SPECIAL FEATURES OF NUCLEAR WASTE REPOSITORY VENTILATION SYSTEM VIS-A-VIS EXPERIENCES AT THE WASTE ISOLATION PILOT PLANT*

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ABSTRACT

The paper presents an analysis and discussion of the underground ventilation system at the Waste Isolation Pilot Plant (WIPP). Particular emphasis is placed on specific repository-related requirements and the gradual evolution of engineering designs relative to the WIPP Project scope.

Because the WIPP Project is a research pilot project and the first of its type in combining mining and nuclear technologies, it is accumulating data and experience that may be fruitfully applied in planning the future designs of ventilation systems for new commercial nuclear waste repositories.

The ventilation system for a nuclear waste facility similar to WIPP is designed to provide a suitable environment for personnel and equipment during normal activities. It is also designed to provide confinement and channeling of potential airborne radioactive material in the event of an accidental release.

It is desirable to identify and design all parallel activities and the required process equipment prior to completion of the repository mine final design. Such factors as ventilation requirements, drift sizes, bulkhead sizes, and placement are dependent on these items. Mine creep closure properties must be factored into the mine and ventilation equipment design considerations. Effects of natural ventilation pressures deserve due consideration in the design.

Mine ventilation requirements are dominated by the diesel equipment to be operated in the underground horizon. To minimize ventilation requirements, it is desirable to select electrically operated equipment.

WIPP engineers have also found it extremely desirable to have automated real-time monitoring and control for the underground ventilation air. Final testing and balancing of the ventilation system is an extremely important startup requirement. For a successful repository operation, this step must be repeated at regular intervals or whenever any major modifications are made.

INTRODUCTION

The underground repository at WIPP is being developed in a thick salt bed 665 meters below the surface. The ventilation system for this facility is designed to provide a suitable environment for personnel and equipment during normal activities. It is also designed to provide confinement and channeling of potential airborne radioactive material in the event of an accidental release or fumes from an underground fire.

The ventilation system at WIPP was originally designed and constructed for the performance of various activities as then envisaged. However, based on new information and requirements and actual site-specific experience, the ventilation needs were reassessed and the design modified. A fourth shaft called the Air Intake Shaft (AIS) was constructed and a set of two new main fans installed. (1).

A general description of the modified ventilation system is provided in the following paragraphs. (2).

WIPP VENTILATION SYSTEM

Surface Facilities

Waste Handling Building: The Waste Handling Building is located in the radioactive materials area of the plant and is separated from the Waste Shaft through a set of doors to allow for eventual transport of waste underground. The primary function of this building and its associated systems is the safe and efficient receipt and transfer of defense transuranic (TRU) waste from the incoming transporters to the underground storage areas through the Waste Shaft located beneath the building. The Waste Handling Building is divided into three functional areas: 1) Contact-handled (CH) TRU waste handling area; 2) remote-handled (RH) waste handling area; and 3) the support areas.

The Waste Handling Building Ventilation requires maintenance of negative pressures relative to the atmosphere to prevent any radioactive release to the environment.

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Exhaust Filter Building: The Exhaust Filter Building is located within the radioactive materials area of the site and adjacent to the exhaust shaft. The primary function of this building is to house the filtration equipment associated with the underground ventilation system. Under normal conditions, the exhaust fans draw air from underground areas up the exhaust shaft. This exhaust air is discharged through an exhaust stack that disperses the air into the atmosphere. During normal operation, there is no measurable radiological contamination in this air stream, and the filtration units are bypassed. In the event of an underground radiological accident, airflow to the underground is reduced and is diverted through the filtration units located in this building in order to remove airborne radioactive particulates from the air stream.

The Exhaust Filter Building is classified as a Design Class II facility and designed in accordance with Uniform Building Code (UBC)[2] requirements. The design of the building incorporates impermeable surfaces to facilitate decontamination.

The major areas within the Exhaust Filter Building are the filter room and the mechanical equipment room. The filter room houses the high efficiency particulate air (HEPA) filtration units. The underground ventilation exhaust fans, which move air up the exhaust shaft and out through the exhaust stack, are located outdoors.

Provisions are made for effluent monitoring and sampling. A short stack is provided to elevate the vertical exhaust discharge above-ground level to ensure that workers are not exposed to undiluted exhaust ventilation.

Shafts: The WIPP underground facility is serviced by four shafts--the AIS, the Salt Handling (SH) Shaft, the Waste Shaft, and the Exhaust Shaft. The AIS and the SH Shaft are the primary intake and the Exhaust Shaft the combined return.

The Waste Shaft (to be used for lowering of the waste material to be stored underground), is basically neutral with a small quantity of air downcasting through it. All these shafts are approximately 655 meters in depth. The SH shaft is used for men and material transport and for hoisting mined salt.

Underground Facilities

The underground facility is divided into three major areas. The north end of the facility is the experimental area. It contains design validation test rooms and Sandia National Laboratory's technology experiment areas. The central area is called the shaft pillar area. This area has a restricted number of entries and crosscuts to prevent the adverse effects that a large volume of mining would produce on the stability of the shafts. This portion of the facility contains mostly shops and personnel areas. The southern portion of the facility will be the storage area. This is the area where the TRU waste will be emplaced. Limited mining has been accomplished in this area, with development of Panel 1 having been completed.

Ventilation System Description

Surface arrangements of the ventilation system consist of the exhaust shaft plenum, five centrifugal fans set in parallel, two identical filter assemblies (each with 50 percent of filtered mode airflow capacity) also arranged in parallel, isolation dampers, filter bypass arrangement, air monitoring instrumentation, and associated ductwork.

Normal Mode: This exhaust system provides continuous ventilation of the underground areas during normal operation. Fresh air for storage, construction, and experimental areas is brought down the AIS, and the SH shaft. The air is split two ways--north and south--with the north split ventilating the experimental area and the south split providing ventilation to the mining and waste storage areas (Reference Fig. 1). The south side air is once again split at S1000 and W30 junction so as to provide independent airflows to the construction and storage areas. Air separation between the construction and storage sides is maintained throughout the underground facilities up to the common Exhaust Shaft. A pressure differential is established between the two sides so that air leakages always take place from the construction side to the storage side.

The Waste Shaft is basically a neutral shaft, required mainly for lowering the waste material underground for storage. Fresh air is induced down the Waste Shaft primarily offsetting natural updraft convection currents, minimizing the potential of any radioactive particles escaping up the shaft, and providing ventilation for the shaft station area. This air is immediately routed to the Exhaust Shaft, and is not used for ventilating any area underground other than the shaft station area. Ventilation air from all underground areas is exhausted through the upcast Exhaust Shaft connected to the surface fans. During normal plant operations, no airborne radioactive contamination is expected, and if the levels remain below the setpoints of the exhaust radiation monitoring system, exhaust is not filtered.

Filtration Mode: The filtration mode is activated automatically on detection of concentrations higher than a preset value of airborne radioactive particulates by the radiation monitoring system. The filtered exhaust air passes through two identical filter assemblies with one of three Exhaust Filter Building centrifugal fans operating (Reference Fig. 2). All other fans shut down automatically. This system provides a means for removing the airborne radioactive contaminants in the reduced exhaust flow before they are discharged through the exhaust stack to the atmosphere.

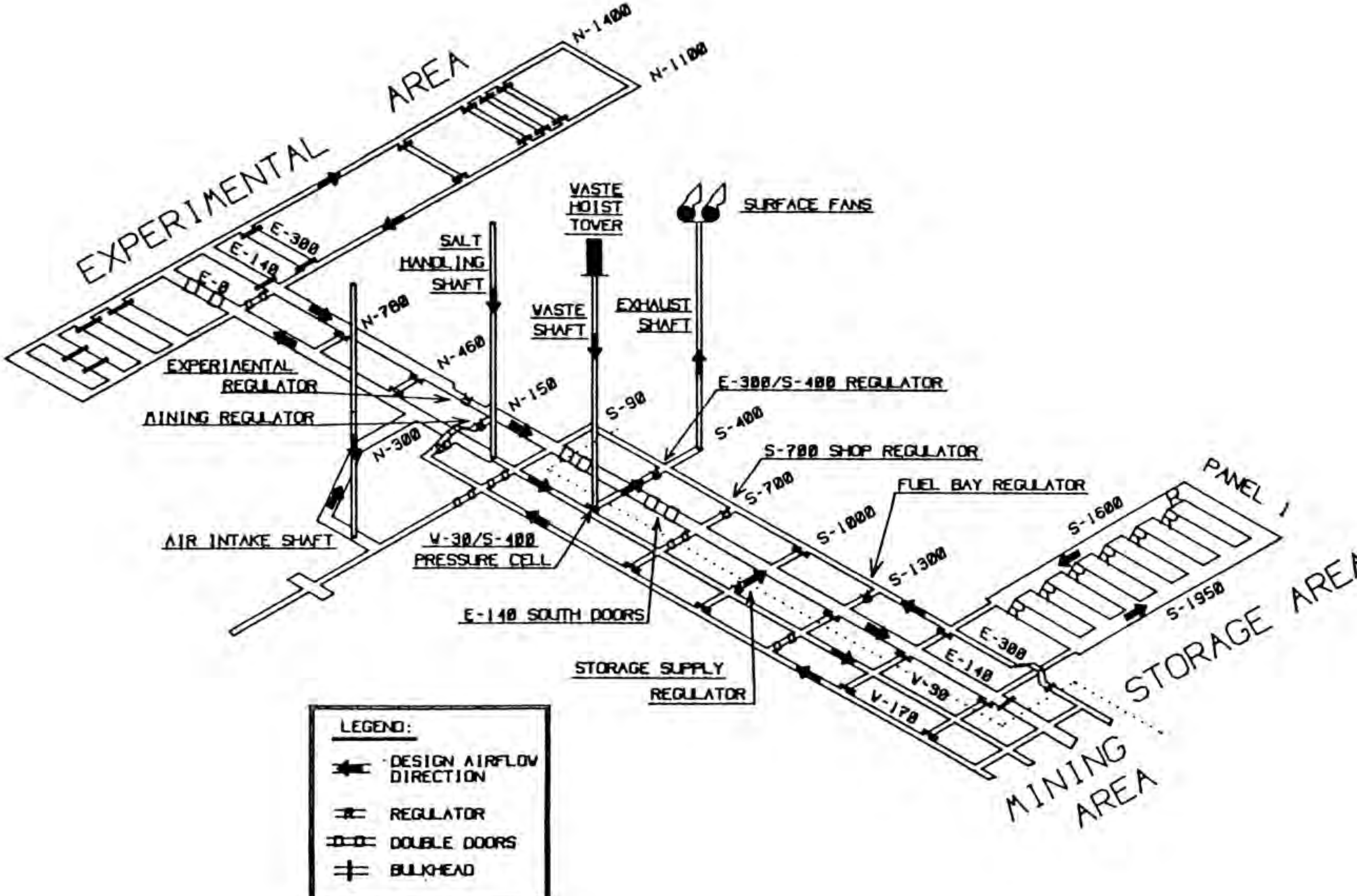

Fig. 1. WIPP facility layout (not to scale).

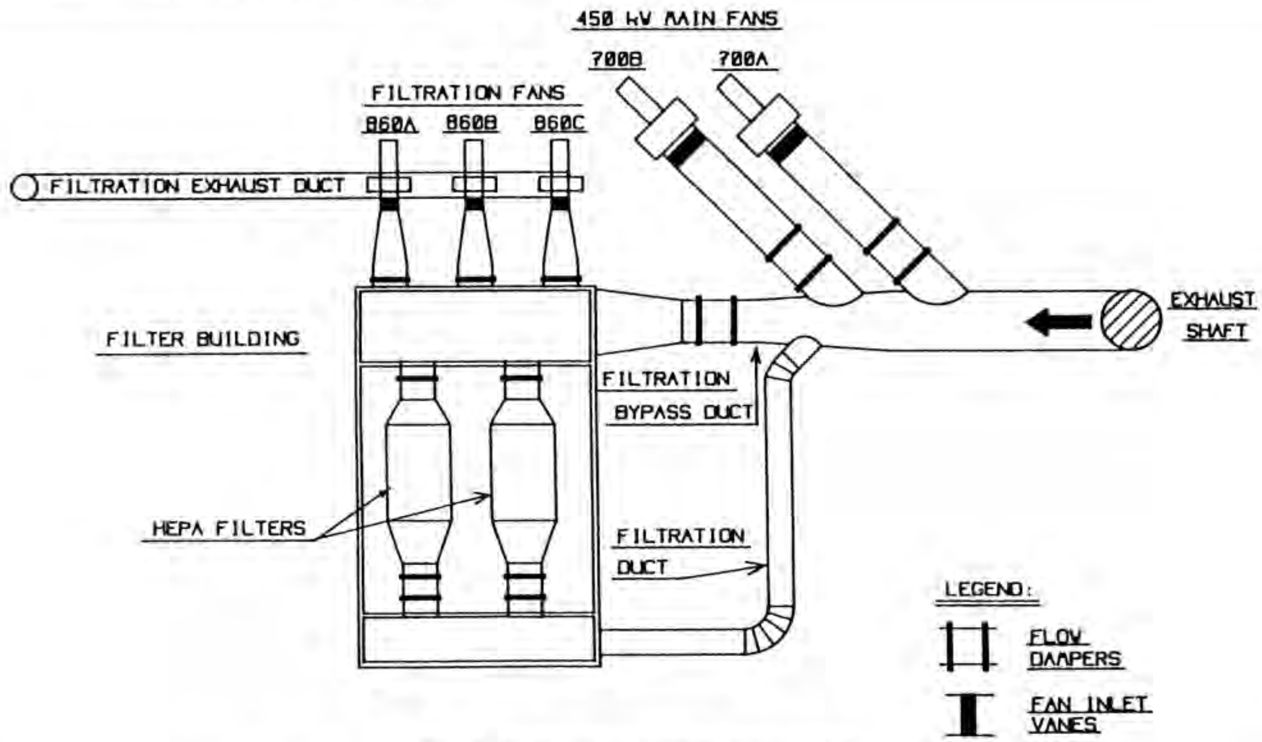

Fig. 2. Surface fan and filtration system.

The reduced exhaust flow is diverted to the HEPA filters by isolation and diversion dampers on the exhaust fans and ductwork. Unfiltered exhaust flow is therefore prevented from escaping to the atmosphere.

One fan is capable of delivering the design flow rate with all filters at their maximum anticipated pressure drop. Fan failure is monitored by a flow-sensing device at the discharge side with an alarm in the central monitoring station (CMS).

Emergency or Fire Mode: Acquainting underground personnel with the ventilation system and where to go to get to fresh air in case of an emergency is a vital part of the training program at WIPP. Hence, the general rule followed at WIPP during fires or other emergencies will be never to change the ventilation unless considered absolutely necessary to save lives.

Though the chances of reversing air at WIPP may appear to be rather remote, air reversal capability in all areas of the mine, except the waste storage areas, has been incorporated in the ventilation system design.

The air is reversed by opening and closing certain ventilation doors and regulators and, in some cases, reversing the underground booster fans.

SPECIAL FEATURES OF REPOSITORY VENTILATION

The WIPP ventilation system clearly indicates certain features which are unique to a repository, when compared to normal underground mining operations. These include:

- The waste shaft is maintained as a down-cast to prevent any potential radioactive contamination from underground from being released through the waste shaft.
- Independent air circuits for waste storage and non-storage areas are provided. Total separation needs to be maintained between them, to prevent any contamination of the non-storage areas in case of accidental release.
- A higher pressure on the construction side is provided to prevent leakage of potentially radioactive contaminated air from storage side.
- The Exhaust Filter Building is provided with redundant HEPA filtration systems to prevent radioactive releases to the atmosphere beyond acceptable limits. Centrifugal fans are used to maintain constant ventilation quantities under changing total mine ventilation pressures due to particulate plugging of HEPA filter.
- The ventilation system performs under three modes of operation. This includes: the normal mode; the filtration mode, when the exhaust air is filtered

through a HEPA filtration system; and the emergency or ventilation reversal mode.

- Automatic and manual controls are provided for activating the HEPA exhaust filtration system.
- Air monitoring system needs to be very accurate and sophisticated.
- Increased levels of automation are required for monitoring and controlling airflows underground from the surface CMS.
- Air reversal is not desirable in the waste storage areas. In fact, air reversal should be avoided in all areas to prevent the potential of spreading radioactive contamination.

LESSONS LEARNED AT WIPP

The different phases of development of the WIPP Project have provided very useful experiences.

A basic lesson learned at WIPP is that the waste handling methodology and equipment design should be established early, before the mine design is firmly established. Such criteria as drift size, bulkhead size and placement, ventilation requirements, storage room size, and intersection sizes are very dependent on handling equipment size and operation. Ventilation requirements are greatly dependent on whether the equipment is diesel-operated or electrically powered. All equipment and processes to be run concurrently must be established early in the design stage to adequately size the supply and exhaust shafts and ventilation equipment.

The creep-closure property of salt represents a major design consideration to the mine and equipment engineers. The WIPP salt is gradually closing at an approximate rate of two to three inches per year. Bulkheads and other ventilation structures need to be designed to accommodate this drift-closure.

Doors should be hung so the usable opening of the door is not lessened by the door and hinges. Bulkhead and all facility door widths and heights should be specified as actual clear openings (not nominal size openings), so there is no mistaking the clear, usable opening available.

Bulkheads must be wide enough to allow the equipment to pass easily. A minimum of 12 inches of clearance on each side of the machine or carried load is suggested.

In most modern underground mining applications, the impact of natural ventilation pressure (NVP) is rarely a concern. In fact, many mines ignore the effect and simply notice variations in airflow during different times of the year. However, at the WIPP site, it was observed that large NVPs could cause potential problems of pressure differential and airflow direction requirements through parts of the facility. To mitigate these problems, structures were engineered and installed and alternative system configurations were implemented. (3).

Cost considerations and a general lack of detailed information, led the engineers to design the WIPP as a three-shaft facility. A reassessment based on the type and size of equipment required to perform the various activities, later established the need for another ventilation shaft. It is, however, desirable to have at least five shafts at a nuclear waste repository so as to provide totally independent air intakes and air returns for the mining and waste storage areas. This will also permit a push-pull system of ventilation--with forcing fans installed in the mining air circuit and exhaust fans at the waste exhaust shaft.

There is a high cost involved in maintaining the neutrality of the waste shaft. Though it is a large shaft, the current design does not allow it to be used for ventilation purposes, thereby necessitating the construction of an additional shaft. Innovative design or safety risk reevaluations could resolve this conflict and reduce facility construction costs.

Extensive use of diesel equipment at WIPP has led to substantially higher air requirements underground. Use and development of more electrically powered equipment should be considered.

The requirement for independent parallel ventilation circuits in the underground facility significantly increases total underground ventilation quantities over normal series ventilated mining conditions.

Air reversibility greatly upsets the airflow and pressure differential balance with a potential of spreading radioactive contamination to other parts of the repository.

The underground ventilation system must be tested and balanced periodically, and also whenever any major modifications are made.

CONCLUSIONS

Experience at WIPP has shown that the repository design and operation requires recognition of the characteristics and needs of both the nuclear and mining industries. It is desirable to identify and design all parallel activities and required process equipment prior to completion of the repository mine final design. Such factors as ventilation requirements, drift sizes, bulkhead sizes and placement are dependent on these items. Mine creep closure properties must be factored into the mine and ventilation equipment design considerations.

Mine ventilation requirements are dominated by the diesel equipment to be operated in the underground horizon. It is desirable to select electrically operated equipment, whenever practical, to minimize ventilation requirements.

Provisions for additional air should be made in the estimated ventilation requirements at the design stage to accommodate evolution of unforeseen activities as construction proceeds.

WIPP engineers have also found it extremely desirable to have automated real-time monitoring and control for the underground ventilation air. The items monitored and controlled are air quality and quantity in any given area. This ability is particularly important if ventilation air must be routinely redirected to meet process needs.

WIPP is in a startup mode at the present time. Systems are being checked out for proper operation. Many lessons are being learned in starting the nation's first repository site. Some seem elementary, yet can be easily neglected in the complex process of designing and building the facility. Attention to design details such as airflow pattern, bulkhead and overcast designs incorporating drift closures, door sizes, remote air monitoring and control from the surface CMS, maintenance of pressure differentials and impact of natural ventilation pressures on the system during varying weather conditions are crucial to a successful repository operation.

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REFERENCES

1. S. C. SETHI, "Modification of Ventilation System at WIPP" - 3rd Mine Ventilation Symposium, (1987).
2. S. C. SETHI, and R. T. DILLON, "Special Features of WIPP Underground Ventilation System" - SME Annual Meeting, (1988).
3. D. J. BRUNNER, K. G. WALLACE, and J. B. DEEN, "The Effects of Natural Ventilation Pressure on the Underground Ventilation System At the Waste Isolation Pilot Plant" - 5th U.S. Mine Ventilation Symposium, (1991).