disagree with DOE's

[14]Department of Energy, *DOE Standard: Review and Approval of Nuclear Facility Safety Basis Documents*, DOE-STD-1104-96, May 2002.

characterization of the February 2007 supplement as "simple." In fact, without it—that is, on the sole basis of the documentation from DOE and UDS's original investigation—our expert panel was not convinced of the adequacy of DOE and UDS's worker safety analyses. Thus we maintain that the information and analyses included in the February 2007 supplement should have been included in the original investigation report.

As our draft report noted, we and our expert panel agree that the assumptions DOE used in reaching its judgment on possible phosgene contamination turned out to be reasonable in this case. Nevertheless, the fact that DOE was fortunate this time does not reduce the need for future DOE hazards analyses to be adequately documented to sufficiently demonstrate that workers and the public will not be harmed by potential risks to their safety. In our view, by questioning the need for explicit documentation of its analyses, DOE is contending that those outside the department should believe DOE's conclusions on the basis of trust rather than on the basis of rigorous, scrupulously documented analyses. We feel that, given the potentially deadly results of a phosgene release, workers, the public, and Congress deserve better than simply being asked to take DOE's conclusions on faith.

Regarding DOE's independent review of the investigation, DOE stated in its comments that four high-level, technically qualified officials who had no direct connection to the investigation provided an independent review of its findings. DOE's argument, however, is misleading because two of these reviewers were also named on a list provided to us by DOE during our review as staff who provided input on the direction of the investigation and who were involved in reviewing and approving investigation plans. In our view, staff who have provided direction to an investigation are not sufficiently independent to provide an objective review of the quality or the results of that investigation.

Finally, regarding our finding that explicit information on the fate of phosgene in the uranium enrichment process was not included in DOE and UDS's investigation, DOE noted that uranium enrichment facilities are operated by USEC, which analyzed the fate of phosgene in the enrichment process and concluded that the gas would not survive. DOE stated that it was neither necessary nor appropriate for DOE to repeat USEC's assessment. Contrary to DOE's assertion, our draft report did not argue that DOE should duplicate USEC's analysis of the fate of phosgene in the enrichment process. Instead, we believe that DOE should have, at a minimum, noted in its investigation that USEC had performed such an analysis and summarized its results. We agree, and our draft report noted,

that the February 2007 supplement sufficiently documents the conclusion that phosgene would be destroyed in the enrichment process. Nonetheless, as with DOE's analysis of worker safety, we continue to believe that a supplement should not have been necessary at all, because the information and analyses explained in the February 2007 supplement should have been included in the original investigation report.

We are sending copies of this report to the Secretary of Energy. We will also make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or AloiseE@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix II.

Gene Aloise
Director, Natural Resources
and Environment

# Appendix I: Comments from the Department of Energy

**Department of Energy**
Washington, DC 20585
MAY 1 0 2007

Mr. Ryan Coles
Assistant Director
Government Accountability Office
441 G Street, NW
Washington, D. C. 20548

**GAO REPORT ENTITLED "DOE'S INVESTIGATION OF PHOSGENE GAS CONTAMINATION WAS INADEQUATE, BUT EXPERTS CONCLUDE THAT WORKER SAFETY AND FACILITIES ARE NOT THREATENED" – (Report GAO-07-712)**

Dear Mr. Coles:

The Department of Energy (DOE) agrees with the Government Accountability Office's (GAO) conclusions that neither workers nor the public would have been at risk by the possibility of small amounts of phosgene remaining in 30 inch cylinders that were previously used in Chemical Warfare Service. DOE takes exception to GAO's allegations of inadequacies and/or flaws in the DOE investigation. We are disappointed that you were not able to include more of our significant comments in the draft report.

There are three basic assertions in the Government Accountability Office draft report on the Department of Energy investigation of potentially contaminated storage cylinders that are incorrect, inaccurate, or misleading. The issues are summarized below and are addressed in greater detail in Sections 1 through 3 of Attachment 1.

Assessment of Worker Safety

In the initial sections of the draft report, GAO stated that DOE simply assumed that existing worker safety procedures were adequate to protect workers from any potential contamination. In fact, long before GAO began their review of this issue, DOE explicitly assessed the potential risk to workers using widely accepted chemical hazard measures and initial determinations of the maximum possible phosgene contamination. DOE concluded the possibility of phosgene in the absence of uranium hexafluoride increased the risk to workers and imposed

additional administrative controls. These controls included the immediate measures taken to isolate the suspect cylinders, restrict cylinder movements, minimize the operational events that have the potential to breach a suspect cylinder, minimize the number of personnel in the vicinity of a suspect cylinder and other administrative controls documented in the investigation report.

A timeline detailing the various analyses supporting the worker safety is provided as Attachment 2 of this response.

In the safety document "Justification for Continued Operations while Resolving the Potential Presence of Phosgene in Selected 30-inch Cylinders" (DUF6-G-JCO-001, November 30, 2005), DOE specified that "Personnel working in the cylinder storage yards containing the suspect cylinders will be trained to recognize actual or suspected off-nominal conditions and on evacuation and emergency notification procedures." This action was carried out. Workers were briefed when the initial concern was raised and provided routine status of the investigation. The JCO states that the UDS Safety Management Programs provide the necessary controls to safely address the potential phosgene issue, a conclusion based on an expert understanding of the relative risks of a small amount of phosgene (if present) in a large amount of uranium hexafluoride. For additional protection beyond the existing protection provided by the standard safety measures developed for activities around uranium hexafluoride, interim compensatory measures were implemented to further minimize the risks associated with the suspect cylinders. The appropriate response practices required were those already in place for existing hazards and this was understood by the workers. When cylinder sampling occurred, specific activities required by workers were reviewed with them (to obtain their input) and the final instructions were signed by all workers involved in the activities. These documents are part of the *Phosgene Characterization Study* reviewed by GAO.

The absence of explicit documentation of the calculations and reasoning leading to the DOE worker safety assessment in the *Phosgene Characterization Study* does not jeopardize worker safety just as the presence of explicit documentation of the assessment would not ensure worker safety. The GAO continues to assert that the DOE study did not explicitly address worker safety in spite of DOE providing a supplement to the study (see Attachment 3) that convinced the GAO expert panel that workers were not at risk.

The worker safety assessment, documented in supporting information provided to GAO, clearly demonstrated that the exceedingly low risk from potential phosgene contamination was overwhelmed by the risk of the much larger quantities of uranium hexafluoride. This early worker safety determination allowed DOE to focus its subsequent investigations on assessing the potential risk to the public in the event phosgene contamination actually existed. The GAO report states

*"...DOE and UDS issued a supplement to the original investigation report, which documented the assumptions, reasoning, and calculations used to reach the conclusion that existing safety procedures would protect workers from the possible presence of phosgene. All members of our expert panel agreed with the conclusions presented in the supplement."*

Independent Review

The GAO stated that the independent reviewers of the DOE study also supervised the investigation and thus were too familiar with the investigation to identify the alleged weaknesses identified by GAO. In fact, the DOE report was reviewed by at least four, high level, technically qualified DOE officials who had absolutely no role in supervision of the investigation.

The development and implementation of the investigation was strictly the responsibility of the DOE Portsmouth-Paducah Project Office and was supported by their contractors and DOE Oak Ridge where some of the suspect cylinders were located. The independent reviewers did not supervise or otherwise direct any aspects of the investigation. The GAO report states that

*"...DOE and UDS's analysis conclusively demonstrated that the public would not be harmed from any phosgene that could be present in uranium storage cylinders."*

Also, in the previous quotation above, the GAO report states that their expert panel agrees that the small amounts of possible phosgene contamination represent no increased risk to the health and safety of the workers under any circumstances. These conclusions of the GAO expert panel suggest that independent review of the *Phosgene Characterization Study* did not fail to identify significant flaws.

Phosgene Fate in Enrichment Facilities

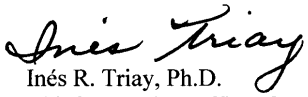
GAO stated in their draft report that the DOE assumed but did not explicitly document that any phosgene introduced into the uranium enrichment process would be destroyed. In fact, the enrichment facilities are operated by a commercial firm, the United States Enrichment Corporation (USEC). The management alert on potential phosgene contamination was promptly forwarded to USEC. They conducted an analysis of the potential consequences for their operations and concluded that there are none. In response to the GAO assertion that explicit information on the fate of phosgene should be included in the *Phosgene Characterization Study* for the convenience of their expert panel, DOE provided a supplement addressing the topic. The supplement is provided as Attachment 3 of this response.

DOE, based on the experience and knowledge of their own experts, agreed with the USEC determination and that it was neither necessary nor appropriate to repeat the USEC assessment of the fate of hypothetical phosgene in enrichment facilities. The GAO and their expert panel also agreed with the USEC conclusions and the GAO report states that

> *"…phosgene, if introduced into the uranium enrichment process, would have reacted with other chemicals in the process and been destroyed, or it would have been purged from the process with other waste gases."*

Please be assured, our first commitment is to the health and safety of our workers and the public.

Sincerely,



Inés R. Triay, Ph.D.
Chief Operating Officer for
Environmental Management

Attachments

cc:
W. Murphie, PPPO/LEX
J. Zimmerman, PPPO/LEX
R. Holland, EM CBC
J. Craig, EM CBC
T. Brown, MA-62

**Attachment 1**

## Response to the GAO Review of the DOE Investigation of Potential Phosgene Contamination

### 1. Assessment of Worker Safety

In its report, the GAO stated that "*DOE and UDS assumed, without explicitly documenting, that existing worker safety procedures were adequate to protect workers from the possible presence of phosgene*" (emphasis added). This is not correct. DOE and UDS declared, in the positive Unresolved Safety Question (USQ) issued on November 8, 2005, that the presence of phosgene could increase risk of health consequences to both workers and the public. This was stated again in the Justification for Continued Operations (JCO), dated January 5, 2006 in which additional controls were established on cylinder yard operations to further reduce the risk to workers and the public. Both of these documents were provided to GAO during their review.

These controls remained in place until:

- DOE and UDS demonstrated that 1.2 grams of phosgene would not result in increased health consequences to a member of the public.
- DOE and UDS determined that the existing safety management program was sufficient to protect workers if no more than 1.2 grams of phosgene were present in individual 30 inch cylinders.
- Criteria were developed for demonstrating that cylinders could contain no more than 1.2 grams of phosgene.
- The characterization of all 30 inch cylinders was completed in accordance with the criteria established above.
- Cylinders that could not be cleared based on cylinder records were sampled to verify that phosgene was not present at a level above 1.2 grams.

Although the final report did not specifically document that 1.2 grams would not increase health consequences to workers, the data contained in the calculations provided to GAO on April 19, 2006 show that the ratio of phosgene to uranium hexafluoride vapor in the cylinder head space is almost two orders of magnitude below the ratio required to cause increased health consequences to workers.

The GAO report repeatedly makes the assertion that undocumented conclusions are assumptions. This is not correct. GAO concluded that it was not until February 2007, after the matter was brought to the attention of DOE by the GAO, that DOE adequately demonstrated that there would be no increased health consequences for workers. In reality, the fact that the existing safety management plan fully protected workers from small quantities of phosgene was so obvious to those involved in the investigation, including the independent technical reviewers, that explicit documentation in the *Phosgene Characterization Study* was unwarranted.

**Attachment 1**

The GAO asserted that because the DOE did not explicitly document its analysis of safety risk to workers in the *Phosgene Characterization Study* that the investigation was flawed. In fact, explicit documentation in the study was not deemed necessary by the authors or reviewers that approved the report. DOE repeatedly reminded GAO during their investigation that the study in response to the DOE Inspector General management alert was written by technical experts for review and approval by technical experts.

The GAO report makes statements such as "*DOE and UDS officials...decided that workers would not be harmed by the possible presence of small amounts of phosgene.*" or "*they reasoned that since this procedure was sufficient...*" In point of fact, the ERPG levels for phosgene, hydrogen fluoride, and uranium hexafluoride that were used to "decide or reason" are established by the American Industrial Hygiene Association and are considered consensus standards throughout the country. DOE takes exception to the implication that DOE's conclusions were based on anything less than valid data and quantitative analyses.

The GAO investigation process prohibited direct communication between their panel of experts and the personnel performing the DOE phosgene investigation. DOE and UDS believe that the questions related to assessment of worker safety could have been resolved with GAO's panel of experts if direct communication had been allowed. Evidence to support this belief is presented by the fact that a simple supplement to the original report was all that was necessary to convince GAO's expert panel that workers would not be affected by the presence of 1.2 grams of phosgene in a 30 inch cylinder containing uranium hexafluoride.

**2. Independent Review**

GAO asserts in their report that the DOE review of the phosgene investigation may not have been sufficiently independent. DOE considers this claim is without merit and reflects a misunderstanding of the DOE review process.

The DOE study was authored by UDS, a DOE prime contractor. Before submitting the report to DOE it was reviewed by UDS management as well as a technical expert from Areva (a UDS member company). This technical expert was not affiliated with the project in any way. When the final draft study was submitted to DOE it was first reviewed by the DOE Federal project director and DOE Portsmouth-Paducah Project Office staff. Following local review, the report was reviewed by the EM Chief Operating Officer, Deputy Assistant Secretary for Safety Management and Operations and the Chief of Nuclear Safety (Office of the Undersecretary of Energy). In total, at least 3 different reviews were conducted by persons who had no direct connection to the $DUF_6$ project. None of the reviewers beyond the local level supervised the phosgene investigation as stated by GAO.

**Attachment 1**

**3. Phosgene Fate in Enrichment Facilities**

The GAO asserted that, "*DOE and UDS assumed but did not explicitly document that any phosgene introduced into the uranium enrichment process would be destroyed*". Uranium enrichment activities in the US are carried out by the United States Enrichment Corporation (USEC), a publicly traded company. Both UDS and DOE notified USEC management of the IG Alert when it was received. USEC officials conducted their own internal investigation into possible consequences of phosgene in $UF_6$ cylinders and concluded (correctly) that there were no consequences to their operations or potential health consequences to their workers or the public. UDS and DOE personnel are familiar with the operating principles of the enrichment plants including, in some cases, the classified aspects of the process and with that knowledge agreed with the USEC conclusions. DOE and UDS disagree that it was necessary or appropriate for DOE to repeat the assessment of USEC to validate a conclusion that they find entirely consistent with their knowledge of the enrichment process.

**Attachment 2**

**Timeline for DOE Activities Performed to Assess and Effect Worker Safety due to the Potential Presence of Unknown Quantities of Phosgene in $UF_6$ Storage Cylinders**

Documentation of the activities described in the following timeline was provided to the GAO investigators during their site visit or as part of DUF6-G-RGN-008, *Phosgene Characterization Study*.

**September 30, 2005**

Department of Energy Office of the Inspector General issued the management alert that identified the potential for the presence of phosgene in 30-inch $UF_6$ cylinders. This report was received on October 3, 2005.

**October 5, 2005**

Cylinder Yard crew was briefed.

The daily order and end-of-day briefing in the narrative logbooks for cylinder yard supervisors dated October 5, 2005 document that the phosgene issue was discussed with the cylinder yard crews.

Per procedure, UDS-GFP-001, *Portsmouth Cylinder Yard Management*, and UDS-GFP-002, *Paducah Cylinder Yard Management*, the cylinder yard supervisor maintains a narrative logbook for the purpose of process control and event reconstruction. At a minimum, the narrative logbook contains entries for the following:

- Changes in cylinder storage area operating mode or condition (shutdown due to weather, equipment failure, etc.).
- Force report (personnel reporting for work each shift).
- Record of general $UF_6$ cylinder related activities such as number of cylinder inspections, relocations, as-found and as-left conditions, and maintenance activities performed. This record supplements the cylinder information database (CID) record but does not replace any CID entry requirements.
- Yard maintenance performed.
- Status changes in safety-related or important equipment.
- Occurrences of reportable events.
- Actions that breach operational safety limits.
- Security incidents.
- Out-of-specification process results.
- Shift relief.
- Personnel changes.
- Illness or injuries occurring during the shift.
- Training activities.

**Attachment 2**

The logbooks provide a documented record of the phosgene issue and implementation of immediate actions. These forms of communication are required by DOE Order 5480.19, *Conduct of Operations Requirements for DOE Facilities.* Documentation of the daily orders was provided in Attachment F of DUF6-G-RGN-008, *Phosgene Characterization Study.*

**October 6, 2005**

UDS issued an Occurrence Reporting and Processing System (ORPS) report and notifications were made.

The ORPS report EM-PPPO-UDS-PORTDUCON-2005-0003, *Management concern involving storage of Uranium Hexafluoride ($UF_6$) Cylinders*, was issued to inform management of the issue and to track progress on resolution of the issue. The ORPS report noted that all work on the 30A cylinders was suspended and that ETTP (Bechtel-Jacobs Corporation) and UDS had initiated the Unreviewed Safety Question (USQ) process with a Potential Inadequacy in the Safety Analysis (PISA).

**October 7, 2005**,

As part of Daily Order 06-0004, the cylinder yard manager provided a briefing that included a presentation consisting of the following:

- photographs of the $UF_6$ service modification performed on the cylinders, obtained from the U.S. Army Chemical Warfare Service to allow workers to identify the potential variations,
- data indicating the presence of phosgene,
- immediate actions which included suspending work on 30A cylinders,
- future actions,
- preliminary findings in the investigation, and
- Material Safety Data Sheets for phosgene.

In addition, the daily orders noted the development of a phosgene binder. The binder was located in the break room used by the cylinder yard crew. Any existing information and all updates to the investigation were placed in the binder for any of the workers to read. Documentation of the daily orders was provided in Attachment F of DUF6-G-RGN-008, *Phosgene Characterization Study.*

**November 8, 2005**

UDS issued a positive Unreviewed Safety Question Determination (USQD) identifying a PISA in both the Paducah and Portsmouth cylinder yards. At the time of preparation of the USQD, cylinder records and other information had not yet been collected and fully reviewed to demonstrate that the maximum quantity of theoretical phosgene in the cleared cylinders did not exceed the 1.2 grams found to present no significant hazard to the public or workers.

**Attachment 2**

The USQD was positive for three determination questions.

1) The potential presence of phosgene increased the consequences of an accident previously evaluated in the existing safety basis.

The basis as revised to account for the phosgene USQD notes that during a cold cylinder breach:

"*The site facility worker is protected by SMPs [Safety Management Programs] and the risk is not evaluated against ERPG [Emergency Response Planning Guidelines] limits. The credited control for the site worker is 'see and flee'. This control is based on the 'white smoke' produced by the reaction of $UF_6$ and moisture in the air to produce HF and $UO_2F_2$. While in a cold cylinder breach, the quantity of white smoke is much less than that of a liquid cylinder breach, nevertheless, the reaction can be visibly seen. The odor threshold for HF is 0.04 ppm while that of phosgene ranges from 0.4 to 1.5 ppm depending upon the sensitivity of the worker. Phosgene has a distinctive odor similar to that of fresh mown hay or moldy hay. In the event where phosgene and $UF_6$ are both present in the cylinder, 'see and flee' is still a viable control since the worker will see the white smoke.*

*In the case of the seven* [sic] *unmodified cylinders at Portsmouth, workers can be trained to recognize the smell of phosgene, however, since the odor threshold is above the permissible exposure limit, training the workers to recognize the smell of phosgene is not adequate. Based on current industry practices, it is likely that the worker will smell the phosgene and be able to flee, and it is probable that the worker will flee and have health damage due to the exposure prior to odor threshold; however, the exposure does not necessarily result in a fatality. Therefore, the presence of phosgene does not change the 'see and flee' control, however, additional training is required for the worker to identify the odor of phosgene as an additional measure to the visible white smoke and HF odor and additional protective measures such as alarms are required to adequately protect the worker and allow for emergency response, thus, protecting the public."*

Therefore, the effect of phosgene on the cylinder yard workers and the hypothetical on-site worker was evaluated and additional controls and training were deemed necessary to protect the workers when performing work associated with the 30A cylinders.

2) The PISA concluded there were higher consequences from a malfunction of the cylinder wall.

The basis as revised to account for the phosgene USQD notes the following:

"*The cylinder wall is [a] designated design feature in both the Portsmouth and Paducah cylinder yard DSAs [Documented Safety Analyses]. If the cylinder wall*

**Attachment 2**

*were to malfunction and fail, the resulting breach would be equivalent to a cold breached cylinder event. By applying the air modeling data provided in the attachment, the ERPG-3 limit is exceeded for both the hypothetical on-site worker and the public.*

*If the cylinder wall were breached as a malfunction, the consequences to the facility worker, on-site worker, and public would increase due to the effects of phosgene in the air."*

Therefore, the effect of phosgene during a cylinder wall failure was evaluated for the facility worker and determined that additional controls would be required to protect the facility worker, on-site worker, and public. Again, this determination was made prior to collecting and reviewing cylinder records and other information to demonstrate that the maximum quantity of theoretical phosgene in the cleared cylinders did not exceed the 1.2 grams found to present no significant hazard to the public or workers.

3) The potential presence of phosgene reduced the margin of safety.

The basis as revised to account for the phosgene USQ notes the following:

"*The Paducah and Portsmouth cylinder yard DSAs do not have specific measured parameters that can be associated with the effect due to phosgene in the cylinders. However, the potential presence of phosgene increases the consequences to the worker during a majority of the event scenarios listed in the site DSAs. Due to the significant impact to the worker, on-site worker and the public, the margin of safety has been reduced due to the potential presence of phosgene.*"

Therefore, the effect of phosgene was evaluated for the facility worker and determined to increase the consequences to the facility worker during the accident scenarios deemed possible in the approved documented safety analysis and hazard analysis for the cylinder yards. (Subsequent analyses demonstrated that cleared cylinders would not exceed the 1.2 grams of theoretical phosgene found to present no significant hazard to the public or workers. The small number of cylinders that did not satisfy the clearing criteria were sampled and found to contain no detectible phosgene.)

Overall, the USQD documented the results of the investigation and clearly shows that UDS and DOE considered the facility worker, on-site worker, and the public during the evaluation. Since the USQD was positive, UDS and DOE determined that additional controls were necessary to provide sufficient protection to the facility worker if phosgene was found in a cylinder. A record of the approved USQ-019, *Potential Presence of Phosgene in 30-inch $UF_6$ Cylinders*, was provided to the GAO for inclusion in their investigation.

**Attachment 2**

**November 28, 2005**

The cylinder yard manager issued a standing order, FY 06-02, documenting the following items relative to the 30A cylinders:

- No vehicles are permitted on the cylinder yard.
- No maintenance or movement of 30A model cylinders is permitted unless directed by facility manager.
- No radiological surveys of 30A model cylinders are permitted unless directed by the facility manager.
- Entrance into the cylinder yard or any activities is with the explicit permission of the facility manager.

The standing order was initialed by the cylinder yard crew documenting that they had been provided this information.

Documentation of the standing orders was provided in Attachment F of DUF6-G-RGN-008, *Phosgene Characterization Study.*

**December 19, 2005**

DOE approved DUF6-G-JCO-001, *Justification for Continued Operations in the Paducah and Portsmouth $UF_6$ Cylinder Storage Yards While Resolving the Potential Presence of Phosgene in Selected 30-inch Cylinders.* This Justification for Continued Operations (JCO) documents the hazard analysis results from the DOE and UDS analysis of the postulated accidents scenarios.

The JCO states the following:

*"The existing UDS SMPs provide the necessary controls to safely address the potential phosgene issue. Additional administrative controls have been implemented based on the specific cylinder surveillance and maintenance program activity to be performed and the potential cold breach accidents."*

The potential presence of phosgene did not result in any new design basis accidents from those in the Documented Safety Analysis. It was determined that the procedures supporting the existing Safety Management Program were adequate for safely managing the potential presence of phosgene. However, based on the hazard analysis of the design basis accidents, additional compensatory measures were implemented to provide protection beyond the current procedures.

All facility workers were briefed to the JCO and the interim compensatory measures. Documentation of the briefings was provided in Attachment F and G of DUF6-G-RGN-008, *Phosgene Characterization Study.*

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**January 11, 2006**

DOE approved the revised JCO which was updated to include sampling activities. All facility workers were briefed on the changes. The final JCO was provided as Attachment E of DUF6-G-RGN-008, *Phosgene Characterization Study.*

UDS approved the work package to begin sampling the suspect cylinders at Portsmouth. Facility workers were briefed on the work flow and instructions, activity hazard analysis, radiological work permits, implementation of the JCO, and equipment to be used. In addition, facility workers were provided with Material Safety Data Sheets for all chemicals used in the sampling activity. The complete work package was provided as Attachment F of DUF6-G-RGN-008, *Phosgene Characterization Study.*

**January 12, 2006**

Sampling activities were started and completed at the Portsmouth facility. No phosgene was detected in the cylinders. Activities are noted in the Portsmouth sampling work package number WA-PO-06-0001, *Perform Sampling of 10 Cylinders (2.5-ton 30 inch) Suspected of Containing Phosgene*, which was provided as Attachment F of DUF6-G-RGN-008, *Phosgene Characterization Study.*

**January 26, 2006**

UDS approved the work package to begin sampling the suspect cylinders at Paducah. Facility workers were briefed on work flow and instructions, operation of the equipment to be used, implementation of the JCO, activity hazard analysis, and radiological work permit. Documentation of the facility worker briefing was provided in Attachment G of DUF6-G-RGN-008, *Phosgene Characterization Study.*

Sampling activities were initiated.

**February 6, 2006**

Paducah cylinder yard operations completed sampling activities. No phosgene was detected in the cylinders. Activities are noted in the Paducah sampling work package number WA-PA-06-0001, *Sampling of Suspect 30-inch Diameter Cylinders for Phosgene at Paducah*, which was provided as Attachment G of DUF6-G-RGN-008, *Phosgene Characterization Study.*

# Appendix II: GAO Contact and Staff Acknowledgments

## GAO Contact

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## Staff Acknowledgments

In addition to the individual named above, William R. Swick, Assistant Director; James Ashley; Ellen W. Chu; Ryan T. Coles; Doreen Feldman; Cindy Gilbert; Cynthia Grant; George Hinman; Wyatt R. Hundrup; Alison O'Neill; Laina Poon; Keith Rhodes; Sushil Sharma; and John Stradling made key contributions to this report. Also contributing to the report was Jena Sinkfield.

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