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Q200505260001

Scientific Notebook No. 506: Review of DOE
Subsurface ventilation Analysis/Design
(03/14/2002 through 05/20/2005)

LABORATORY NOTEBOOK

CNWRA/SwRI

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COPY 506

NOTEBOOK NO. _____

ISSUED TO Troy Maxwell T.M.

ON 3-13-02

DEPARTMENT _____

RETURNED _____

20.01402.671

—SCIENTIFIC NOTEBOOK CO.—
2831 LAWRENCE AVE.
P.O. BOX 238
STEVENSVILLE, MI 49127
616-429-8285

TITLE

Ventilation Review

Project No. 20.01402.671

Book No. 506

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From Page No.

The principal investigator of this activity is Troy Maxwell. The objective of the activity is to review DOE subsurface ventilation reports.

3-14-02 The approach of the review includes independent confirmatory analysis using the computer software listed below.

Title: Review of DOE Subsurface Ventilation Analysis/Design

Objective: To model the subsurface ventilation system of Yucca Mountain to confirm the analysis or results of analysis in DOE reports.

Project : 20.01402.671

Computer Software: Vnet PC 2000 (Version 1.0.4); CLIMSIM Version 1.0

The principal investigator is familiar with these software. 3-14-02 T.M.

3-15-02

Coordinates of the emplacement area were input into Vnet PC in the (Junction Data). The coordinates are from the DOE report "Lower-Temperature Subsurface Layout and Ventilation Concepts" page 111-3 of 111-5 in Table 111-1 "Bounding Coordinates for the Emplacement Area by Emplacement Drift." Table 111-1 provided the drift number, Northing and Easting coordinate, and elevation of each point that forms the emplacement area. The "New Branch" function was used to connect the appropriate coordinates to form 91 emplacement drifts.

3-15-02 T.M.

3-19-02

Shaft coordinates for the intake shafts and exhaust shafts were input into (Junction Data) Vnet PC. The coordinates are from DOE report "Lower-Temperature Subsurface Layout and Ventilation Concepts" page 60, Table 14 "Shaft Coordinates". The length of each shaft is not given in this table. On page 59, the report gives the excavated diameter of the shafts to be 8 meters. This value will be used in Vnet later in this analysis.

3-19-02 T.M.

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3-21-02

Using the "Add Fan" function, fans were added to each exhaust shaft. From DOE report "Overall Subsurface Ventilation System", section 5.4 page 14, a 10 inch water gauge pressure was assumed while a 75% fan efficiency was assumed in section 5.8 page 16 of the same report. In section 6.2.3 on page 99 from "Lower-Temperature Subsurface Layout and Ventilation Concepts", the fans are said to operate in parallel. ~~That~~ ^{3-21-02 T.M.} That is two fans on each exhaust shaft operating in parallel.

75% was input in Model Data under Avg Fan Efficiency.
2.491 kPa (10 in wg) was input in Fan Input under Fan Pressure.

No fan curve has been input into Vnet to define the fans yet.

3-21-02 T.M.

3-26-02

To remove 70% of the heat generated by the waste packages, a 15 m³/s flow rate is chosen for each emplacement drift according to "Overall Subsurface Ventilation System" section 4.1.1 page 8. Under Fixed Quantities a 15 m³/s flow rate was input for each emplacement drift. The resistance caused by the waste packages in each emplacement drift is not addressed in either of the before mention DOE reports.

3-26-02 T.M.

3-29-02

In order to incorporate the different diameters of the different shafts and drifts, a "k Factor" type resistance is chosen under Branch Information. Then under Branch Input, the appropriate cross-sectional area may be input for each branch.

Shaft Diameter: 8 meters } Preliminary values from
Ventilation Raises: 2 meters } "Overall Subsurface Ventilation System"
Emplacement Drift: 5.5 meters }

3-29-02 T.M.

4-1-02

When hitting the "execute simulation" button, Vnet gives an error for every surface intake and exhaust. The error states there is one branch for every surface intake and exhaust all connected to the same node which does not exist. The error is these "phantom branches" exceed the limit of 32,000.

The program does not include these "phantom branches" in the calculation.

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of the networks in the system. Hence the error appears to be a bug in the program and does not affect the results of the simulation.

4-1-02 T.M.

4-4-02

The "k Factor" type resistance uses the Atkinson friction factor with the following equation:

$$R = \frac{k \times (L + L_{eq}) \times Per}{c \times A^3}$$

where:

R = airway resistance

k = friction factor

L = length of airway

L_{eq} = length of shock loss

A = area

Per = perimeter of airway

c = constant (SI=1)

The Vnet software provides a broad spectrum of airways likely expected to be found in a mine, with a k factor corresponding to each airway. Until the actual friction factor can be measured accurately, the following values will be used in the model that are from the Vnet software:

k factor (SI)

Mains + Drifts : 0.01

Raise : 0.005

The L_{eq} (equivalent length) will be looked at in other references to identify if it can represent the waste packages in the emplacement drifts.

4-4-02 T.M.

4-8-02

The diameter of the Access Mains and Ramps and Exhaust Main are 7.62 m. This value was given on page 76 of the DOE report "Lower-Temperature Subsurface Layout and Ventilation Concepts."

4-8-02 T.M.

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4-11-02

The DOE reports, up to this point, do not have a working drawing of the ventilation system. From the drawings that are given, it appears the exhaust main is connected to the east main. The Vnet model has the exhaust main connected to the east main at the coordinates given from Figure 11-1 and Figure 11-2 from "Lower-Temperature Subsurface Layout and Ventilation Concepts". These two figures will also be used to locate observation drift intersections.

4-11-02 T.M.

4-15-02

In DOE reports, the exhaust main is split into a service side and an exhaust side. The current Vnet model does not include this split exhaust scheme. The split exhaust does not affect the volume of air removed and therefore will not be included in the model.

4-15-02 T.M.

4-19-02

From 3-26-02 of this notebook, 15 m³/s was input as a fixed quantity in each emplacement drift. The Vnet software will add a booster to any fixed quantity branch that has a flow rate below the input quantity. For example, if 15 m³/s is input and the fans only pull 13 m³/s through this particular branch, the software will add a booster for an extra 2 m³/s.

From the DOE reports, the ventilation system does not have boosters. The air enters and is regulated through louvers. This difference will have to be addressed in the current model.

4-19-02 T.M.

4-24-02

The following are drifts that were added to the model for the 70,000 MTHM Case Study

4	Cross Block	at	19.63 m ³ /s	} from Lower-Temperature Subsurface Layout and Ventilation Concepts
2	Stand by	at	15 m ³ /s	
4	Observation Drifts	at	19.63 m ³ /s	

The placement of these drifts are from Figure 11 on page 67 of the above mentioned DOE report.

4-24-02 T.M.

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4-29-02

A question was emailed to www.mysengineering.com regarding the way the boosters operate in the fixed quantity branches in the Vnet PC software. The following information was given:

(a) $p > R \cdot Q^2$: resistance R_r is added to the branch

such that $p = (R + R_r) \cdot Q^2$

(b) $p < R \cdot Q^2$: booster fan (pressure p_b) is added such that $(p + p_b) = R \cdot Q^2$

(c) $p = R \cdot Q^2$: branch resistance is sufficient to balance the desired flow.

where:

 p = branch pressure R = branch resistance Q = branch flow rate

It is possible to simulate louvers by adjusted the branch resistance R given R_r from the software. The draw back of this is if R is used to simulate louvers, the fan pressures could not be changed or the 15 m³/s flow rate would change.

4-29-02 T.M.

5-3-02

From 3-29-02 of this notebook, the emplacement drift diameter is listed as 5.5 meters. This results in a 23.76 m² cross-sectional area for the Vnet input (branch input). To account for the line of waste packages (1 meter diameter $\Rightarrow$ 0.79 m² area), 23.0 m² will be input as the area of the emplacement drifts.

5-3-02 T.M.

5-6-02

From Mine Ventilation and Air Conditioning^{2nd ed.}, Hartman 1991 Table 6-1 page 151, friction factor values are given for non coal mine airways and openings for different airway surfaces and orientations. The model will be run at several different friction factors from this Table (Table 6-1) to provide an upper and lower bound in which the 10 in operating pressure will be effective.

5-6-02 T.M.

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5-9-02

The model was run with the following scenarios:
Scenario I ($f = 0.004 \text{ N s}^2/\text{m}^8$):

- smooth lined
- average irregularities
- straight airway
- slightly obstructed

Scenario II ($f = 0.019 \text{ N s}^2/\text{m}^8$):

- igneous rock
- minimum irregularities
- straight airway
- clean

Scenario III ($f = 0.028 \text{ N s}^2/\text{m}^8$):

- igneous rock
- average irregularities
- straight airway
- moderately obstructed

The values are from Table 6-1 of Mine Ventilation and Air Conditioning^{2nd ed.} with the following description:

average + minimum irregularities: surfaces, areas, or alignment

- application: drift turnouts

smooth lined + igneous rock: Type of airway

- application: how smooth of a tunnel is bored

clean, slightly, or moderately obstructed: obstacles in air path

- application: steel sets, waste packages ect.

5-9-02 T.M.

5-15-02

The following values are areas and flow rates of drifts and ramps input for the model followed by a line plot from Vnet PC of the system.

	Area	Flow Rate (fixed)
Emplacement drift	22.98 m ²	15 m ³ /s
Observation drift	23.76 m ²	19.63 m ³ /s
Cross Block	23.76 m ²	19.63 m ³ /s
Stand By	23.76 m ²	15 m ³ /s

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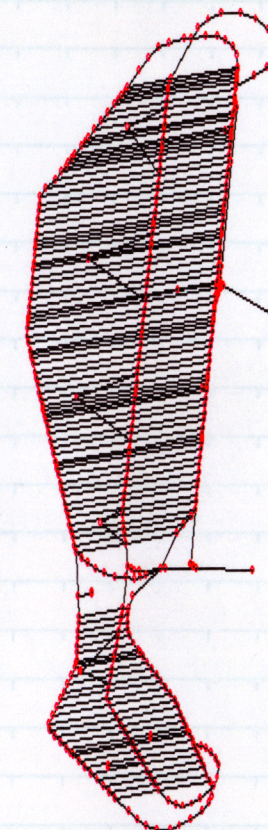
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	Area
Exhaust Main	45.6 m ²
Access Mains/Ramps	45.6 m ²
Intake Shaft + Accesses	45.6 m ²
Exhaust Shaft Accesses	60.25 m ²
Drift Raises	3.14 m ²



T.M.
5-15-02

Line Plot Schematic (91 emplacement drifts)

5-15-02 T.M.

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5-20-02

The Vnet PC model does not include the drift turnouts since the coordinates provided by the report were of the theoretically last emplaced waste package. The turnouts contain the doors that regulate the flow into the emplacement drifts (louvers). In the Vnet PC model, the emplacement drifts are set to a fixed quantity of $15 \text{ m}^3/\text{s}$. As illustrated on page 5 of this notebook, if the branch pressure is greater than the branch resistance multiplied by the branch flow rate squared then the software adds resistance to the branch such that they will be equal. This added resistance simulates the effect the louvers would have on the system. As more information is accumulated, the drift turnouts can be added to the model.

5-20-02 T.M.

5-23-02

As stated from the above entry, the added resistance from the software with the fixed quantity feature simulates the effect the louvers will have on the system. Scenario I from page 6 of this notebook was run and the results were plotted in Excel. The added resistance is called the Regulator Resistance given in the fixed quantities window of Vnet. The Regulator Resistance was plot for the east and west main for each emplacement drift. The plot illustrates the system had an ample amount of air flow to pull $15 \text{ m}^3/\text{s}$ in each emplacement drift. If any emplacement drift reads close to zero for the Regulator Resistance, that drift is not receiving enough air pressure from the east or west main. Hence the fan pressure would need to be increased or the friction factor lowered.

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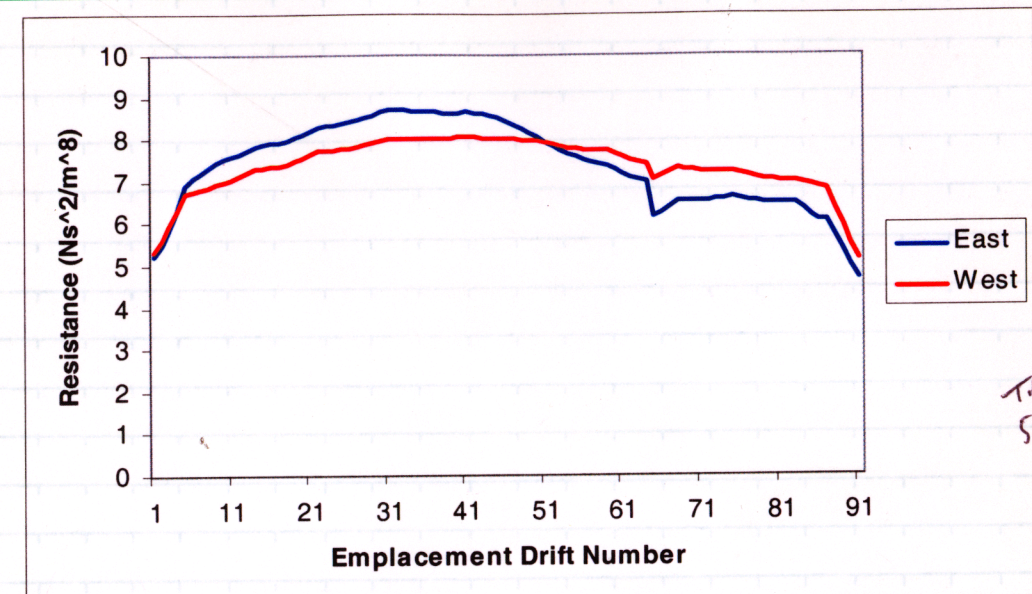
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Scenario I (friction factor: $0.004 \text{ N s}^2/\text{m}^8$)

5-23-02 T.M.

5-27-02

Scenario II was run and plotted into Excel. The plot illustrates the system is still able to pull enough air to meet the $15 \text{ m}^3/\text{s}$ criteria for each emplacement drift. The Regulator Resistance is getting lower hence the pressure in the east and west mains is lower for a higher friction factor which is expected. Both show a drop near the 60th emplacement drift. This is due to the gap in the footprint illustrated on page 7 of this notebook. Also the east side of the emplacement drift is receiving more air than the west illustrated by the higher Regulator Resistance of the east side. This is because the west side emplacement drifts are longer than the east side requiring more air from the west main. Therefore the thinner the air in the west main, the lower the Regulator Resistance for the west side of the emplacement drifts.

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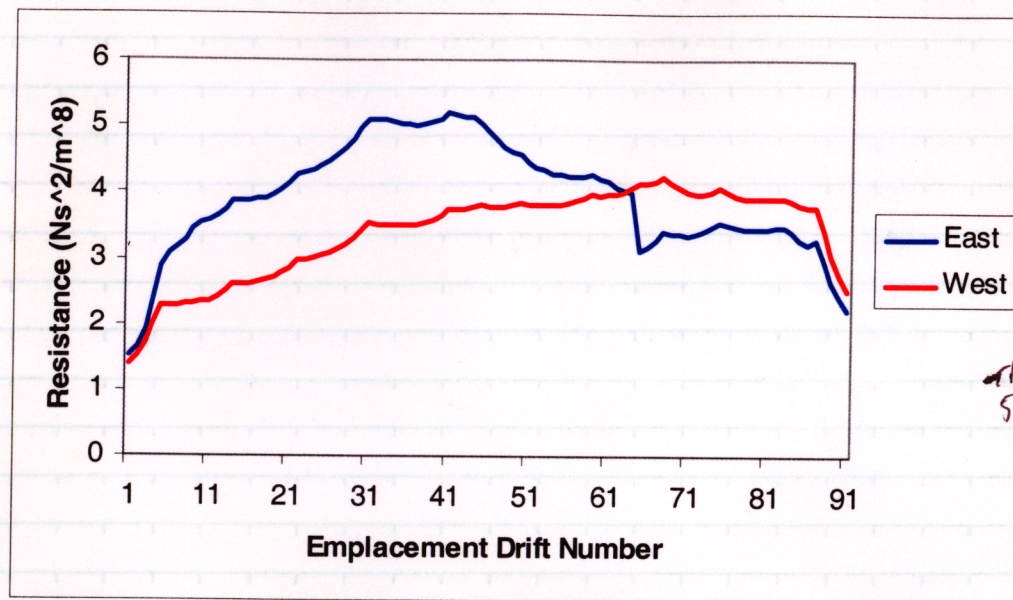
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Scenario II (friction factor: $0.017 \text{ Ns}^2/\text{m}^8$)

5-27-02 T.M.

5-28-02

Scenario III was run and plotted into Excel. The results are consistent with Scenario II that the Regulator Resistance is dropping with the higher friction factor. The system was unable to pull $15 \text{ m}^3/\text{s}$ in each emplacement drift at this friction factor. The friction factor in each of the three Scenarios was applied to each branch in the model. For example, for Scenario I, a $0.004 \text{ Ns}^2/\text{m}^8$ friction factor was applied to every branch in the model. In reality the branches would not have the same friction factor. The emplacement drifts should be expected to have a higher friction factor with the waste packages and drip shield. However, the fixed quantities function of Vnet software makes this irrelevant. When a drift (branch) is set to $15 \text{ m}^3/\text{s}$ the software pulls $15 \text{ m}^3/\text{s}$ independent of what the resistance of that branch may be. Hence the plots would not change if the system friction factor was set to $0.004 \text{ Ns}^2/\text{m}^8$ and the emplacement drift friction factor was set to $0.5 \text{ Ns}^2/\text{m}^8$. The Regulator Resistance is the resistance the software adds to the branch to keep the flow rate from going above $15 \text{ m}^3/\text{s}$. The plots illustrate if the system is able to get enough air to each emplacement drift

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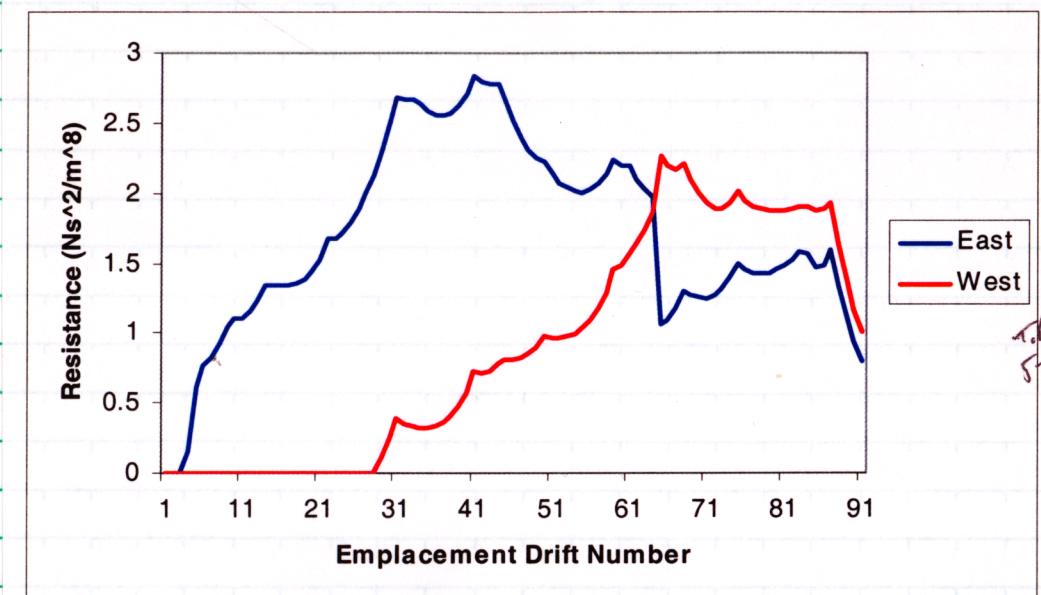
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to pull $15 \text{ m}^3/\text{s}$ but does not demonstrate what happens to the air flow in the drift.



Scenario III (friction factor: $0.028 \text{ Ns}^2/\text{m}^8$)

5-28-02 T.M.

6-3-02

The three Scenarios were also plotted in the form of maximum and average velocity for the exhaust main, west main and east main. From the branch results window, the airflow in each branch was divided by the area of that branch. In "Overall Subsurface Ventilation System" the air velocity is not expected to exceed 8 m/s which is listed as a maximum recommended value for smooth lined drifts in section 6.4.1. The exhaust main displayed the highest velocity which is expected since it is receiving large volumes of air from the east and west main. The east and west main averaged between 2 and 3 m/s (≈ 5 to 7 mi/hr) with the maximum between 5 and 10 m/s ($\approx 11 \text{ mi/hr}$ to 22 mi/hr).

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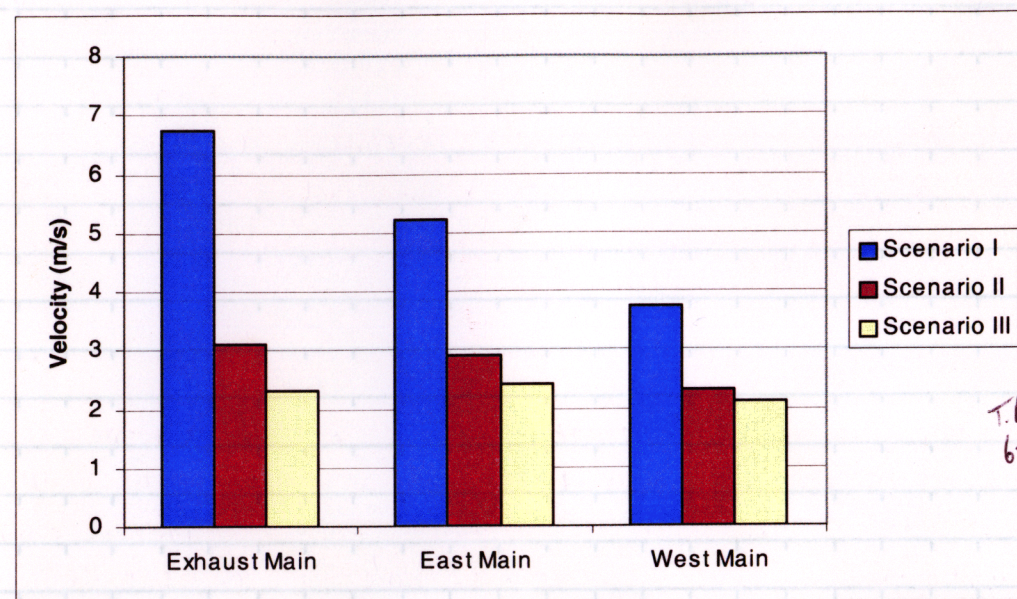
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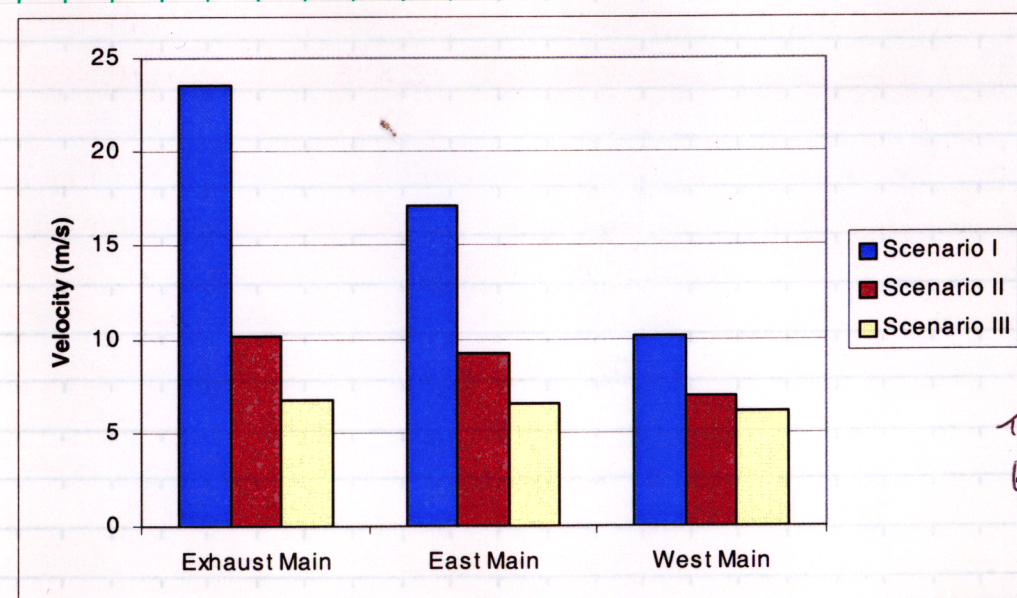
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Average Velocity (Scenario I, II and III)

T.M.
6-3-02

Maximum Velocity (Scenario I, II and III)

T.M.
6-3-02

6-3-02 T.M.

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6-5-02

In "Overall Subsurface Ventilation System", assumption 5.4 states, "The system can be designed to a 10 inch wg operating pressure by reducing the friction losses in the system, or by enlarging the drift diameters to reduce the airflow velocity." Hence the previous 3 scenarios were run with a 10 inch operating pressure as stated on 3-21-02 of this notebook. Hence no fan curve was input.

6-5-02 T.M.

6-12-02

In section 6.2.3 of "Overall Subsurface Ventilation System", the report states, "some or all of the cooler air contained in the Service Side can be redirected to the warm airflow stream in the Exhaust Side to cool that air stream." What ever methodology used to implement this scheme must be able to keep the exhaust air from entering the service side and going into the cross block or performance confirmation drifts if there is a power outage.

6-12-02 T.M.

6-14-02

There is no mention of air velocity control in the service side of the exhaust main. Section 6.2.3 of "Emplacement Ventilation System" states "The service main must be kept at a temperature suitable for personnel access." There would need to be a means to regulate air velocity on the service side of the exhaust main if the temperature is to be controlled.

6-14-02 T.M.

6-18-02

The 3-D view in the schematic section is not producing a 3-D view. It is possible this is related to the error mention on page 2 of this notebook. This glitch in the software does not affect the data.

6-18-02 T.M.

6-21-02

For the three scenarios run, the autolength function was enabled for all three runs.

6-21-02 T.M.

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6-26-02

The air density used for this model was 1.201 kg/m^3 . This was the software's default air density. The following is the model information:

Avg Air Density: 1.201 kg/m^3

Reference Junction: 1

Units: SI

Avg Fan Eff.: 75%

6-26-02 T.M.

7-2-02

No contaminant was used in the model. The contaminant tool can be used to trace a contaminant from a point source, through the ventilation network. Options such as emission rate, concentration ect. can be applied to an individual branch. To this point, friction is the only factor looked at in the model.

7-2-02 T.M.

7-8-02

The Vnet software is capable of calculating operating cost per year. This does not factor in the model currently but could be used later in the simulation.

7-8-02 T.M.

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5-9-05

The following pertains to the validation of the software CLIMSIM for Windows Version 1.0. CLIMSIM predicts the variation in psychrometric and thermodynamic properties of airways. This very useful for rapid predictions of temperature attributes for emplacement drifts. CLIMSIM was validated by inputting data into CLIMSIM and inputting the same data into an EXCEL worksheet that uses the same equations as CLIMSIM. The equations used in EXCEL are taken from section 7.0 General Theory of CLIMSIM for Windows Version 1.0 Users Manual and General Theory. The EXCEL worksheet produced the same results as CLIMSIM with the same input. The worksheet and CLIMSIM file used for this validation can be found on the CD attached to the Software Validation and Plan and Report For CLIMSIM for Windows Version 1.0 in QA records. The following equation is a correction to the users manual on page 19, equation 11:

$$td_2 = td_1 + \left\{ \frac{v_1^2 - v_2^2}{2} + PE + \frac{\sum Q_s}{m} \right\} / c_{pm}$$

The users manual omits the '+' after 'td', this error was caught long before validation results were compared.

5-9-05 T.M.

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5-20-05

The following printouts illustrate the CLIMSIM Validation input and results data, and EXCEL worksheet results. The Dry Wall, VRT, MST, and HTC were not included in the EXCEL results since the algorithm 5-20-05 CLIMSIM manual did not provide equations that could be input into EXCEL.

VALIDA-1.CSW - Branch Data Summary

General Branch Information:

Branch Name - Validation Model

Description -

Output Interval = 20 m

Airway Properties:

Length = 20 m

Depth at Inlet = 0 m

Depth at Outlet = 0 m

Area = 19.50 m²

Perimeter = 17.23 m

Friction Factor = 0.0100 kg/m³

Wetness Factor = 0.01

Age at Inlet = 1 days

Age at Outlet = 1 days

Ventilation at Intake:

Quantity = 15.00 m³/s

Pressure = 40.000 kPa

Dry Bulb Temperature = 25.00 °C

Wet Bulb Temperature = 23.00 °C

Rock Thermal Properties:

VRT at Inlet = 22.0 °C

Geothermal Step = 30 m/°C

Conductivity = 1.400 W/m°C

Diffusivity = 2.000 m²/s × 10⁻⁶

Heat Source Data:

Linear beginning at 0 m, Length = 20 m

Sensible Heat = 1.45 kW, Latent Heat = 0.00 kW

CLIMSIM Input Printout

T.M.
5-20-05

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Row	Distance (m)	Dry Bulb (°C)	Wet Bulb (°C)	Pressure (kPa)	Moisture (g/kg)	Density (kg/m ³)	Humidity (%)	Enthalpy (kJ/kg)	Sigma Heat (kJ/kg)	Dry Wall (°C)	VRT (°C)
1	0	25.00	23.00	40.000	46.02	0.455	87.02	142.37	137.94	24.4	22.0
2	20	24.92	22.99	40.000	46.03	0.455	87.43	142.30	137.87	24.3	22.0
3	Linear heat source starts at 0 m, length = 20 m, sensible heat = 1.45 kW, latent heat = 0.00 kW										
4	Strata heat totals: sensible heat = -2.00 kW, latent heat = 0.06 kW										
5	Other heat totals: sensible heat = 1.45 kW, latent heat = 0.00 kW										
6	Metabolic rate = 200 W/m ² , Skin temperature limit value = 36.00 °C										

VALIDA-1.CSW - Results Table - Validation Model

Row	MST (°C)	ET (°C)	WBGT (°C)	Strata QL (kW)	Strata QS (kW)	HTC (W/m ² °C)
1	27.71	20.69	23.60	0.00	0.00	8.978
2	27.69	20.64	23.57	0.06	-2.00	8.969
3						
4						
5						
6						

VALIDA-1.CSW - Results Table - Validation Model

CLIMSIM Output Printout

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CLIMSIM Validation Results

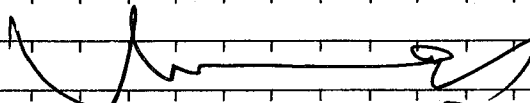
T.M. 5-20-05

Distance m	Dry Bulb C	Wet Bulb C	Pressure kPa	Moisture g/kg	Density kg/m3	Humidity %
0	25.000	23.000	40.000	46.022	0.455	87.020
20	24.922	22.991	40.000	46.025	0.455	87.432
Enthalpy kJ/kg	Sigma Heat kJ/kg	ET C	WBGT C	Strata QL kW	Strata QS kW	
142.374	137.942	20.693	23.600	0.000	0.000	
142.299	137.868	20.635	23.570	0.056	-2.002	

EXCEL Worksheet Results

T.M. 5-20-05

I have reviewed this scientific notebook and find it in agreement with QAP-001.


5-24-05

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