ABSTRACT: This paper describes an on-going study at the Waste Isolation Pilot Plant (WIPP) to integrate underground airflow, differential pressure, primary fan information, and psychometric monitors with a ventilation software model. WIPP is the first nuclear waste repository in the United States. It is designed to safely dispose of the nation’s defence related transuranic radioactive waste. The ventilation software, called WIPPVENT, is based on the commercially available package VnetPC developed by Mine Ventilation Services, Inc. The WIPPVENT package has been upgraded to read in real-time sensor data into a ventilation model of the underground facility. The software operator may elect to use the data obtained from the sensors or modify the data as necessary to be used in the model. The program also allows the user to average the input readings over a selected timeframe. The program uses the input data to calculate natural ventilation pressures, airflow and differential pressures through strategic underground ventilation controls and regulators (which may be used to calculate the regulator resistance). The regulator resistance is compared to an established “regulator resistance curve”. In this way, the operator can adjust a regulator in the model and determine an actual setting (in percent open) that the regulator needs to be at for a desired airflow. The software has been written to allow for new sensors and regulators to be easily added in the facility. In addition, sensor data is checked for reasonableness with the user identifying the range for each sensor. An example data input is presented.

1 Introduction

The Waste Isolation Pilot Plant (WIPP) facility is an underground repository in a bedded salt deposit located in New Mexico approximately 660 meters (m) below surface. The authors have performed a program of testing and balancing the ventilation system at this facility since 1988. Components of the ventilation system were re-engineered by the authors to mitigate the effects of natural ventilation pressures. The authors installed the original ventilation monitoring system and achieved remote control of main underground regulators. Modifications to the VnetPC ventilation software package were performed to allow for continuous real-time updated ventilation models from the field measurement stations. The modifications to incorporate the real-time sensor data into the WIPPVENT program are described in this paper.

2 Overview of WIPP

The WIPP underground facility, is located in bedded salt as determined by the US Department of Energy, and provides for the isolation of transuranic (TRU) waste.

TRU waste is defined as radioactive waste that contains artificially produced radioactive materials with alpha-emitting elements above atomic number 96. TRU waste primarily consists of clothing, tools, rags and other items contaminated with trace amounts of radioactive elements, mostly plutonium. The TRU waste that is to be disposed of at the WIPP site is classified as low to medium-level waste that can be safely isolated from the environment in steel drums until placed in a permanent disposal facility. Initial evaluations of WIPP began in 1974. In 1979, the US Congress enacted Public Law 96-164 for the construction and development of the WIPP Project. The mission of WIPP is to provide safe, long-term disposal of TRU waste generated by the national defence programs of the United States.

The underground facility at WIPP is constructed with four main ventilation splits. These splits are identified as the north area (formerly the experimental area), the mining area, the waste-disposal area and the waste-shaft station. To minimize potential impacts to underground personnel, the facility is designed and constructed with the "as low as reasonably achievable" (ALARA) concept of minimizing occupational exposure to radiation and radioactive materials. This concept led to a ventilation design in which the nuclear-waste transportation and disposal area are separated from the mining and nonradioactive areas. The ventilation system is also designed so that air leakage is from the mining and non-radioactive areas to the waste-disposal areas. Furthermore, radiation detectors are located strategically throughout the underground facility, and an exhaust-filtration building on the surface minimizes the potential release of radiation to the environment.

The ventilation system at the WIPP facility utilizes three shafts for intake air, the salt-handling shaft (SHS), waste-handling shaft (WHS) and air-intake shaft (AIS). A single exhaust shaft (ES) is utilized for the return airway at the facility. During normal operations, fresh air is supplied.
primarily by the air-intake shaft with secondary intake from the salt-handling shaft. Additionally, the salt-handling shaft is used for personnel and material access as well as removal of the mined salt. Nuclear waste is lowered through the waste-handling shaft which is equipped with an enclosed headframe. The waste-handling shaft provides access for personnel and equipment to the waste repository with limited intake downcasting the shaft. The air from the waste-handling shaft is directly routed to the exhaust shaft after ventilating the waste-handling shaft station.

Ventilation through the facility is achieved by running of one or two of the 450-kW (600 hp) centrifugal main fans. During concurrent mining and waste-handling operations, both fans operate in parallel to provide 230 m$^3$/s (490,000 cfm). This airflow quantity is required to maintain proper ventilation for the operation of diesel equipment throughout the facility. When either mining or waste emplacement is inactive, the ventilation demand decreases. In this configuration, only one main fan operates, resulting in an airflow of 140 m$^3$/s (300,000 cfm). In the unlikely event of an underground radioactive release, the ventilation system is either automatically or manually shifted to a filtration mode. The airflow demand during filtration mode decreases to 28 m$^3$/s (60,000 cfm). The shift consists of the main fans being turned off and one of the three 175 kW (235 hp) centrifugal standby fans. During concurrent mining and waste-handling operations, both fans operate in parallel to provide an airflow of 230 m$^3$/s (490,000 cfm). The waste-handling fan where the sensor data is not to be used.

3 Preliminary Software

The VnetPC program is designed to assist mine engineers in the modeling of ventilation layouts. Using data obtained from ventilation surveys or determined from known airway dimensions and characteristics, existing ventilation networks can be simulated in such a manner that airflow rates, frictional pressure drops and fan operating points approximate those of the actual system. The program is developed based upon the assumption of incompressible flow, adherence to Kirchhoff's Laws, and the utilization of an accelerated form of the Hardy Cross iterative technique to converge to a solution. WIPPVENT is a specifically modified version of VnetPC2007 (Mine Ventilation Services, Inc ©2007) design exclusively for WIPP. WIPPVENT incorporates specific ventilation controls for the facility into the models such as; Natural Ventilation Pressure (NVP), regulator curves and transient time calculator. WIPPVENT was written in a Windows operating system to be user-friendly.

4 Hardware

The ventilation system at WIPP utilizes an Underground Ventilation Remote Monitoring and Control System (UVRMCS) with multiple sensors installed throughout the underground and surface infrastructure. Sensor data is collected every 30 seconds and is recorded and stored in the surface central monitoring room (CMR) at WIPP. The installed sensors record airflow quantities (cfm), pressure differentials (inches water gauge (in.w.g.), fan operating airflows (cfm) and pressures (in.w.g.), psychometrics (barometric pressure (Hg), relative humidity (%RH) and dry bulb temperature (°F)) and regulator louver settings (% open). Sensors are also defined by group such as; surface, underground, fan airflow and regulators.

5 Merging WIPPVENT and Recorded Sensor Data

Prior to the integration of the sensor data and WIPPVENT, all data was manually input into the program using the recorded sensor data obtained from the CMR. A computer software programmer was used to design the software required to call the sensor data from the central monitoring system (CMS) virtual address extension (VAX). Figure 1 illustrates a sample of the sensor TagID page in WIPPVENT.

Once the Tagnames are imported into WIPPVENT, the user may select a date, time of day (0-24 hours) and an averaged range of the data recorded (1-60 minutes) to be retrieved from the CMS VAX an example is shown in Figure 2. The data selected in Figure 2 is for April 16, 2008 from 12:00 pm (noon) to an end time of 12:09 pm (the range of data retrieved is for 10 minutes).

Based on the selected date, time and range, the archived sensor data is imported into the ventilation model. A summary of the data imported for each sensor is shown in Figure 3.

Prior to the data being utilized in the model, the user must select which of the recorded sensor data that has been retrieved will be applied into the ventilation model. If the user does or does not want to use all the retrieved viable data from the CMS VAX for the set date, time and range, the user may select what will be incorporated into the ventilation model.

For example, the sensor data for the fan pressures indicate Fan 47,17 has a recorded measured pressure of 50,969.3 Pascal (Pa) (204.623 in.w.g.) and Fan 700C has a recorded measured pressure of 1,150.8 Pa (4.620 in.w.g.).

At this point the user may select to apply to Fan 700C recorded measured pressure to the model and omitted the Fan 47,17 recorded measured pressure as shown in Figure 4. If the user selects apply the Fan 700C recorded data, both fans will utilize the recorded data, otherwise the user must manually input a fan pressure or curve for the fan where the sensor data is not to be used.

Once the data is imported to WIPPVENT for the designated date, time and range, the user may select to apply the sensor data to the ventilation model. The ventilation model will adjust to incorporate the sensor data for the designated date, time and range selected. By importing the recorded sensor data, the user may see the predicted model operating ventilation conditions for the selected date and time.
Figure 5 illustrates the ventilation model with manually entered data for Fan 700C and Fan 47,17. Using the data entered, both fans are exhausting with approximately 100.0 m³/s (211.8 kcfm) flowing through Fan 700C and approximately 1,271.6 m³/s (269.4 kcfm) going through Fan 47,17.

Figure 6 shows the ventilation model with the selected recorded sensor data applied to both Fan 700C and Fan 47,17. Using the sensor data, both Fan 700C and Fan 47,17 are operating at 1,150.8 Pa (4.620in. w.g.).

Figure 7 illustrates the ventilation model after the selected recorded data for the date and time selected are applied. The fan pressure recorded for Fan 700C was incorporated into the ventilation model. The fan pressure for Fan 47,17 was manually imputed and not obtained from the recorded sensor data. As shown in Figure 7, the airflow through Fan 700C is reversed and exhausted through Fan 47,17.

Figure 1 Recorded Data Sensors Identification Tags.

Figure 2 Selection for the Date and Time for the Recorded Sensor Data to be Retrieved.
The WIPPVENT program is the initial design for utilizing real-time data to update and adjust ventilation systems. Currently, WIPPVENT provides the user the ability to monitor and record past ventilation events which can be simulated in a ventilation model. As technology advances, the data received from the sensors may be utilized to adjust the system for current equipment being utilized or when changes in the operations are occurring in the underground. If a system can use the measured data from
sensor, the ventilation may be adjusted for the required scenario (such as Ventilation on Demand). A Ventilation on Demand network may adapt the system at a certain time when additional airflow is required for various tasks and may reduce the airflow rates to minimum operational limits when they are not required. The benefits of this type of system will potentially allow for lower overall power costs when air quantities are not required as well as providing additional air quantity in various areas of the mine as required.
Summary and Conclusion

WIPPVENT is a software package that utilizes an ongoing study at the Waste Isolation Pilot Plant (WIPP) to integrate underground airflow, differential pressure, primary fan information, and psychometric monitors into a ventilation model. The ventilation software, called WIPPVENT, is based on the commercially available package VnetPC developed by Mine Ventilation Services, Inc. The WIPPVENT package has been upgraded to import recorded real-time sensor data into a ventilation model of the underground facility. WIPPVENT allows the user to select and use the data recorded from the sensors or modify the data as necessary before used in a ventilation model. The software has also been written to easily accommodate new sensors and regulators as they are added, and/or as the ventilation system changes, in the facility.

The WIPPVENT software package is the initial phase of integrating monitoring sensors with ventilation models of the system. Currently, WIPPVENT allows the user to model past/recorded occurrences in the ventilation system. As systems and technology advance, the goal is to achieve real-time continuous monitoring of ventilation systems with models and sensors so that the ventilation system may operate more efficiently.

References

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