REALTIME MINE VENTILATION SIMULATION .

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ABSTRACT. This paper describes the development of a Windows based, interactive mine ventilation simulation software program at the Waste Isolation Pilot Plant (WIPP). To enhance the operation of the underground ventilation system, Westinghouse Electric Corporation developed the program called WIPPVENT. While WIPPVENT includes most of the functions of the commercially available simulation program VNETPC ([c] 1991 Mine Ventilation Services, Inc.) and uses the same subroutine to calculate airflow distributions, the user interface has been completely rewritten as a Windows application with screen graphics. WIPPVENT is designed to interact with WIPP ventilation monitoring systems through the sitewide Central Monitoring System. Data can be continuously collected from the Underground Ventilation Remote Monitoring and Control System (e.g., air quantity and differential pressure) and the Mine Weather Stations (psychrometric data). Furthermore, WIPPVENT incorporates regulator characteristic curves specific to the site. The program utilizes this data to create and continuously update a REAL-TIME ventilation model. This paper discusses the design, key features, and interactive capabilities of WIPPVENT.

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INTRODUCTION

The ventilation system at the U.S. Department of Energy's Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, is designed to perform two distinct functions. First, it fulfills normal mine ventilation requirements compliance with all state and federal mine regulations. Second, it limits the uncontrolled release of radioactive contaminants from the facility. Although a nuclear radiation release in the facility is considered very unlikely, the ventilation system incorporates many special features to prevent the spread of contamination.

OVERVIEW OF THE WASTE ISOLATION PILOT PLANT

The U.S. Department of Energy determined that the plastic nature of bedded salt will provide the best feasible solution to isolate transuranic (TRU) waste from the biosphere. TRU waste is defined as radioactive waste that contains artificially produced radioactive materials with alpha emitting elements above the atomic number 96. TRU waste consists, primarily, 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 (WIPP). Initial evaluations of WIPP began in 1974. In 1979, the U.S. Congress enacted Public Law 96-164 for the construction and development of the WIPP Project[2]. The mission of WIPP is to provide safe, long-term disposal of TRU waste generated by the national defense programs of the U.S.

The WIPP site is located approximately 47 km (29 miles) east of Carlsbad, New Mexico in the Chihuahuan Desert. The repository is located in the 630 m (2000 ft) thick Salado Formation. This Permian Basin salt deposit is about 250 million years old and appears to have been stable from earthquake, faulting, and groundwater activity since it was deposited. The underground facility is 660 m (2,150 ft) below the surface, approximately halfway through the Salado Formation. Since 1984, underground nonradioactive experiments have been performed at WIPP to determine site characterization for performance as a nuclear waste repository.

The underground facility at WIPP is constructed with four main ventilation splits. These splits are called the north area (formerly the experimental area), the mining area, the waste storage area, and the waste shaft station. In order to minimize the potential impacts to underground personnel, the facility is designed and constructed with the "as low as reasonably achievable" (ALARA) concept of maintaining occupational exposures to radiation and radioactive materials to a minimum. This concept led to a ventilation design where the nuclear waste transportation and storage areas are separated from the mining and nonradioactive experimental areas. The ventilation system is also designed so that air leakage is from the mining and experimental areas to the waste storage 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.

DESCRIPTION OF THE VENTILATION SYSTEM

The three intake shafts at WIPP are the Salt Handling Shaft, Waste Handling Shaft, and Air Intake Shaft. The Exhaust Shaft is the only return airway for the facility. During normal operation most of the intake air enters the underground through the Air Intake Shaft. The Salt Handling Shaft, which provides personnel and material access, is used for the removal of the mined salt and is a secondary intake shaft. The Waste Handling Shaft is equipped with an enclosed headframe, and will be used to lower the nuclear waste to the repository horizon. This shaft also provides access for personnel and materials to the repository horizon. A limited amount of intake air enters this shaft. After ventilating the shaft station area, the Waste Handling Shaft air is routed to the Exhaust Shaft.

Ventilation through the facility is achieved by running one, or two in parallel, of the 450 kW (600 hp) centrifugal main fans. During concurrent mining and waste handling operations both fans are required 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 not active, 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). This shift consists of the main fans being turned off, and one of three 175 kW (235 hp) centrifugal standby filtration fans started. A series of isolation dampers diverts the air through the filtration system. The air is routed through a series of high efficiency particulate air (HEPA) filters.

The WIPP ventilation system utilizes an Underground Ventilation Remote Monitoring and Control

System[3] (UVRMCS). It consists of 15 air velocity sensors, eight differential pressure sensors (strategically placed throughout the repository), and provides local and remote control of the position of the air regulators controlling the four main ventilation splits. The sensors send a 4-20 milliampere signal to one of four local processing units (LPU) in the underground repository. The LPUs digitize and process this signal into engineering units of air velocity in ft/min, differential pressure in inches water gauge (in.WG), and regulator position in percent open. Each signal or "point" has a specific identifier that the LPU software recognizes and in turn performs the calculation necessary to convert the signal to its appropriate engineering unit. The LPUs then transmit the signal onto the Data Highway which extends throughout the facility and terminates at the surface Central Monitoring Room (CMR). The CMR is equipped with operator-machine interface (OMI) terminals. A CMR operator can selectively retrieve the signals and display them on the OMI terminal in graphical or tabular formats as programmed into the OMI software. The CMR operator can use the control functions of the system to open or close the main regulators remotely (provided they are set in the field to remote operation).

In addition, the ventilation system uses eight psychrometric Mine Weather Stations (MWS) to collect data for use in calculating natural ventilation pressures. These monitoring stations collect data on temperature (in degrees centigrade), pressure (in kilopascals) and relative humidity (in percentage). This system interfaces with the CMS through the Data Highway in a manner similar to the operation of the UVRMCS.

Information on the underground ventilation system main fans is also available from the CMR.

These data show which fans are operating, the static pressure, and indicate the airflow quantity through the fan.

A virtual address extension (VAX) interface software program transfers data from the CMS VAX onto the sitewide VAX network. The VAX network can then be accessed by the ventilation engineer, providing real-time data on the status and performance of the system. Figure 1 shows the relationship between all system components.

To enhance the operability of the underground ventilation system, and to utilize the real-time ventilation data available to the greatest extent possible, Westinghouse Electric Corporation- Waste Isolation Division (WID) developed an interactive mine ventilation simulation software program called WIPPVENT for the DOE.

MAJOR FEATURES OF WIPPVENT

WIPPVENT is an interactive mine ventilation simulation software program developed by WID and its subcontractor, Mine Ventilation Services Inc. for exclusive use at WIPP. It is based on the commercially available VNETPC Version 3.1 ([c] 1991 Mine Ventilation Services, Inc.); however, the user interface has been completely rewritten as a Windows® operating system to provide a more user-friendly environment. Many of the Windows® features were developed using existing Windows® applications and shareware technology. Functions such as screen graphics, pull-down menus, zoom, a spreadsheet type data format, and editing features have been added. The use of these features are similar to other Windows® applications and will not be discussed in this paper.

The characteristic that makes WIPPVENT unique is the interactive design connecting it to the WIPP underground ventilation monitoring systems (the UVRMCS and the MWS) through the sitewide CMS. WIPPVENT also incorporates characteristic resistance curves specific to the sites four main underground regulators. WIPPVENT can therefore retrieve real-time data, and use these data to create a real-time ventilation model. The design, key features, and interactive capabilities of WIPPVENT are discussed in the following sections.

THE PI SYSTEM

The real-time data WIPPVENT uses are retrieved from the CMS through a VAX interface program called Plant Information (PI), which is commercially available from Oil Systems Inc. of San Leandro, California. PI is an archival program that collects and screens data, and then archives the data to the VAX for final storage. The PI system connects to the site CMS using computer drivers developed by Oil Systems Inc. WIPPVENT can connect and "talk" to PI by selecting a series of pull-down menu commands. The WIPPVENT user would first connect to the CMS through PI, and then retrieve data in either real or historic time.

DATA SUMMARY

Once the desired data have been imported to WIPPVENT, a remote sensing data summary table appears on the screen providing key information on the ventilation system. Information summarized on the table includes: time period for the data, differential pressures for the Waste Handling Tower and main fans, airflow summary for the shafts and main splits, and the calculated resistances for the Air Intake Shaft and main regulators. Any applicable error signals are displayed in the corresponding field. The summary table also provides access to detailed information on the data available. Once the data has been selected and/or modified, an "apply" button sends the data to WIPPVENT for use in a simulation. Figure 2 shows the Remote Sensing Data Summary table for WIPPVENT.

AIRFLOW AND DIFFERENTIAL PRESSURE DATA

Once a connection has been established between WIPPVENT and PI, the user is able to retrieve data from the UVRMCS and MWS systems. These data are accessed through the remote-sensing data summary table.

Accessing the "Airflows" or "Pressures" buttons from the summary table provides detailed information on the UVRMCS's 15 airflow stations and eight differential stations located throughout the facility. The additional information provided on each table includes: the tag (CMS) number, location, description, status (including applicable errors), node numbers, and the airflow value in thousands cubic feet per minute (kcfm), or differential pressure in inches water gauge (in.WG). respectively. If desired, the data provided in these tables can be altered using the standard Windows edit features. Altered data will have a "modified" message displayed in the status column of the summary table. This feature allows the user to set up various "what if" ventilation scenarios based on real-time data, and at the same time differentiate between real-time modified scenarios. Figure 3 shows the Remote Sensing Airflows table. The Remote Sensing Pressure table is similar.

MAIN REGULATOR DATA

One of the features that makes WIPPVENT a WIPP specific ventilation simulator is that it has the ability to utilize data on the facility's four main regulators. Data on these regulators can be accessed by pushing the "regulators" button on the Remote Sensing Data Summary table. A summary box is provided which gives information on the current status of each bank of regulators. The information provided is; airflow through the regulator in kcfm, pressure drop across the regulator in in.WG, and the calculated resistance of the regulator in Practical Units (P.U.= kcfm/[milli-inches WG]^2). An optional "louvers" button provides access to more detailed information on the individual louvers for each bank of regulators. This additional data includes; the tag (CMS) number, louvre, status, indicated setting (% open), and the calculated setting (degree closed) based on the current airflow/pressure summary data. This data can be applied to WIPPVENT to run a mine ventilation simulation.

Additional information on each of the four main regulators can be accessed through a separate pull down menu. This can be used either in conjunction with data directly from the CMS, or with previously defined ventilation models. Regulator resistance curves for individual louvers in each bank of regulators have been programmed into the simulator. The program shifts from one curve to the next as louvers are adjusted and/or closed in a predefined sequence. This allows the accurate prediction of airflow in any particular split. Figure 4 is a Typical Regulator Data Screen. This table provides the choice between whether the split is to be a Fixed Resistance or a Fixed Quantity branch. If a Fixed Quantity is selected, a corresponding Minimum Resistance can be assigned by the user or defaulted to a predetermined value. A Fixed Resistance setting can be selected, and any desired fixed resistance assigned to the data box. Once an airflow distribution analysis has been run, selecting the "Louvre Settings" in the Fixed Resistance Data box provides additional information on the outcome of the simulation. WIPPVENT calculates the settings for each appropriate louvre in the regulator bank, indicates which (if any) regulators need to be completely closed, and indicates the resistance of the scenario. Figure 5 shows the Louvre Settings Screen. This enables the user to determine how the underground ventilation system needs to be configured in order to achieve a specific distribution.

WIPPVENT can also be used to determine the airflow distribution for a specific regulator scenario. The "Settings" portion of the Louvre Settings box can be used to set the louver(s) in any or all of the regulator banks to any value within the specified limits. When an airflow analysis is performed, this information will be used to determine the airflow in the main ventilation splits for the desired regulator settings. These two features allow for quick and accurate analysis of a variety of airflow quantity and/or regulator configurations depending on changing operational needs.

NATURAL VENTILATION PRESSURE DATA

Natural ventilation pressure (NVP) can effect the WIPP underground ventilation system. Under winter conditions, the WIPP ventilation system can experience an NVP of up to +2.0 in.WG assisting the fans. In the summertime, and NVP of up to -1.0 in.WG opposing the fans is possible[1]. The accurate monitoring and prediction of NVP is helpful to maintain the proper underground airflow configuration throughout the facility.

As previously described, the WIPP site monitors psychrometric data for the calculation of NVP through eight mine weather stations. WIPPVENT is designed to access this data, use it in the calculation of NVP, and apply that data to a mine ventilation simulation. Figure 6 shows the NVP and Station Data screen. NVP summary data for the three intake air shafts is provided, as well as the opportunity to indicate whether that data should be used (active) as part of the simulation.

This feature of WIPPVENT enables the NVPs effecting the underground ventilation system to be accounted for on a real-time basis, and the proper corrective actions taken in order to maintain the desired differential pressures throughout the ventilation system.

SUMMARY

The development of WIPPVENT, Mine Ventilation Simulation Program at the WIPP represents the final phase of a three phase project (UVRMCS and MWS being the other two) to provide real-time monitoring, control and modeling capability to the underground ventilation system. The interactive capabilities of WIPPVENT not only allow for modeling of the current system configuration, but also for accurately predicting changes which must be implemented the system to achieve any desired airflow configuration. The real-time modeling capability helps to insure that the proper airflow quantities and differential pressures are maintained as operational needs and atmospheric conditions change. The use of this program, in conjunction with the UVRMCS and MWS systems, further enhances the safety, flexibility, and operability of the underground ventilation system at WIPP. Future enhancements to WIPPVENT currently planned include an upgrade to operate in a Windows 95® environment, continuous updates of the realtime ventilation simulation, and the development of an expert system for ventilation modeling.

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Figure 1.

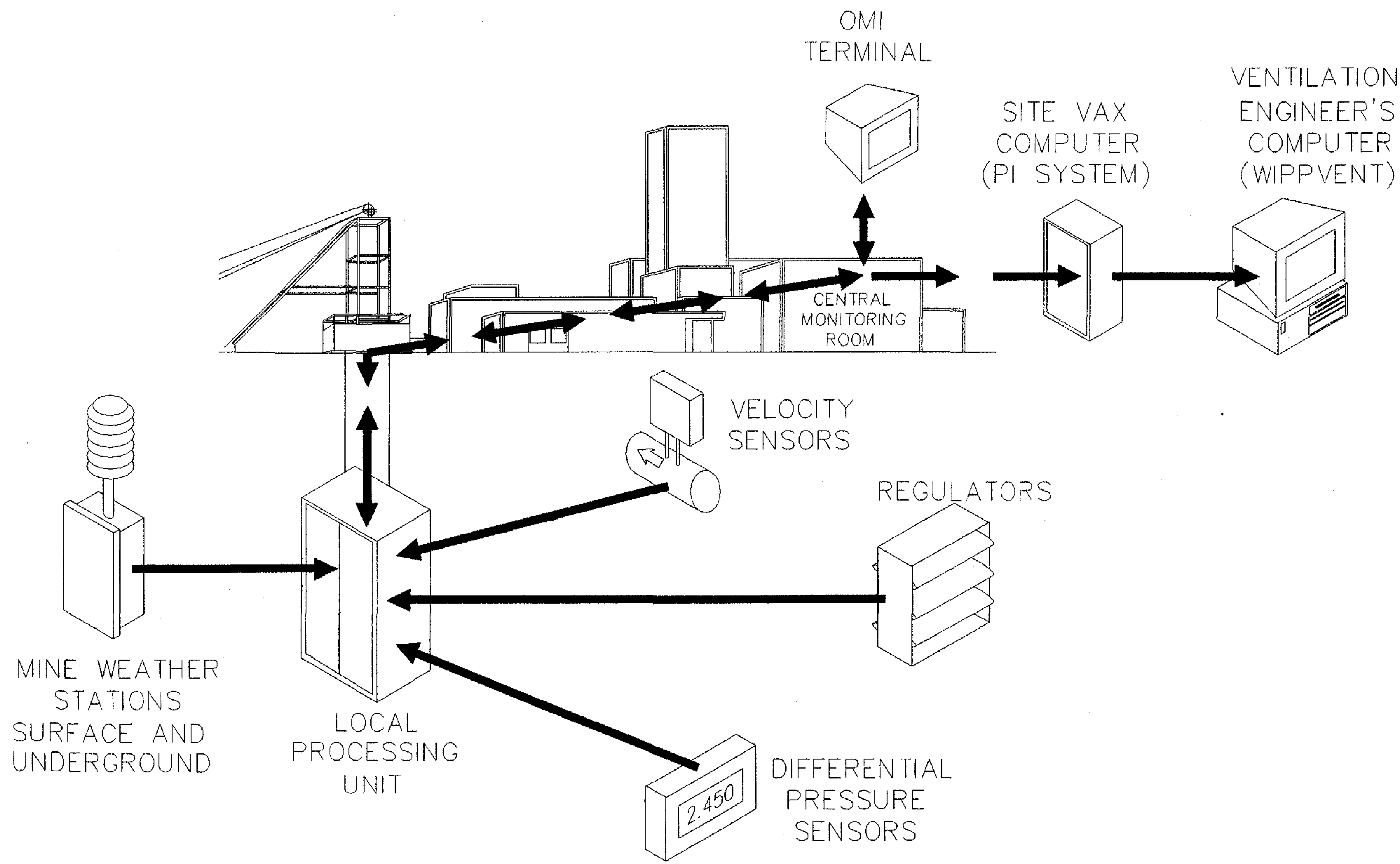

OMI
TERMINAL
SITE VAX
COMPUTER
(PI SYSTEM)
VENTILATION
ENGINEER'S
COMPUTER
(WIPPVENT)
CENTRAL
MONITORING
ROOM
VELOCITY
SENSORS
REGULATORS
MINE WEATHER
STATIONS
SURFACE AND
UNDERGROUND
LOCAL
PROCESSING
UNIT
2.450
DIFFERENTIAL
PRESSURE
SENSORS

Figure 2. Remote Sensing Data Summary.

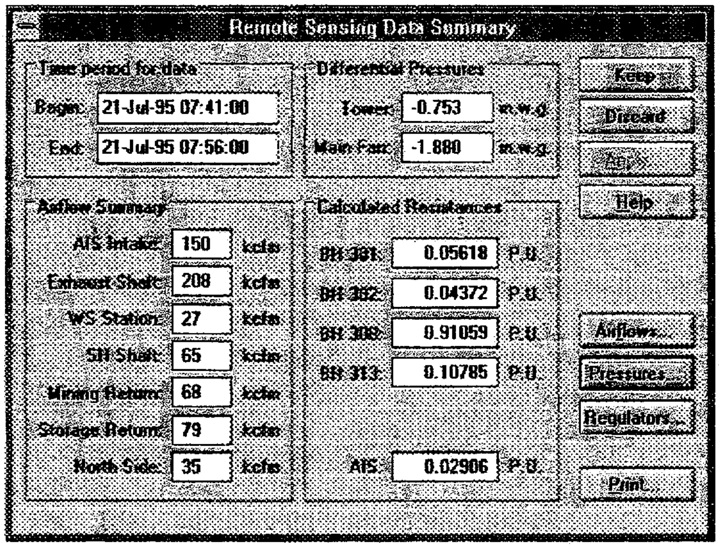


Figure 3. Remote Sensing Airflows.

Airflows

Tag	Location	Description	Status	From	To	Airflow (kcfm)
AM1001	N215/W500	Intake from AIS	Ok	2	300	149.72
AM1002	N1100/W150	Experimental intake	Ok	303	304	52.98
AM1003	N1400/E400	E. of experimental shop	Ok	320	305	44.66
AM1004	N240/E140	BH 301	Ok	401	288	66.44
AM1005	N150/E100	BH 302	Ok	402	288	67.97
AM1006	N80/E0	N. of SHS	Ok	400	9	78.82
AM1007	S300/W30	S. of SHS	Ok	291	11	143.76
AM1008	S800/W30	N. of BH 313	Ok	12	13	106.74
AM1009	S1100/W30	S of BH 313	modified	13	208	42.65
AM1010	S2050/W170	End of mining circuit	modified	280	281	36.91
AM1011	S600/W170	Mining return	Ok	285	286	37.25
AM1012	S320/E300	N. of exhaust drift	Ok	601	186	102.97
AM1013	S500/E300	S. of exhaust drift	Ok	185	186	78.53
AM1014	S1600/E400	Storage panel return	Ok	114	182	53.51
AM1015	S400/E400	Exhaust drift	Ok	186	5	208.32

OK

Cancel

Help

Figure 4. Typical Regulator Data.

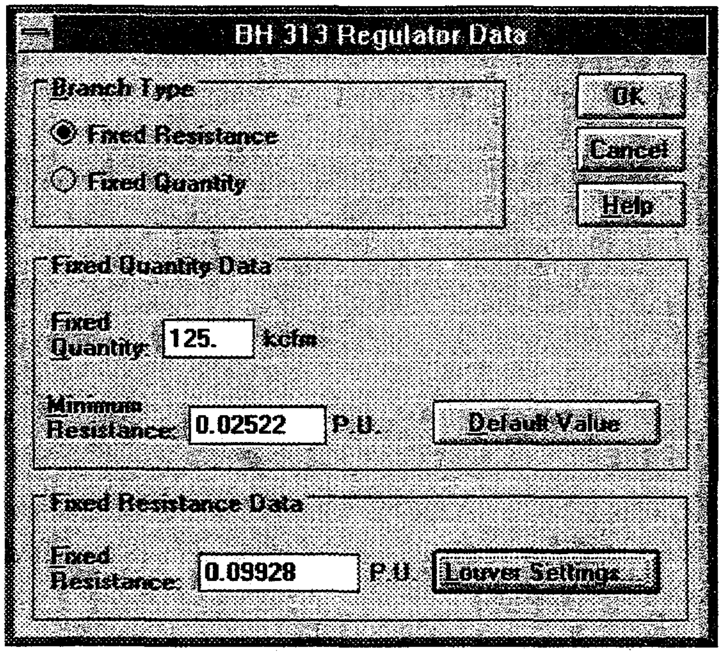


Figure 5. Typical Louver Settings.

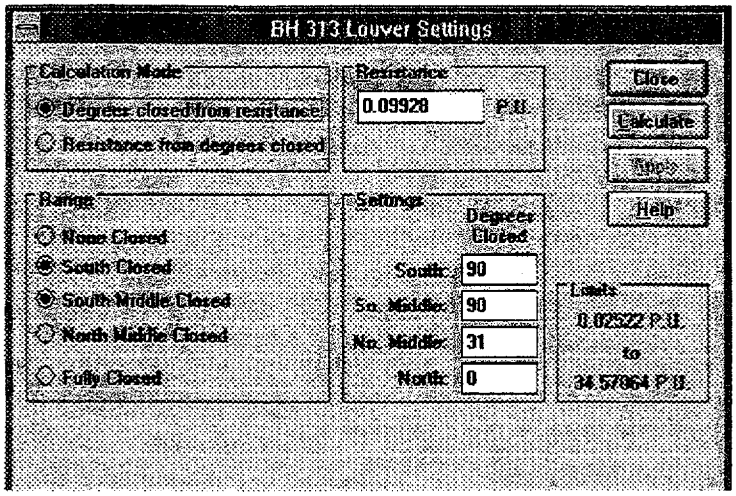
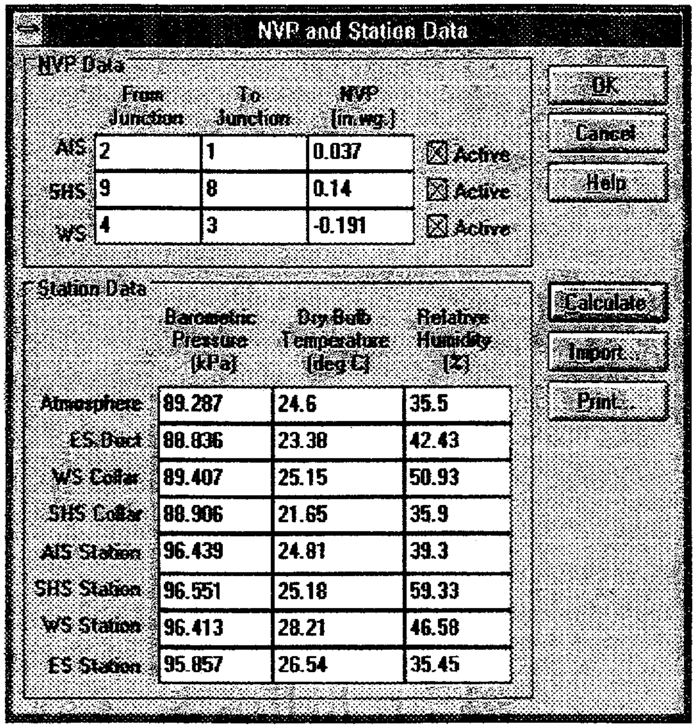


Figure 6. NVP and Station Data



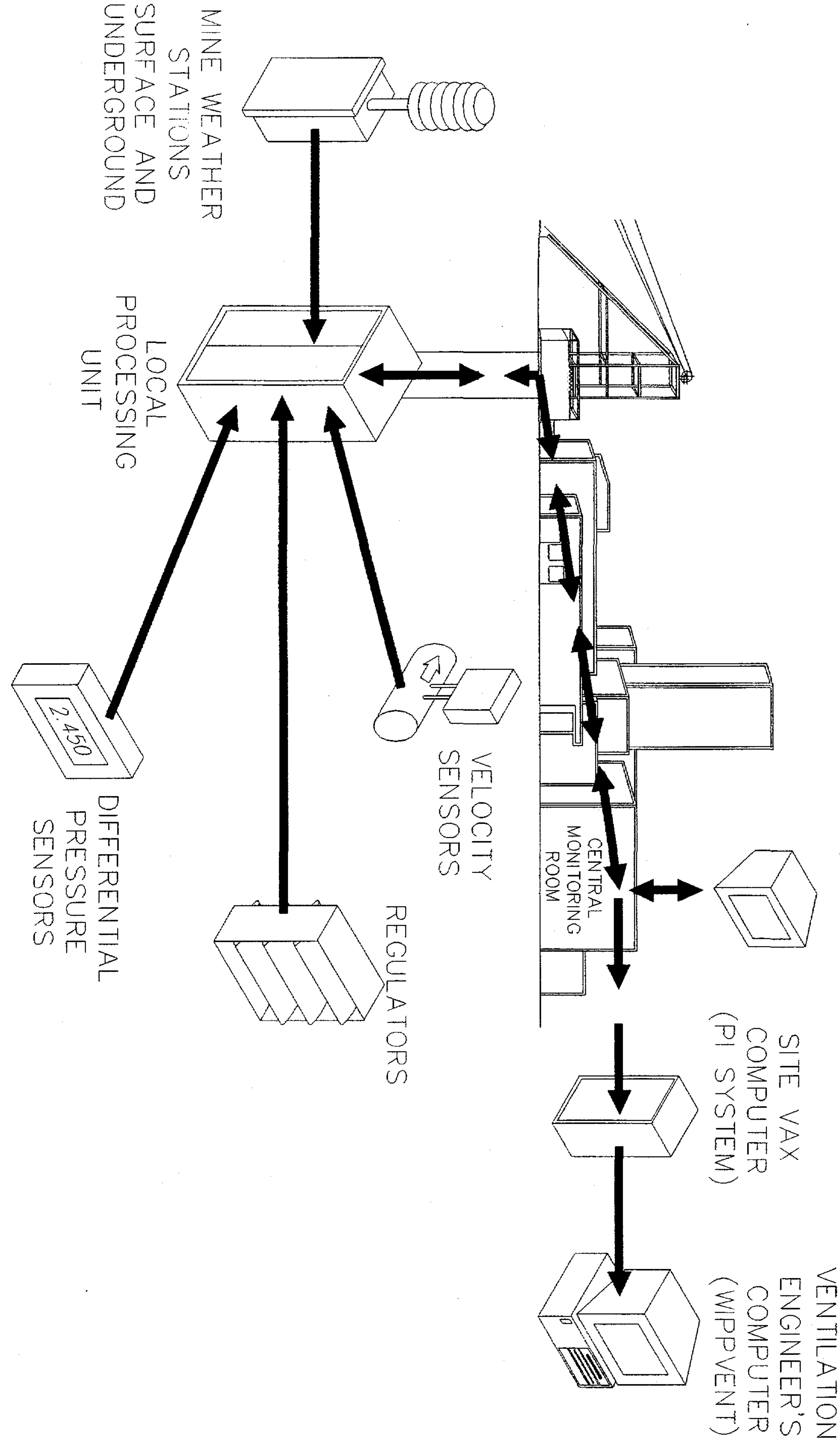


FIGURE 1. RELATIONSHIP BETWEEN UNDERGROUND SENSORS, REGULATORS LPU, CMR, OMI, VAX NETWORK AND WIPPVENT