VENTILATION - HOISTING STUDY OF THE KENILWORTH MINE

INDEPENDENT COAL & COKE COMPANY

KENILWORTH, UTAH

by

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A thesis submitted to the faculty of the University of Utah in partial fulfillment of the requirements for the degree of

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by

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ABSTRACT

This study was made to determine the value of efficiency studies of various aspects of coal mining.

Studies were made of air coursings and the effect of adding or eliminating air courses on fan performance. Mine characteristics were compared under different conditions of fans, stopped and running, at several blade settings. Power costs were compared for various quantities and circumstances.

A detailed study of a hoist indicated that it was underloaded even though it was causing the loaders to be delayed. Steps were taken to correct the defect.

The results of this analysis indicate that efficiency studies of mining operations and equipment can save much money for a mining company.

ACKNOWLEDGMENTS

I wish to express my appreciation to those who helped to further this research program. Professor John E. Willson has been of great help with his advice and suggestions, both technical and informal.

Mr. A. E. Condon of the Jeffrey Manufacturing Company contributed markedly by furnishing fan characteristic curves and professional advice.

The men and officials of Independent Coal & Coke Company deserve particular thanks for their cooperation and patience. I am especially grateful to Mr. E. O. Jackson, Superintendent, and Mr. Henry Trauntvein, Assistant Superintendent.

My wife, Darlene, has earned my gratitude for her patience and consideration while I took time to work on this project.

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INTRODUCTION

Kenilworth, Utah, is located in Carbon County, Utah, approximately five miles north of Price, Utah. The town was named after Kenilworth Castle in the Warwick and Leamington parliamentary division of Warwickshire, England, on a tributary of the Avon. It is said that the cliffs surrounding Kenilworth, Utah, are reminiscent of the ruins of the castle.

The coal mine, which is also called Kenilworth, was first discovered in 1905 by W. H. Lawley. Records indicate that the first coal was produced in the year 1907.

The property is served by a branch line of the Denver & Rio Grande Western Railroad which joins the main line at Helper, Utah.

The mine itself is composed of three principal seams of coal which dip about 6-1/2 degrees to the north and northeast. At present only the upper, or Kenilworth, seam is mined. The middle one, known as the Blue Blaze seam, is low coal from four to five feet thick and has a peculiar bluish tint to its coloring. The lower one, known as the Aberdeen seam, is about ten to twelve feet thick and has been mined extensively in the past.

The access haulage road is a rock tunnel 8,200 feet long driven at right angles to the strike of the bed. Double track is laid the entire length of this rock tunnel except for a 200-foot three-rail system at the intersection of the tunnel with the Aberdeen seam.

The fifteen-foot seam of coal is mined by the room and pillar system. Advance mining is next to the top rock. Rooms and entries are driven from ten to twelve feet high. Retreat mining recovers bottom coal and pillars. Roof bolting is used extensively as roof support on the advance. Roof bolting and timbering are used on the retreat. Ribs are pinned with four-foot wooden pins.

Coal on advance work is prepared with machines known locally as conversions. The name stems from the fact that the machines, at one time, were 7-AU track-mounted cutting and drilling machines. They have been converted at the Kenilworth mine shop to rubber-tired cutting machines, each with an hydraulic bug duster attached and mounted with a Joy CD-40 drill. Each machine is powered with one 50 H.P. electric motor which operates a complex system of hydraulic pumps, and with one 50 H.P. electric motor which operates the cutter chain.

Preparation of coal in pillar work is accomplished with a Joy CD-41 drill and with a Joy CD-25 drill. No cutting of coal in pillar work is done. Shooting is done on the solid in pillar work.

The coal is loaded at the face with Joy 11-BU loaders. These have a rated capacity of five tons per minute and have proven themselves to be especially rugged and adaptable machines.

Coal is transported from the working faces with Joy 10-SC shuttle cars. These cars move the coal to a loaderhead in the entry where they discharge their load into mine cars. The mine cars are moved by means of trolley locomotives to partings on the slope. At this point the loads are moved to the top of the slope with a hoist and rope.

From a parting at the top of the slope, loads are transported with a trolley locomotive along the strike of the seam to the rock tunnel, and then to the tipple outside of the mine.

All machinery in the mine is rated at 250 volts D.C. Primary power is introduced into the mine in the form of 2,300 volts A.C. through a rock tunnel near No. 2 fan, and also through a bore hole from the surface near No. 3 fan. Motor generator sets and rectifier sets convert the alternating current to direct current.

The two main hoists and one pump operate with 2,300 A.C. electricity.

The mine is ventilated with three exhaust-type fans which move about 264,000 cfm of air. It is anticipated that No. 1 fan will be shut down in the near future and ventilation re-routed to No. 2 and No. 3 fans.

No. 1 fan is an 11-foot by 5-foot centrifugal exhaust fan installed in 1924. It is exhausting 115,700 cfm.

No. 2 fan is a 7-foot by 3-foot centrifugal exhaust fan installed in 1918. It is exhausting 43,700 cfm.

No. 3 fan is a Jeffrey 8H-84 Aerodyne fan installed in 1949. It is exhausting 104,700 cfm.

The present workable entries in the mine are located on each of the two slopes. The hoist at the top of No. 2 slope is powered by two 500 H.P. motors and has a maximum speed of 1,390 feet per minute. A 1-1/4 inch rope is used to pull nine-car trips. The maximum grade is 17-1/2 per cent. Cars weigh 2.8 tons, each, with a capacity of five tons of coal.

The hoist at the top of No. 4 slope is powered by a 150 H.P. motor and has a maximum speed of 850 feet per minute. At present, six-car trips are pulled up this slope with a 1-1/8 inch rope. A new hoist is being installed on No. 4 slope which will have two 450 H.P. motors and an estimated maximum speed of 1,500 feet per minute. A 1-1/4 inch rope will be used and ten-car trips will be hoisted as soon as the entries below are made ready to handle them.

PURPOSE

This thesis was written to demonstrate that efficiency studies of the operation of machinery can be made to the economic benefit of a mining company.

SCOPE

Hoisting and ventilation, two important problems common to any underground mining operation, were chosen and efficiency studies completed. The writer had the opportunity to make these studies, inaugurate the changes that he desired, and obtain results that showed a considerable monetary saving due to the work done.

The author made the engineering studies, supervised the actual changes and correlated the results. This work paves the way for similar operational studies.

VENTILATION

A forced flow of air through a mine, adequately controlled and regulated, is an absolute necessity for safe and efficient mining.

In the past, several methods have been used to ventilate mines. Among the most common have been natural ventilation and heated stacks. Today, the most common method of ventilation is either blowing type or exhausting type, electrically driven, centrifugal or axial flow fans.

At Kenilworth, two types of exhaust fans are used. One is a multiblade, forward curved, double inlet, centrifugal type. By opening and closing doors the fan may be used either as an exhausting fan or as a blowing fan. The other is an axial flow fan using propeller blades with seven different settings to produce seven different characteristics. These exhaust fans provide a movement of air in a controlled direction by creating an area of pressure below that of atmospheric on the inlet side of the fan. They may be reversed by changing the direction of rotation, but the output is reduced by about 35 per cent.

There are, basically, three factors which determine the flow of air through a mine:

1 - the quantity of air flowing.

2 - the pressure differential between the intake and the exhaust.

3 - the resistance the mine offers to the flow of air.

At any stage of its development, a mine has a certain characteristic which may be expressed as: $P = rQ^2$.

Atkinson's formula for the pressure required to overcome resistance when a quantity of air is flowing:

$$P = \frac{KSV^2}{A} \quad \text{or} \quad P = \frac{KSQ^2}{A^3}$$

P = pressure in pounds per square foot
K = resistance in pounds pressure per square foot
S = rubbing surface (perimeter times length)
V = velocity in feet per minute
Q = quantity in cubic feet per minute
A = area in square feet

r then becomes $\frac{KS}{A^3}$. The value K, as generally given, is for air weighing 0.075 lbs. per cu. ft., or air at sea level and 70° F. The value P is then corrected for the actual density of the air being measured. K may be found experimentally for any given duct from the formula:

$$K = \frac{P \times A \times 0.075}{w \times S \times V^2}$$, where w = weight of air.

Characteristic curves for each fan comparing quantity, pressure, horsepower and efficiency were obtained from the fan manufacturer for use in this study. The fans can be operated at various speeds within the manufacturer's specifications to produce different characteristics from those provided.

Fan laws, with a constant mine resistance, efficiency remaining constant, are:

1 - volume of air varies as the speed of the fan.
2 - pressure developed varies as the square of the speed.
3 - power required varies as the cube of the speed.

Correction for altitude:

1 - volume remains constant regardless of density of air.
2 - pressure varies directly as the air density.
3 - horsepower varies directly with the density.
4 - efficiency remains constant regardless of density.

Until May 1, 1958, Kenilworth mine was ventilated with three exhaust type fans. No. 1 fan was a Jeffrey multiblade, forward curved, double inlet, reversible, 11-foot by 5-foot centrifugal fan, serial No. 2441, purchased in 1924. No. 2 was a Jeffrey multiblade, forward curved, double inlet, reversible, 7-foot by 3-foot centrifugal fan, serial No. 10502, purchased in 1918. No. 3 was a Jeffrey 8H-84 Aerodyne fan, serial No. 8673, purchased in 1947.

At one time there were seven intakes which supplied air to these fans. The elevations of the fans and intakes:

No. 1 fan	7,363 feet
No. 2 fan	7,247 feet
No. 3 fan	7,209 feet
Main portal intake	6,705 feet
Old portal in No. 2 canyon, intake	7,060 feet
Manway in No. 2 canyon, intake	7,150 feet
Arronco mine connection, intake	7,150 feet
Millburn mine connection, intake	7,200 feet
*Rock tunnel by No. 3 fan, intake	7,200 feet
*Aberdeen entrance between No. 2 & No. 3 fans, intake	7,000 feet
Average elevation, intakes	7,060 feet

The following calculations for natural ventilating pressures are based on an outside temperature of 70°F. and an inside average temperature of 55° F. Barometric readings are taken at the lamphouse, and barometric readings for the various elevations are calculated for standard conditions and corrected to the lamphouse barometer. The elevation at the lamphouse is 6,690 feet. Pressures designated as "positive" indicate that the air tends to flow from the observer into the mine.

* These openings have since been closed off.

No. 1 FAN

Barometer = 23.29", temp. = 70°F., wt. of air = 0.05831 #/ft.^{3}

Intake elevation = 7,060 ft.

7,363 ft. - 7,060 ft. = 303 ft. difference in elevation.

Average underground barometric reading = 23.42", temp. = 55° F.,

wt. = 0.06034 #/ft.^{3}

0.06034 - 0.05831 = 0.00203 #/ft.^{3} 0.00203 x 303 = 0.61509 #/ft.^{2}

0.61509/5.2 = 0.12" w.g. positive

No. 2 FAN

Barometer = 23.49", temp. = 70° F., wt. of air = 0.05881 #/ft.^{3}

7,247 - 7,060 = 187 ft. difference in elevation.

Average underground barometric reading = 23.58", temp. = 55° F.,

wt. = 0.06076 #/ft.^{3}

0.06076 - 0.05881 = 0.00195 #/ft.^{3}.   0.00195 x 187 = 0.36465 #/ft.^{2}

0.36465/5.2 = 0.07" w.g. positive

No. 3 FAN

Barometer = 23.52", temp. = 70° F., wt. of air = 0.05888 #/ft.^{3}

7,209 - 7,060 = 149 ft. difference in elevation.

Average underground barometric reading = 23.59", temp. = 55° F.,

wt. = 0.06078 #/ft.^{3}

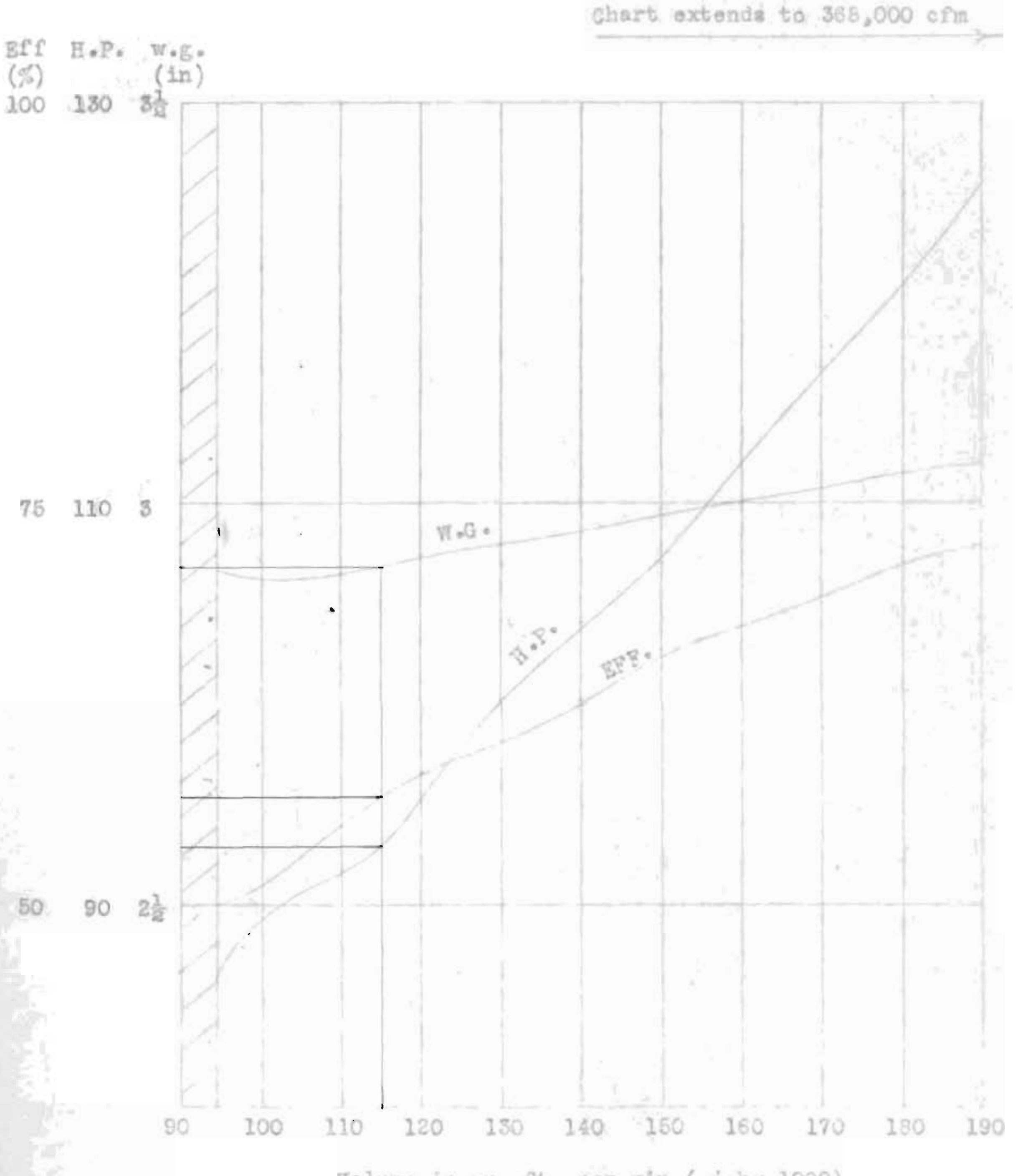
0.06078 - 0.05888 = 0.00190 #/ft.^{3}.   0.00190 x 149 = 0.28310 #/ft.^{2}

0.28310/5.2 = 0.05" w.g. positive

The measured static pressure at No. 1 fan was 2.39 inches water gage. Since the average natural ventilating pressure is in a direction opposite to the flow of air with the fan running, the fan must first overcome 0.12" w.g. before producing a quantity of air. The pressure to be used with the characteristic curve is then 2.39" - 0.12" = 2.27". This pressure must then be corrected for an air density of 0.075 #/ft.^{3}. Therefore, 2.27" x 29.92/23.29 = 2.92" w.g. This is the value to be used with the characteristic curve on page 11 to locate the fan efficiency, quantity of air being delivered, and brake horsepower. The brake horsepower is then corrected for altitude (horsepower varies directly with the altitude.) From the curve: fan efficiency = 56.8%, quantity = 115,700 cfm, and brake horsepower = 93.1 x 23.29/29.92 = 72.5.

The measured static pressure at No. 2 fan was 1.99" w.g. Since the natural ventilating pressure is in a direction opposite to the flow of air with the fan running, the fan must first overcome 0.07" w.g. before producing a quantity of air. The pressure to be used with the characteristic curve is then 1.99" - 0.07" = 1.92". This pressure corrected for an air density of 0.075 #/ft.^{3} is: 1.92" x 29.92/23.49 = 2.45" w.g. From the characteristic curve for No. 2 fan shown on page 12 the fan efficiency = 59.8%, quantity = 43,700 cfm, and brake horsepower = 27.9 x 23.49/29.92 = 21.9.

The measured static pressure at No. 3 fan was 2.42" w.g. The fan must overcome a natural ventilating pressure of 0.05". The pressure to be used with the characteristic curve on page 13 is then 2.42" - 0.05" = 2.37". Corrected for an air density of 0.075 #/ft.^{3} this becomes 2.37" x 29.92/23.49 = 3.02" w.g. From the curve on No. 3 fan, the fan efficiency =

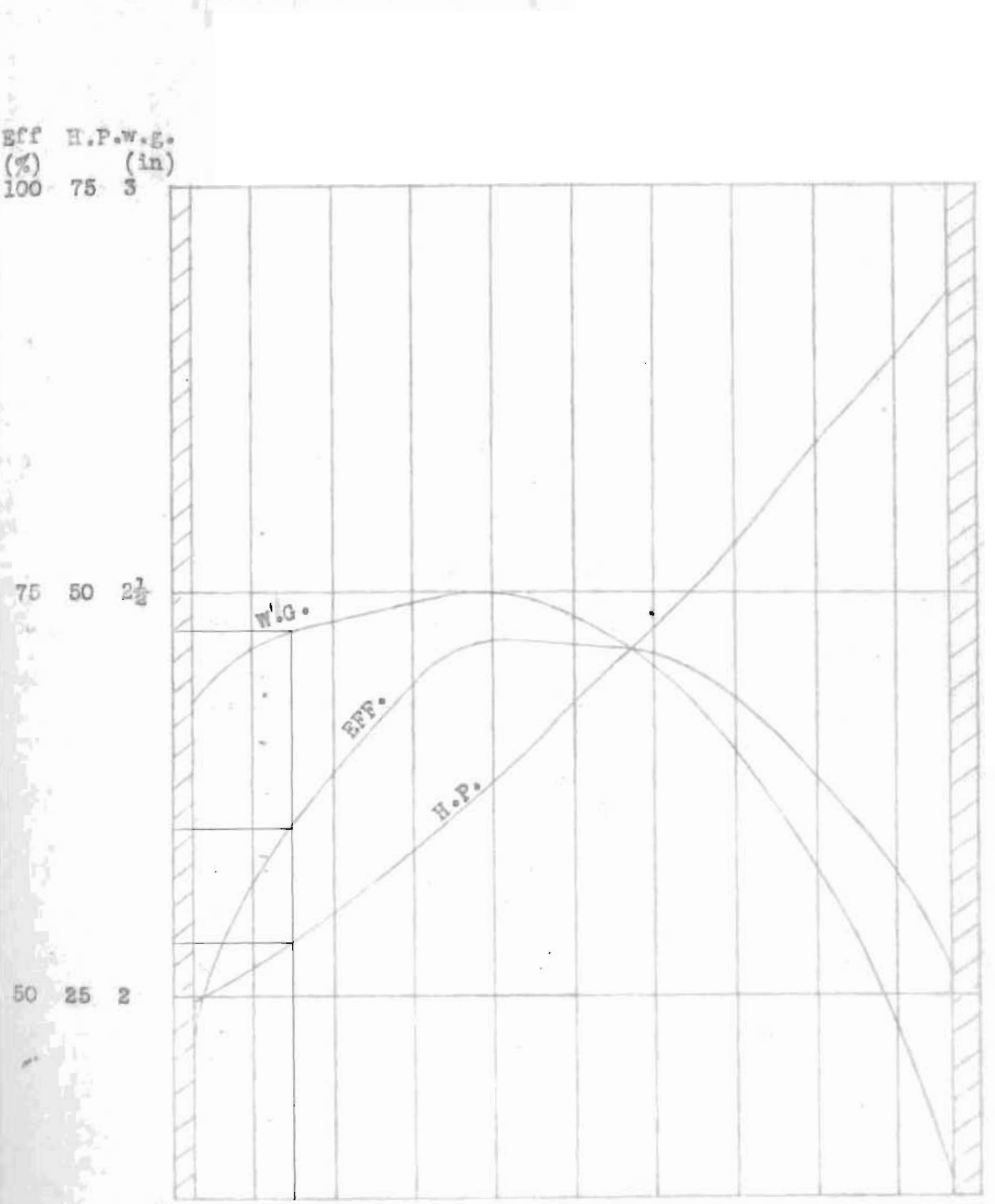


Performance curve for Jeffrey 11' X 5' centrifugal fan

Fan speed = 154 RPM. Weight of air = 0.075 lb per cu ft

Fan Serial #2441

FIGURE NUMBER 1



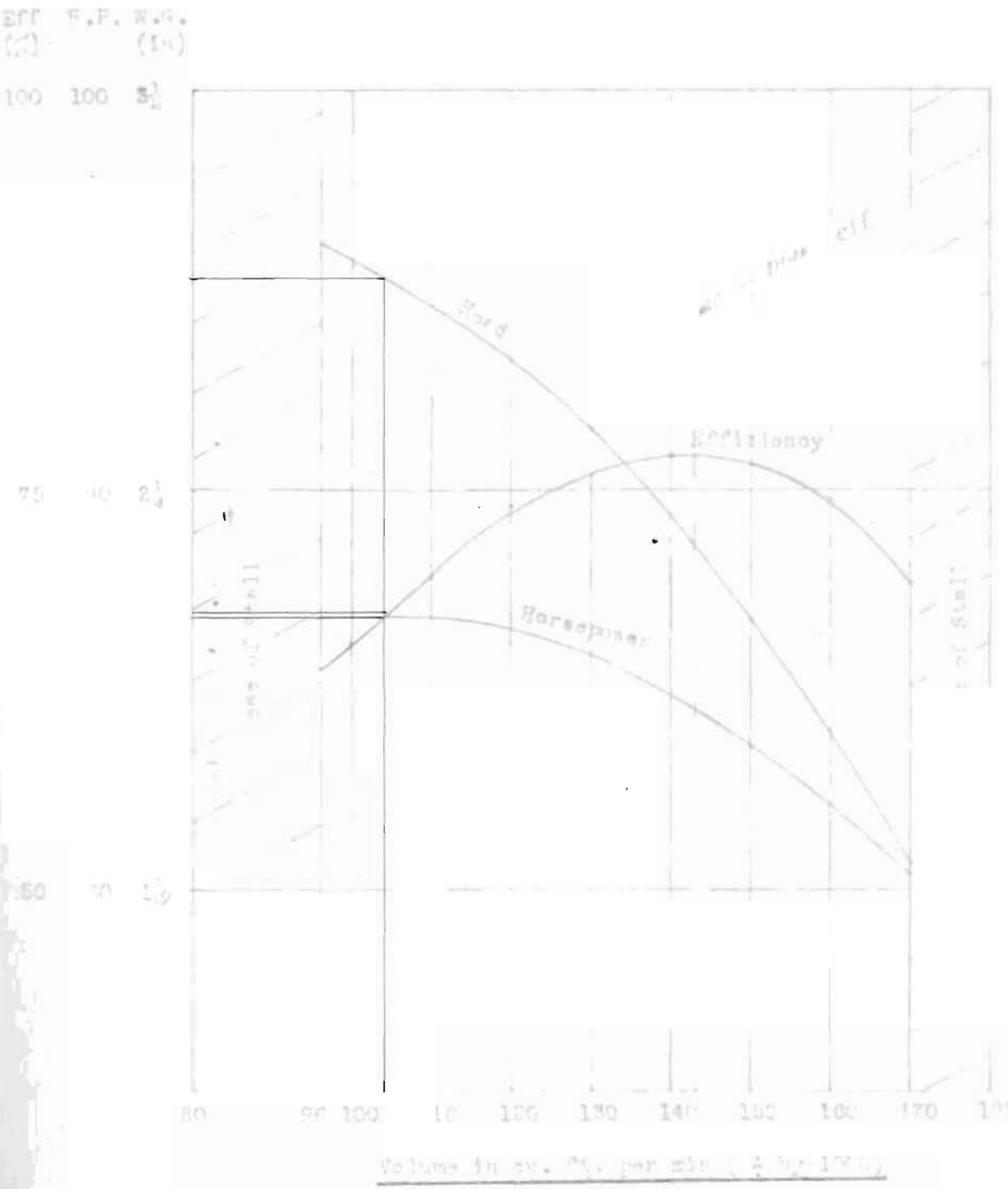
Volume in cu. ft. per min (÷ by 1000)

Performance curve for Jeffrey 7' X 3' centrifugal fan

Fan speed = 220 RPM. Weight of air = 0.075 lb per cu ft

Fan Serial #10502

FIGURE NUMBER 25



Performance curve for [illegible]

[illegible] speed = [illegible] Weight of air = [illegible] lb. per

FIGURE NUMBER 3

67.2%, quantity = 104,700 cfm, and brake horsepower = 73.7 x 23.49/29.92 = 57.9.

After No. 1 fan was shut down and seals installed and air re-routed as shown on pages 17 and 18, tests were made on No. 2 and No. 3 fans.

The measured static pressure at No. 2 fan was 1.35" w.g. The conditions for natural ventilation were the same as before, so the pressure to be used for sea-level conditions is 1.28" x 29.92/23.45 = 1.63" w.g. The characteristic curve furnished by the Jeffrey Manufacturing Company does not cover this range; however, the conditions were measured as follows:

$$\text{BHP} = \frac{2,300 \times 13.5 \times 0.90 \times 1.732 \times 0.95 \times 0.99}{746} = 61.1 \text{ H.P.}$$

$$\text{AHP} = \frac{123,300 \times 1.63 \times 5.2}{33,000} = 31.6 \text{ H.P.}$$

$$\text{Eff.} = \frac{31.6}{61.1} = 51.7\%$$

Quantity = 123,300 cfm

The measured static pressure at No. 3 fan was 2.20" w.g. After correcting for natural ventilation and barometric pressure, the static pressure was 2.74" w.g. From the characteristic curve on No. 3 fan shown on page 19, the fan efficiency = 75%, quantity = 125,000 cfm, and brake horsepower = 72.5 x 23.45/29.92 = 56.9.

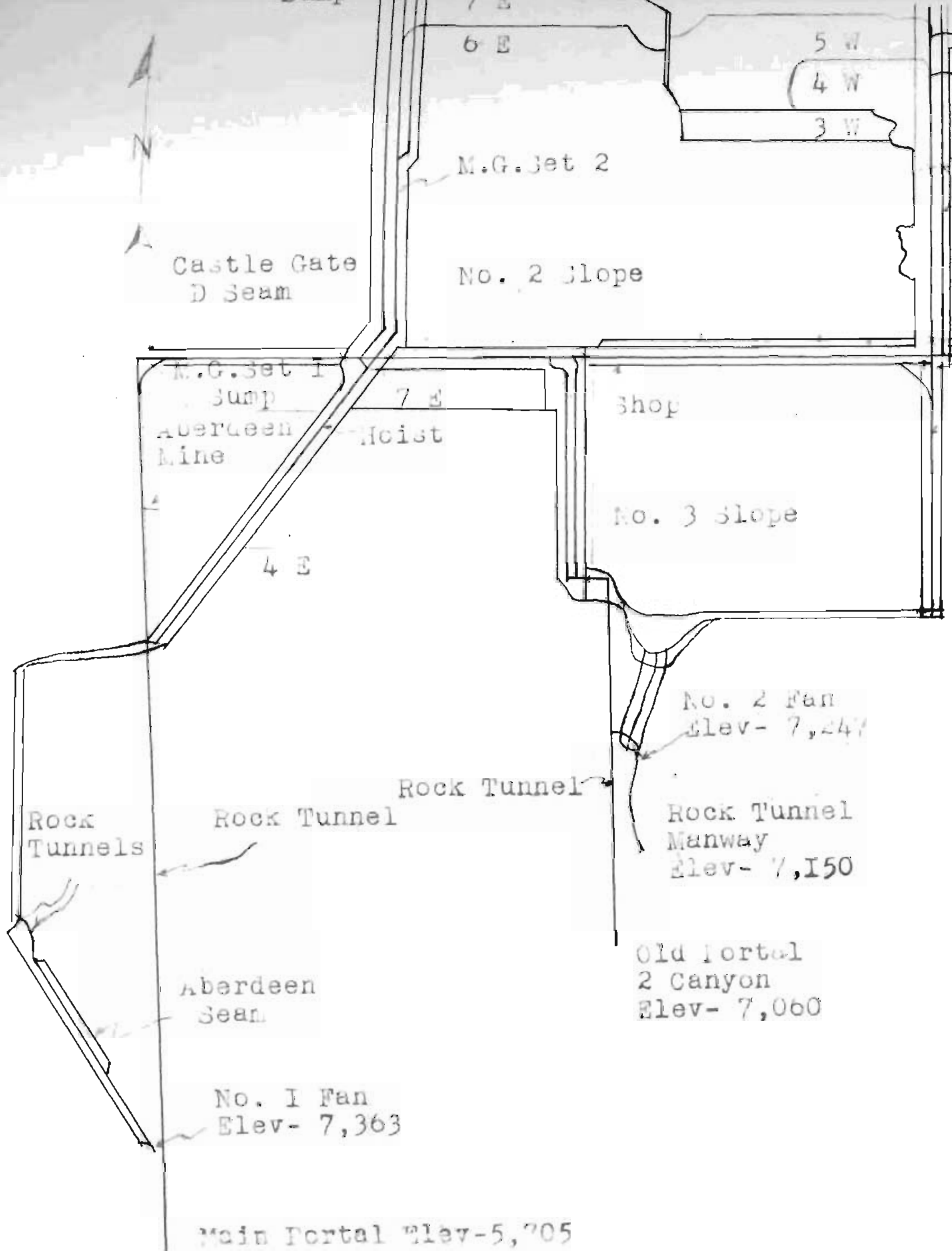
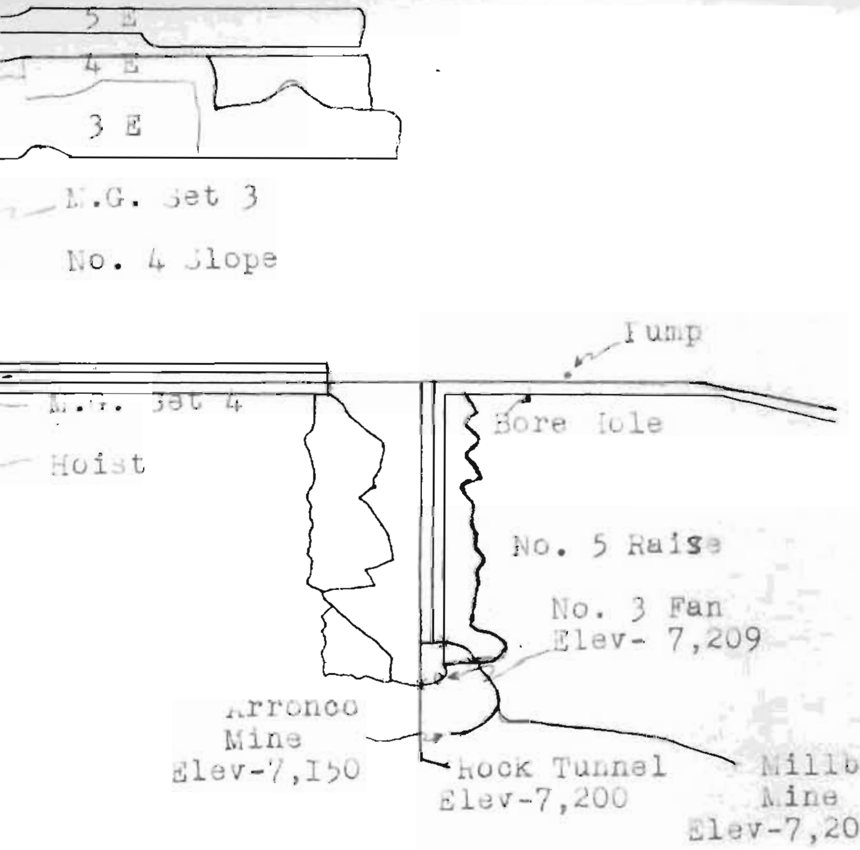


FIGURE NUMBER 4



KENILWORTH MINE
SCALE I"- APPROX. I,500

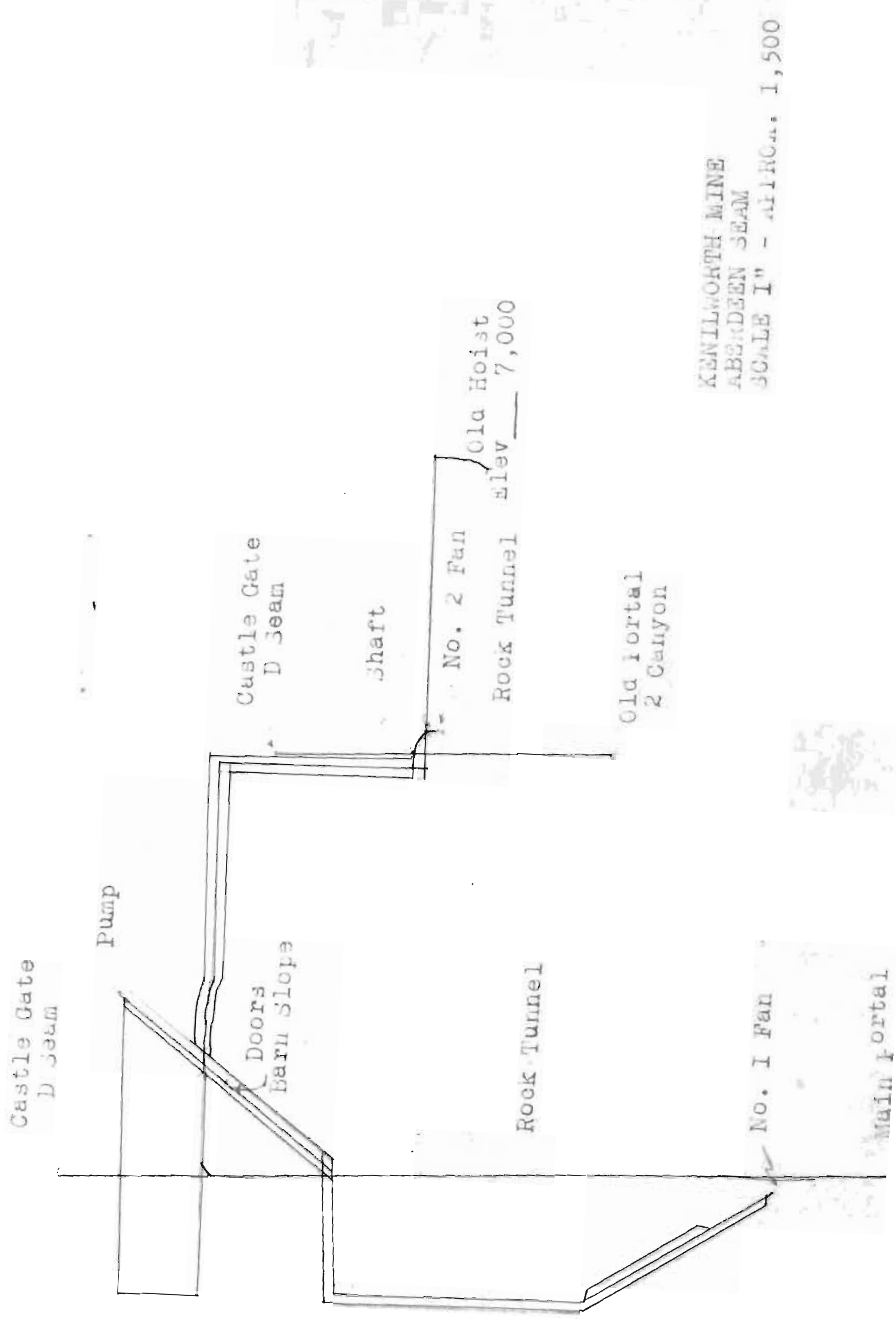
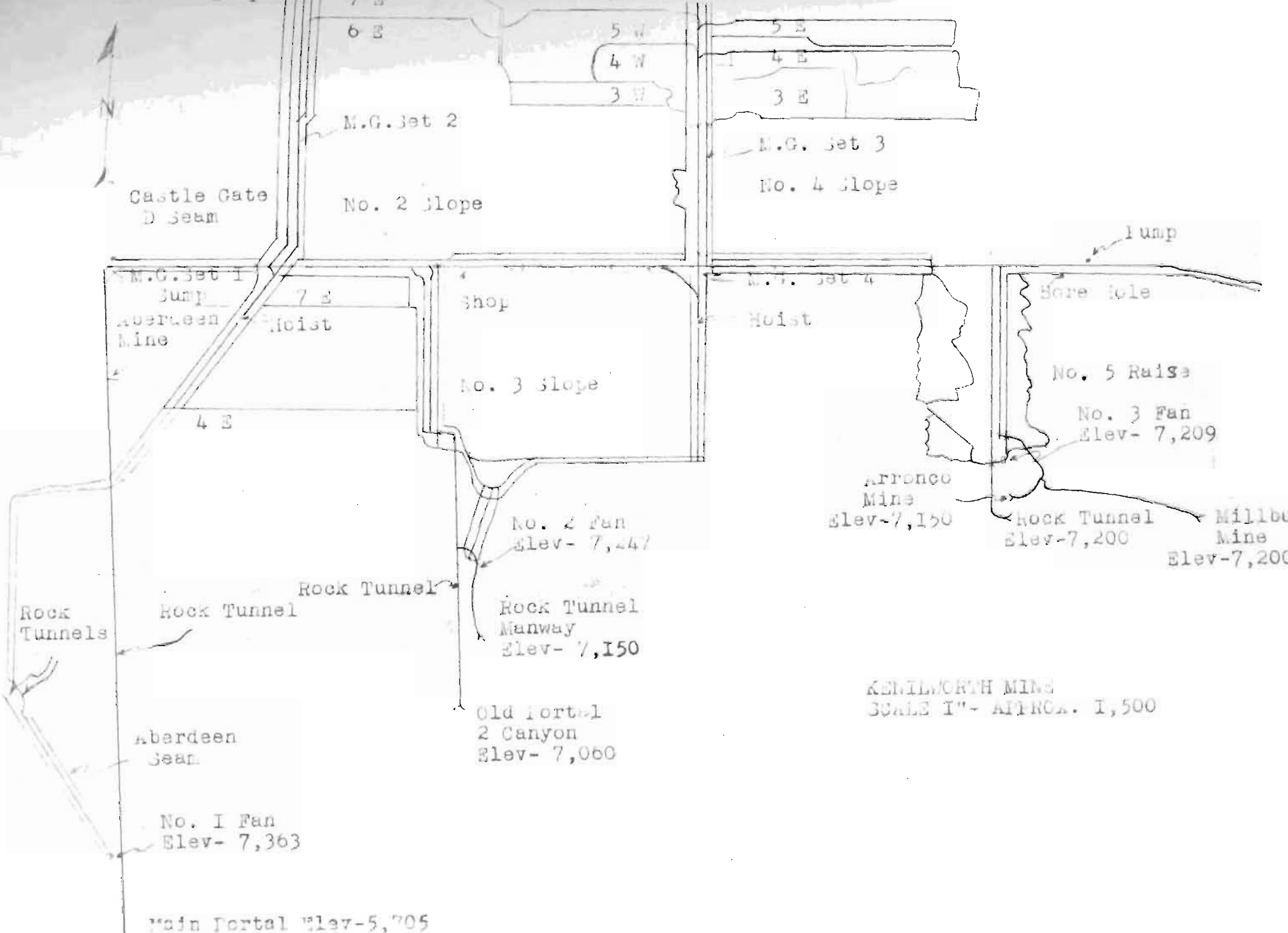
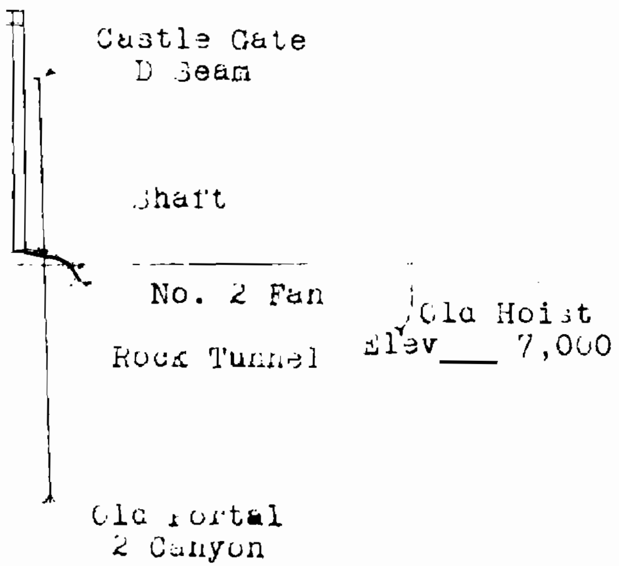


FIGURE NUMBER 5

FIGURE NUMBER 6





KENILWORTH MINE
ABERDEEN SEAM
SCALE I" - APPROX. 1,500

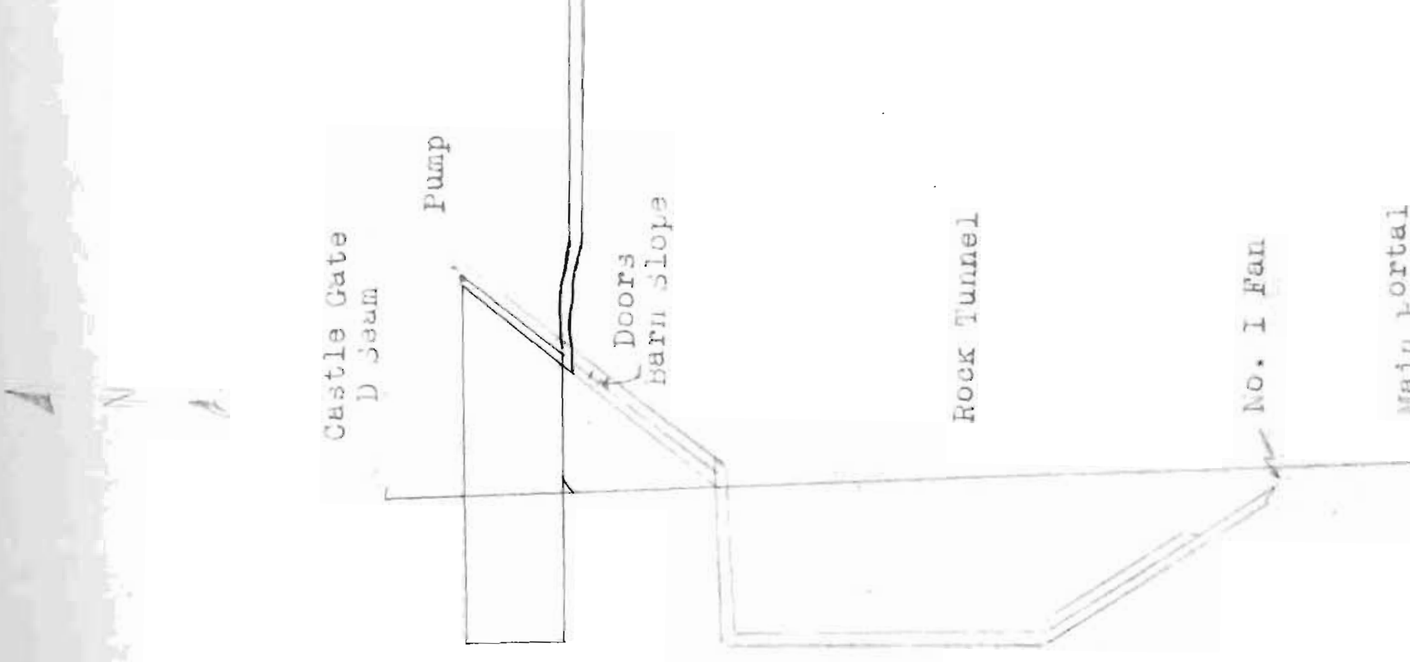
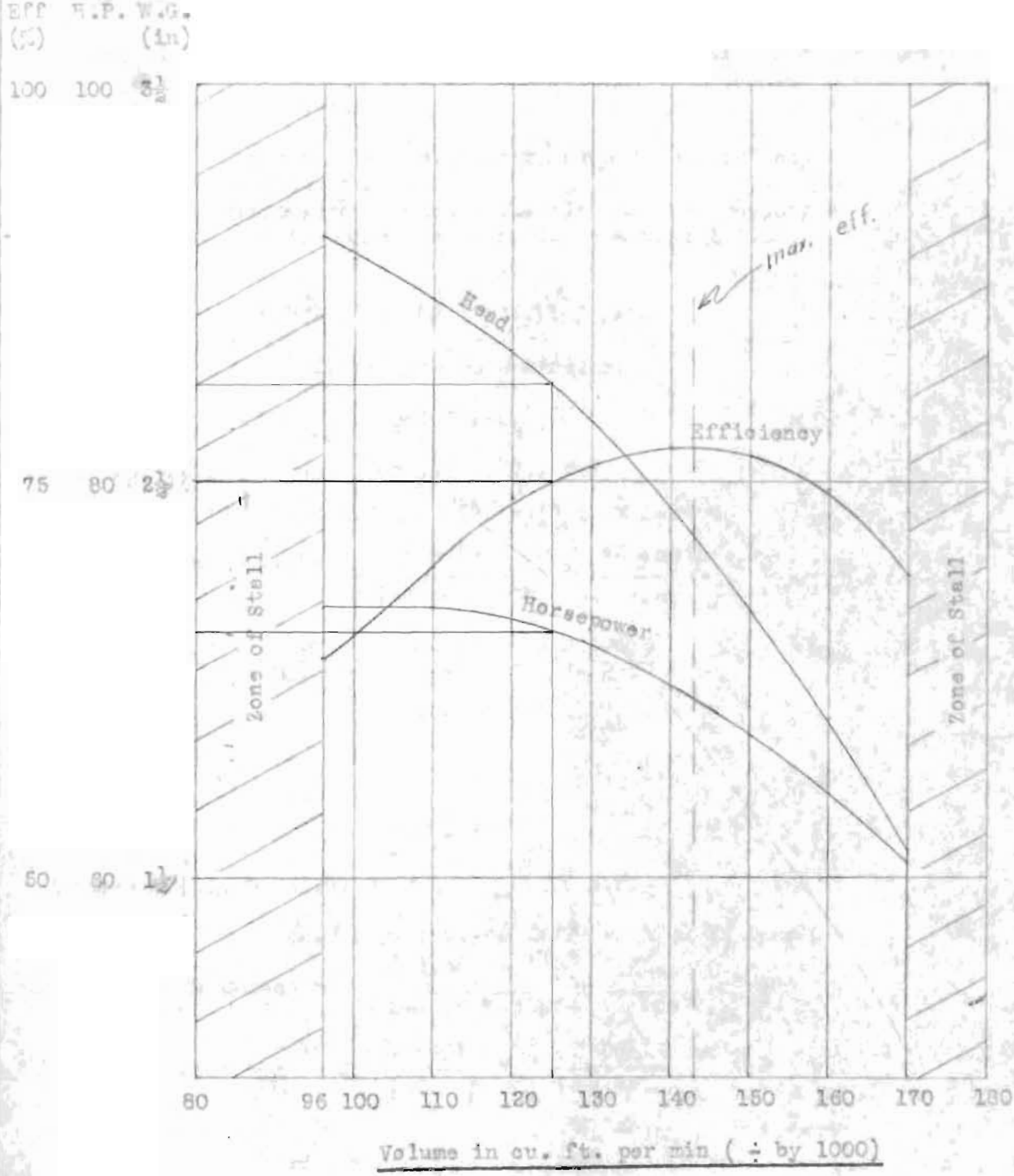


FIGURE NUMBER 7



Performance curve for 8H-84 Aerodyne Fan. No 4 blade position

Fan speed = 630 RPM. Weight of air = 0.075 lb. per cubic foot

FIGURE NUMBER 8

There are two reasons for wanting to make important air changes in a mine by installing or removing a fan, building or removing seals, or changing directions of air coursing:

1 - a change in the distribution of air required at the working faces.
2 - an attempt to eliminate fugitive and unnecessary air, and to achieve economy in mine ventilation.

POWER COSTS OF INDIVIDUAL FANS

Three fans in operation.

No. 1 Fan

Corrected H.P. = 72.5/.95 x .99 = 77.1 H.P.

77.1 H.P. x 0.746 = 57.6 KW Demand

$$57.6 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 1,110$$

$$57.6 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW Hr.}} = \$\ 3,160$$

TOTAL = $ 4,270

No. 2 Fan

Corrected H.P. = 21.9/.95 x .99 = 22.8 H.P.

22.8 H.P. x 0.746 KW/HP = 17.1 KW Demand

$$17.1 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 330$$

$$17.1 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW Hr.}} = \$\ 930$$

TOTAL = $ 1,260

No. 3 Fan

Corrected H.P. = 57.9/.95 x .99 = 60.4 H.P.

60.4 H.P. x 0.746 KW/HP = 45.0 KW Demand

$$45.0 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 860$$

$$45.0 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$2,460$$

TOTAL = $3,320

Total yearly power costs, all three fans = $ 8,850

Two fans in operation.

No. 2 Fan

Corrected H.P. = 48.0/.95 x .99 = 50.0 H.P.

50.0 H.P. x 0.746 KW/HP = 37.3 KW Demand

$$37.3 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 720$$

$$37.3 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 2,040$$

TOTAL = $ 2,760

No. 3 Fan

Corrected H.P. = 56.9/.95 x .99 = 59.3 H.P.

59.3 H.P. x 0.746 KW/HP = 44.2 KW Demand

$$44.2 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 850$$

$$44.2 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 2,420$$

TOTAL = $ 3,270

Total yearly power costs for two fans = $ 6,030

The quantity of air normally required to ventilate a section at Kenilworth mine is 30,000 cfm as measured at the regulator. The true quantity of air passing through a box-type regulator such as that used at Kenilworth is about 85% of the measured value. The actual quantity of air then required to ventilate a section is 25,500 cfm. Prior to the time No. 1 fan was shut down, six sections were being worked in the mine. Of the three sections on No. 2 slope, 6th E. and 7th E. pillar sections were ventilated over the cave and the air was moved up No. 4 slope returns.

The air distribution was as follows:

West return No. 2 slope	8,470 cfm
East return No. 2 slope	32,030 cfm
West return No. 4 slope	37,380 cfm
East return No. 4 slope	86,620 cfm
Total	164,500 cfm

Other air required:

No. 2 hoist	7,000 cfm
No. 4 hoist	7,000 cfm
One MG set, No. 2 slope	5,000 cfm
Two MG sets, No. 4 slope	10,000 cfm
One MG set, Old Dispatch, Main East.	5,000 cfm
One pump and 2300 line, Main East ..	15,000 cfm
One pump, Barn Slope, and seals bottom mine	15,000 cfm
Inside shop	5,000 cfm
Total	69,000 cfm

Total air required to operate .... 233,500 cfm

Air delivered by three fans .... 264,100 cfm

Fugitive air .... 30,600 cfm

$$\text{Effective air} = \frac{233{,}500}{264{,}100} \times 100 = 88\%$$

Power costs wasted per year = $ 8,850 x 0.12 = $ 1,060

When No. 1 fan was shut down, only two sections were in operation - 8th E. and 8th W., No. 2 slope.

The air distribution should have been as follows:

West return No. 2 slope	34,000 cfm
East return No. 2 slope	32,000 cfm
West return No. 4 slope	30,000 cfm
East return No. 4 slope	30,000 cfm
Total	126,000 cfm

Other air required:

No. 2 hoist	7,000 cfm
Seals above No. 4 hoist	7,000 cfm
One MG set, No. 2 slope	5,000 cfm
One MG set, No. 4 slope	5,000 cfm
One MG set, Old Dispatch, Main East	5,000 cfm
One pump and 2300 line, Main East	15,000 cfm
One pump, Barn Slope, and seals	15,000 cfm
Inside shop	5,000 cfm
Total	64,000 cfm

Total air required to operate .... 190,000 cfm

Air delivered by fans .... 248,300 cfm

Fugitive air .... 58,300 cfm

$$\text{Effective air} = \frac{190,000}{248,300} \times 100 = 77\%$$

Power costs wasted per year = $ 6,030 x 0.23 = $ 1,390

On May 8, 1958, the blade position on No. 3 fan was changed from the No. 4 setting to the No. 1 setting, with the following results:

The measured static pressure at No. 2 fan was 1.08" w.g. After correcting for natural ventilation and barometric pressure, the static pressure was 1.30". The chart furnished by Jeffrey Manufacturing Company does not cover this range; however, the conditions were measured as follows:

$$BHP = \frac{2300 \times 14.5 \times .90 \times 1.732 \times .95 \times .99}{746} = 65.5 \text{ H.P.}$$

$$AHP = \frac{141,100 \times 1.30 \times 5.2}{33,000} = 28.9 \text{ H.P.}$$

Quantity = 141,100 cfm

$$\text{Efficiency} = \frac{28.9}{65.5} \times 100 = 44.1\%$$

The measured static pressure at No. 3 fan was 1.70" w.g. After correcting for natural ventilation and barometric pressure, the static pressure was 2.10" w.g. From the chart on No. 3 fan, page 25, the fan efficiency = 80%, quantity = 119,200 cfm, and brake horsepower = 49.2 x 23.45/29.92 = 38.6 H.P.

POWER COSTS

No. 2 Fan

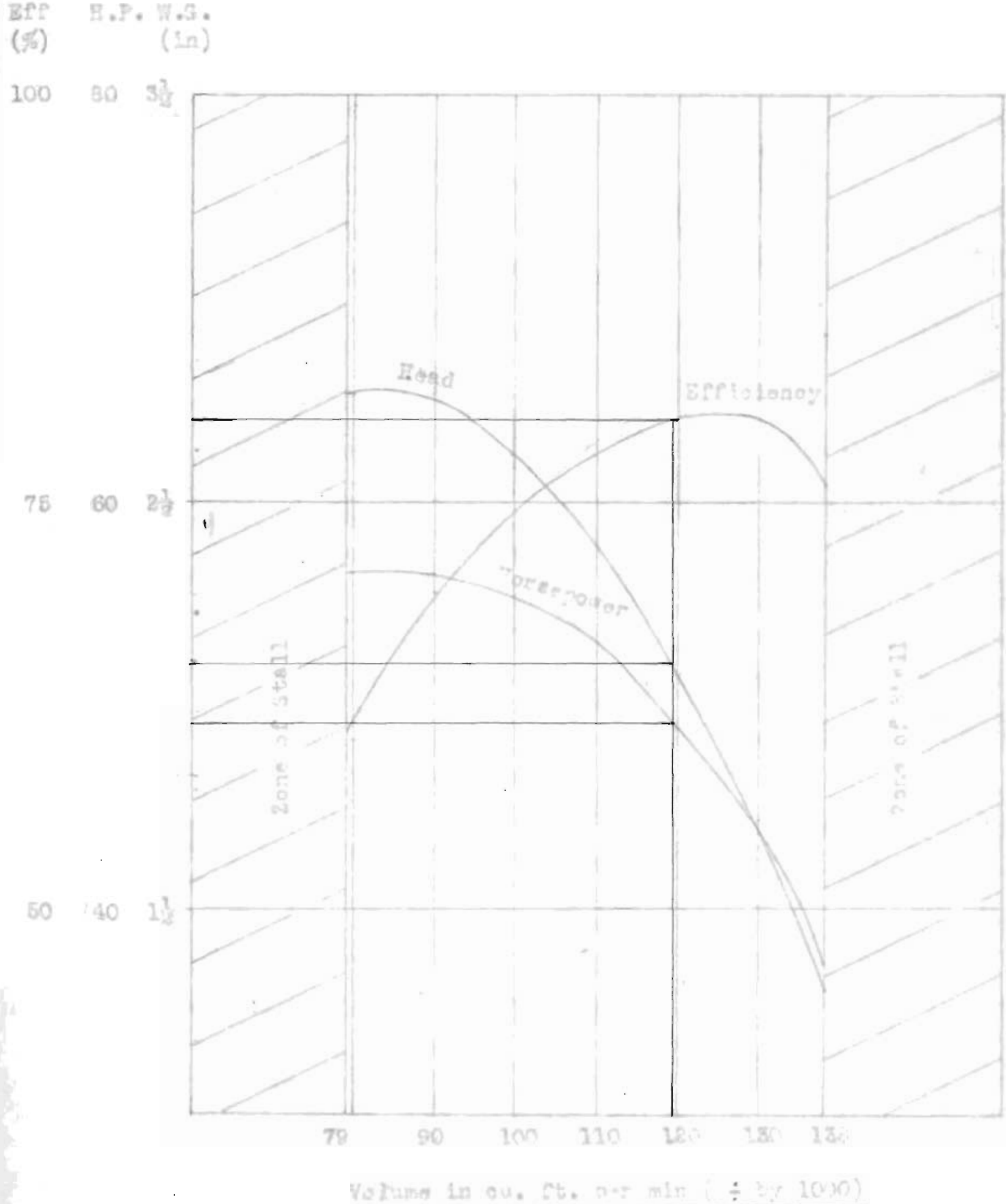
Corrected H.P. = 51.4/M.E. x D.E. = 51.4/.95 x .99 = 53.5 H.P.

53.5 H.P. x 0.746 KW/HP = 39.9 KW Demand

$$39.9 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 770$$

$$39.9 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 2,180$$

TOTAL = $ 2,950



Performance curve for PH-84 Aerodyne Fan. No 1 blade position

Fan speed = 630 RPM. Weight of air = 0.075 lb. per cubic foot

FIGURE NUMBER 19

No. 3 Fan

Corrected H.P. = 38.6/M.E. x D.E. = 38.6/.95 x .99 = 40.2 H.P.

40.2 H.P. x 0.746 KW/HP = 30.0 KW Demand

$$30.0 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand month}} \times \frac{\text{12-month}}{\text{Year}} = \$\ 580$$

$$30.0 \text{ KW} \times \frac{\text{24-hr.}}{\text{Day}} \times \frac{\text{365-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 1,640$$

TOTAL = $ 2,220

Total power costs, two fans = $ 2,950 + $ 2,220 = $ 5,170

Power costs saved by changing blade position on No. 3 fan from No. 4 setting to No. 1 setting:

$ 6,030 - $ 5,170 = $ 860 per year

Total quantity of air delivered by two fans = 260,300 cfm

Total air required to operate.............. 190,000 cfm

Fugitive air .... 70,300 cfm

$$\text{Effective air} = \frac{190,000}{260,300} \times 100 = 72\%$$

Power costs wasted per year = $ 5,170 x 0.28 = $ 1,450

On November 18, 1958, No. 4 slope was sealed off (page 27). This reduced the air required by 60,000 cfm. Air then needed to operate the mine was 190,000 - 60,000 = 130,000 cfm. The effect on the fans of sealing No. 4 slope was as follows:

No. 2 Fan

Barometer = 23.41", temp. = 40° F., wt. of air = 0.06213 #/ft.^{3}

7,247 - 7,076 = 171 ft. difference in elevation.

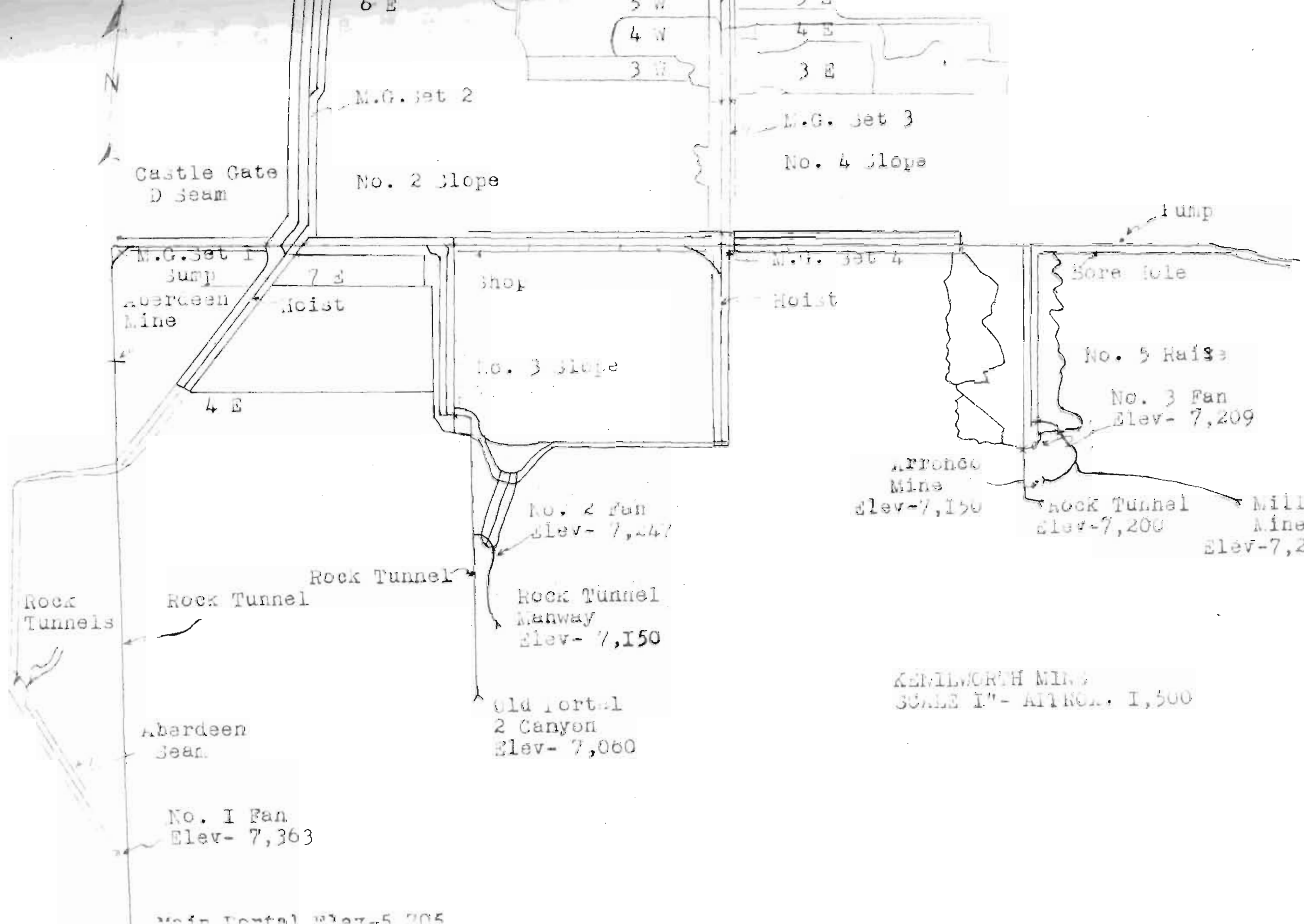


FIGURE NUMBER 10

Average underground bar. reading = 23.49", temp. = 55°F., wt. = 0.06052 #/ft.^{3}

0.06213 - 0.06052 = 0.00161 #/ft.^{3}. 0.00161 x 171 = 0.27531 #/ft.^{2}

0.27531/5.2 = <u>0.05" w.g. negative</u>

No. 3 Fan

Barometer = 23.44", temp.= 40° F., wt. of air = 0.06221 #/ft.^{3}

7,209 - 7,076 = 133 ft. difference in elevation.

Average underground bar. reading = 23.50", temp.= 55°F., wt.= 0.06055 #/ft.^{3}

0.06221 - 0.06055 = 0.00166 #/ft.^{3}. 0.00166 x 133 = 0.22078 #/ft.^{2}

0.22078/5.2 = <u>0.04" w.g. negative</u>

The measured static pressure at No. 2 fan was 1.36". Since the natural ventilating pressure was in a direction which assisted the flow of air through the fan, the following calculations must be made to determine the work done by the fan:

The pressure at the intake of No. 2 fan is greater than atmospheric. In order to arrive at a pressure of 1.36" below atmospheric, the fan must first overcome this pressure. The calculated natural ventilating pressure is 0.05" w.g. This must be reduced to static and to velocity pressure. The volume created by a pressure of 0.05" w.g. is dependent upon the mine characteristic. $P = rQ^2$. r and Q are unknown. r may be calculated approximately from the mine conditions prior to sealing off No. 4 slope. S.P. = 1.30" w.g. V.P. = $(4,000)^2 : (1,411)^2 =$ 1" : V.P. V.P. = 0.12" w.g. Then T.P. = S.P. + V.P. = -1.30 + 0.12 = -1.18" w.g.

$$r = \frac{1.18}{1.411 \times 1.411} = 0.592$$

Quantity due to 0.05" w.g. then equals:

$$Q^2 = \frac{P}{r} = \frac{0.05}{0.59} = 0.0845$$

$$Q = 0.292 \text{ or } 29,200 \text{ cfm}$$

$$V.P. = (4,000)^2 : (292)^2 = 1'' ; V.P. = 0.005'' \text{ w.g.}$$

If this were added on to make 0.01" w.g., then S.P. = -0.05 + 0.01 = 0.04". However, the V.P. is so slight that it will be ignored in this instance.

The static pressure to be used in calculating fan performance will be 1.36" + 0.05" = 1.41" w.g.

The corrected static pressure at No. 2 fan was 1.41 x 29.92/23.41 = 1.80" w.g. From the characteristic curve of No. 2 fan on page 30, the fan efficiency = 52.6%, the quantity = 125,700 cfm, and the brake horsepower = 67.7 x 23.41/29.92 = 53.1.

The measured static pressure at No. 3 fan was 1.91" w.g. After correcting for natural ventilation and barometric pressure, the static pressure was 1.91 + 0.04 = 1.95" w.g. 1.95 x 29.92/23.44 = 2.48" w.g. From the characteristic curve for No. 3 fan on page 31, the fan efficiency = 76.8%, quantity = 106,400 cfm, and brake horsepower = 54 x 23.44/29.92 = 42.4.

POWER COSTS

No. 2 Fan

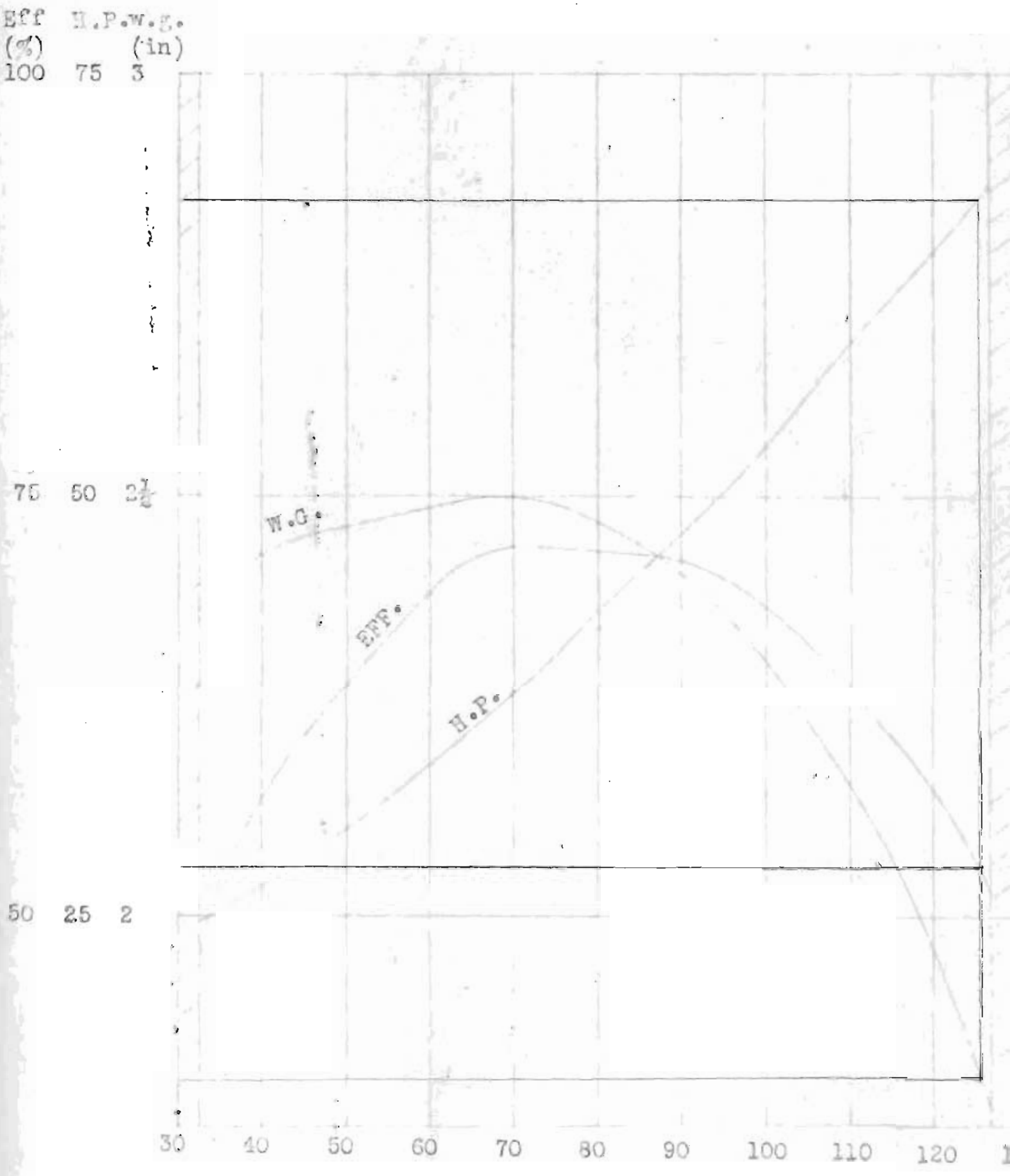
Corrected H.P. = 53.1/.95 x .99 = 55.4 H.P.

55.4 H.P. x 0.746 KW/HP = 41.3 KW Demand

$$41.3 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 790$$

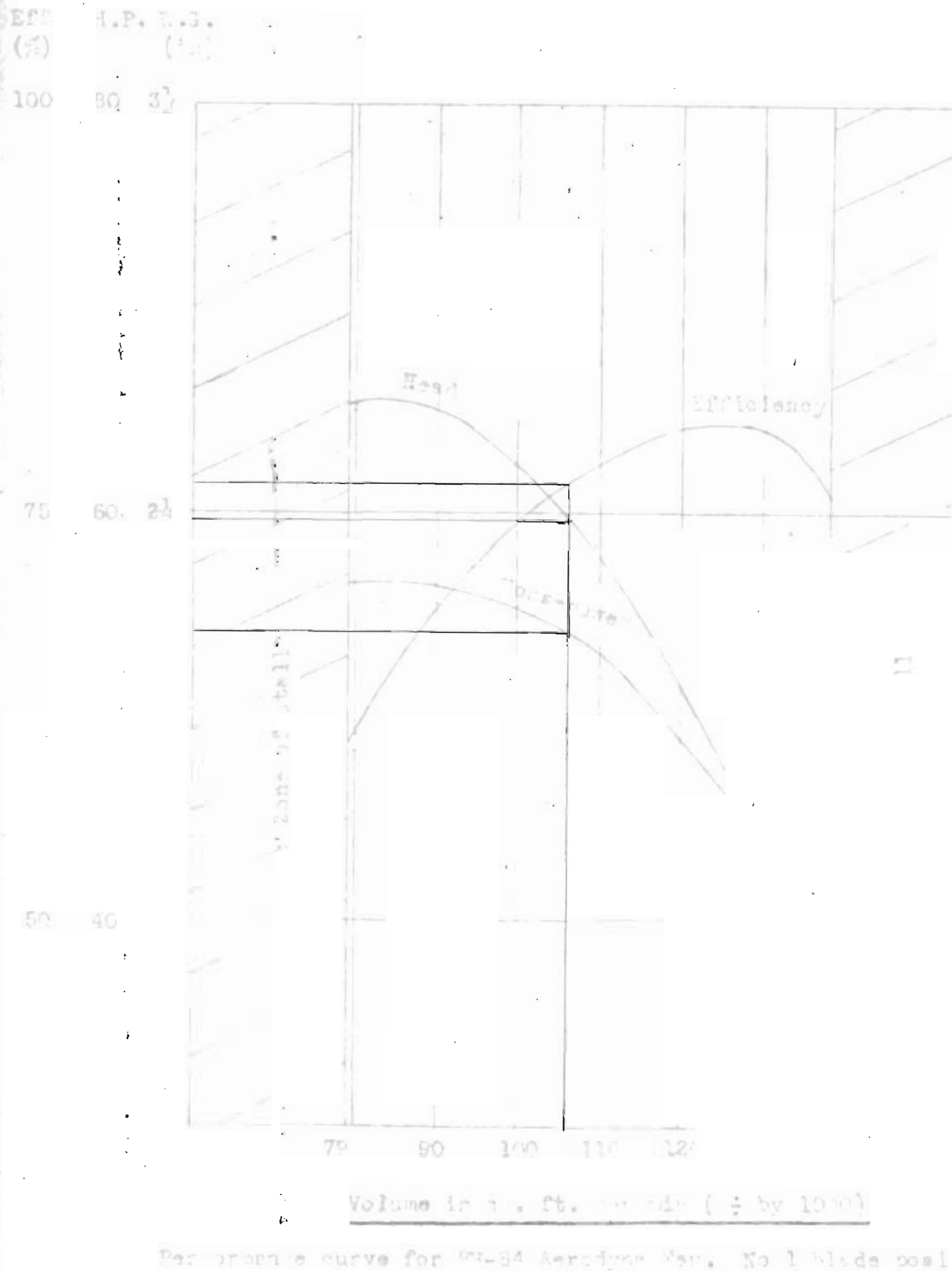
$$41.3 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 2,260$$

TOTAL = $ 3,050



Performance curve for Jeffrey 7' X 3' centrifugal fan

Fan speed = 220 RPM. Weight of air = 0.075 lb per cu ft



Performance curve for ?N-34 Aerodyne Fan. No 1 blade posi

Fan speed = 630 RPM. Weight of air = 0.075 lb. per cubic

No. 3 Fan

Corrected H.P. = 42.4/.95 x .99 = 44.1 H.P.

44.1 H.P. x 0.746 KW/HP = 32.9 KW Demand

$$32.9 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand-Month}} \times \frac{\text{12-month}}{\text{Year}} = \$\ 630$$

$$32.9 \text{ KW} \times \frac{\text{24-Hr.}}{\text{Day}} \times \frac{\text{365-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 1,800$$

TOTAL = $ 2,430

Total power costs, two fans = $3,050 + $ 2,430 = $ 5,480

Price for sealing off No. 4 slope in power costs per year:

$ 5,480 - $ 5,170 = $ 310

Total quantity of air delivered by two fans ... 232,100 cfm

Total quantity of air required to operate ..... 130,000 cfm

Fugitive air .... 102,100 cfm

$$\text{Effective air} = \frac{130,000}{232,100} \times 100 = 56\%$$

Power costs wasted per year = $ 5,480 x 0.44 = $ 2,410

In an attempt to eliminate fugitive air losses, the intakes by No. 3 fan were sealed off. The effect on ventilation was as follows:

No. 2 Fan

Barometer = 23.63", temp. = 45°F., wt. of air = 0.06209 #/ft.^{3}

7,247 - 6,972 = 275 ft. difference in elevation.

Avg. underground bar. reading = 23.75", temp.= 55°F., wt.= 0.06120 #/ft.^{2}

0.06209 - 0.06120 = 0.00089 #/ft.^{3}.   0.00089 x 275 = 0.24475 #/ft.^{2}

0.24475/5.2 = 0.05" negative

No. 3 Fan

Barometer = 23.66", temp. = 45° F., wt. of air = 0.06217 #/ft.^{3}

7,209 - 6,972 = 237 ft. difference in elevation.

Avg. underground bar. reading = 23.77", temp. = 55°F., wt. = 0.06125 #/ft.^{3}

0.06217 - 0.06125 = 0.00092 #/ft.^{3}. 0.00092 x 237 = 0.21804 #/ft.^{2}

0.21804/5.2 = <u>0.04" w.g. negative</u>

The measured static pressure at No. 2 fan was 1.71". Since the natural ventilating pressure was a negative value, the pressure then becomes 1.71 + 0.05 = 1.76" w.g. This, corrected for barometric pressure, becomes 2.22" w.g. From the chart on No. 2 fan, page 34, the fan efficiency = 65.6%, quantity = 105,600 cfm, and brake horsepower = 56.6 x 23.63/29.92 = 44.8 H.P.

The measured static pressure at No. 3 fan was 2.03". This, corrected for natural ventilating pressure and barometric pressure, becomes 2.62" w.g. From the characteristic curve for No. 3 fan on page 35, the fan efficiency = 74.1%, quantity = 99,400 cfm, and brake horsepower = 55.3 x 23.77/29.92 = 43.9 H.P.

POWER COSTS

No. 2 Fan

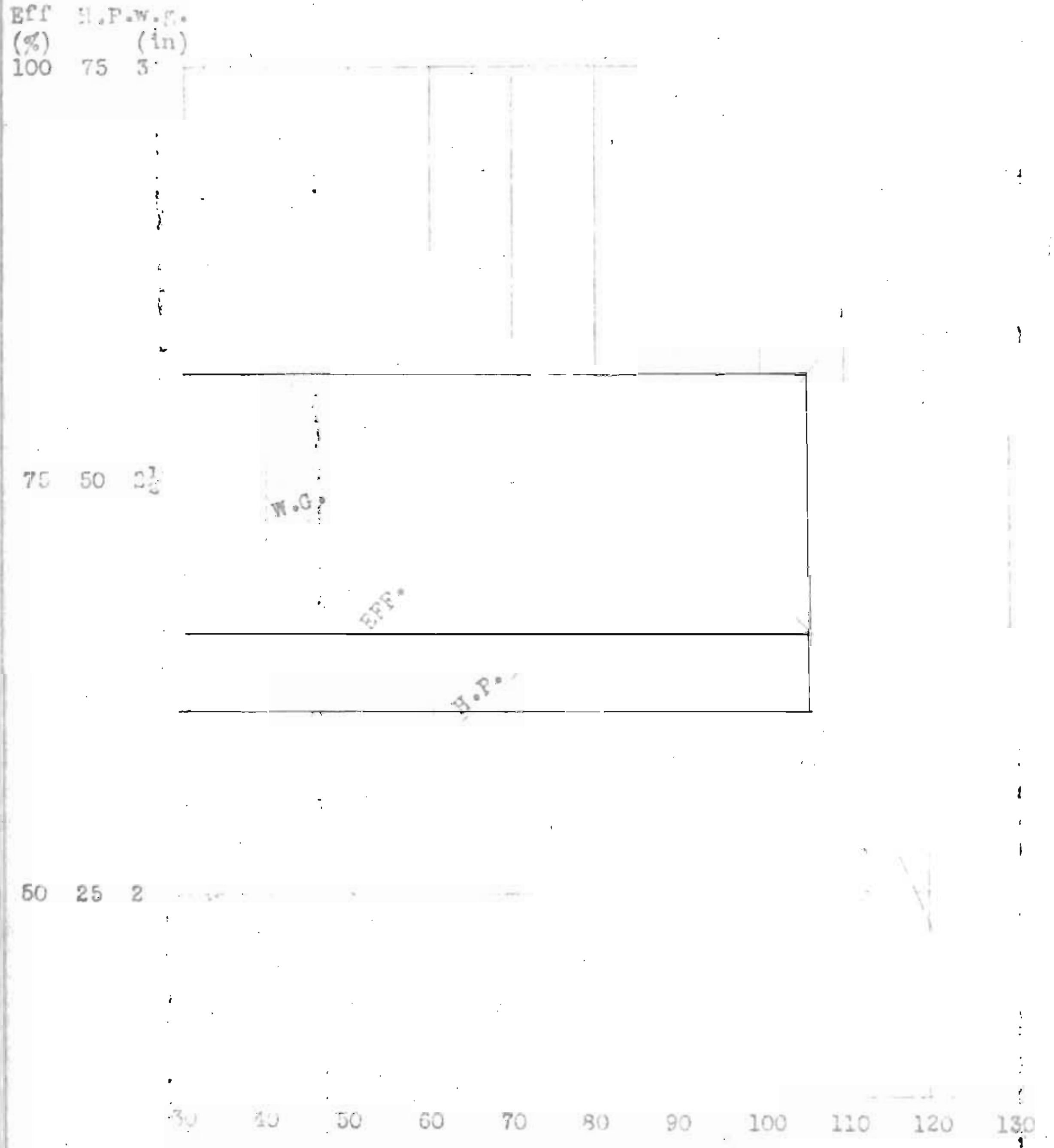
Corrected H.P. = 44.8/.95 x .99 = 46.7 H.P.

46.7 H.P. x 0.746 KW/HP = 34.9 KW Demand

$$34.9 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{\text{12-month}}{\text{Year}} = \$\ 670$$

$$34.9 \text{ KW} \times \frac{\text{24-hr.}}{\text{Day}} \times \frac{\text{365-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 1,910$$

TOTAL = $ 2,580



Volume in cu. ft. per min (÷ by 1000)

Performance curve for Jeffrey 7' X 3' centrifugal fan

Fan speed = 220 RPM. Weight of air = 0.075 lb per cu ft

Fan Serial #10502

FIGURE NUMBER 13

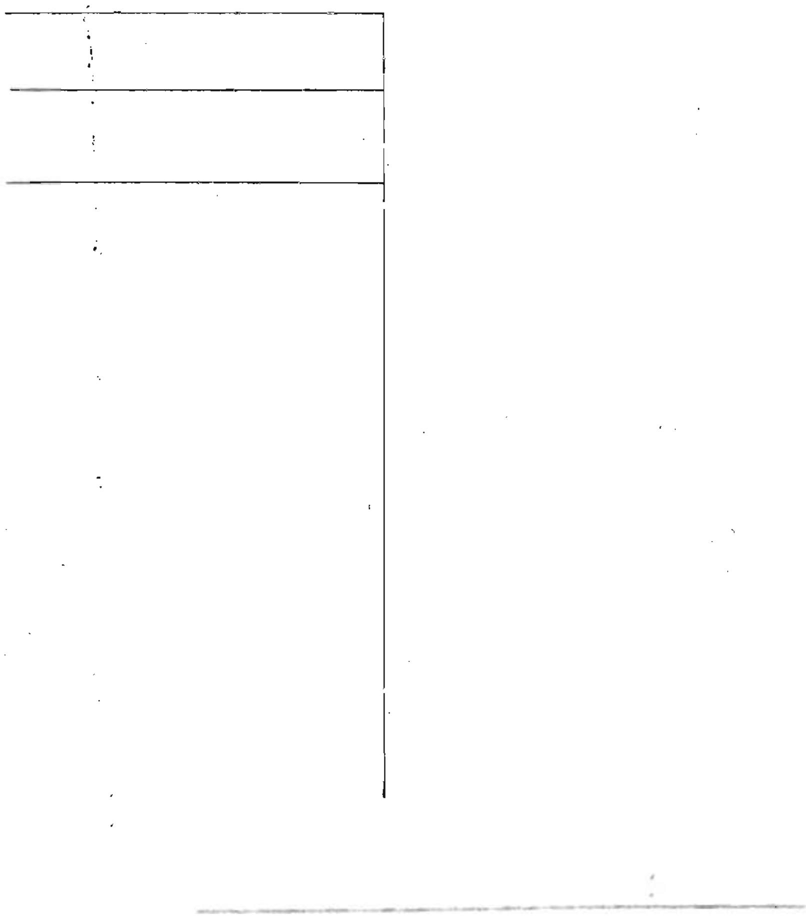


FIGURE NUMBER 14

No. 3 Fan

Corrected H.P. = 43.9/.95 x .99 = 45.7 H.P.

45.7 H.P. x 0.746 KW/HP = 33.1 KW Demand

$$33.1 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 650$$

$$33.1 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 1{,}810$$

TOTAL = $ 2,460

Total power costs, two fans = $ 2,580 + $ 2,460 = $ 5,040

Money saved per year on power costs by sealing off intakes:

$ 5,480 - $ 5,040 = $ 440

Total quantity of air delivered by two fans ... 205,000 cfm

Total quantity of air required to operate ..... 142,000 cfm

Fugitive air .... 63,000 cfm

$$\text{Effective air} = \frac{142{,}000}{205{,}000} \times 100 = 69\%$$

Power costs wasted per year = $ 5,040 x 0.31 = $ 1,560

This would seem to have corrected the problem to some extent; however, about two days after the intakes by No. 3 fan were sealed, the fan began to stall at intervals. The characteristic curve for No. 3 fan, shown on page 35, for the No. 1 blade setting, indicates that with a static pressure of 2.77" and a quantity of 78,000 cfm, the fan is at the stall zone. If the barometer remained at 23.66" and the outside temperature dropped to 25° F., the static pressure would be 2.77" w.g. Also, a change in wind velocity and direction tends to upset the balance and throw the fan into a stall.

No. 3 fan is unfavorably located at the apex of two canyons. Any differences in temperature between the bottom and top of the canyons cause a wind which affects the fan performance.

The No. 4 blade position of the fan allows a quantity of 96,000 cfm and a w.g. of 3.12" as the low quantity and high w.g., respectively, before the fan will stall. In an attempt to stop the fan from stalling, the blade position was changed to the No. 4 position. The fan still attempted to stall, and a door in the stopping on the east side of No. 3 fan had to be opened slightly. The fan conditions now appeared as:

No. 2 Fan

Barometer = 23.61", temp. = 30° F., wt. of air = 0.06394 #/ft.^{3}

7,247 - 7,053 = 194 ft. difference in elevation.

Avg. underground bar. reading = 23.70", temp.= 55°F., wt.= 0.06107 #/ft.^{3}

0.06394 - 0.06107 = 0.00287 #/ft.^{3}.   0.00287 x 194 = 0.55678 #/ft.^{2}

0.55678/5.2 = 0.11" w.g. negative = 0.10" w.g. static pressure

No. 3 Fan

Barometer = 23.64", temp. = 30° F., wt. of air = 0.06402 #/ft.^{3}

7,209 - 7,053 = 156 ft. difference in elevation.

Average underground bar. reading = 23.71", temp.= 55°F., wt.= 0.06109#/ft.^{3}

0.06402 - 0.06109 = 0.00293 #/ft.^{3}.   0.00293 x 156 = 0.45708 #/ft.^{2}

0.45708/5.2 ≐ 0.09" w.g. negative = 0.08" w.g. static pressure

The measured static pressure at No. 2 fan was 1.77". This, corrected for natural ventilating pressure and barometric pressure, becomes 2.24" w.g. The fan characteristic curve for No. 2 fan on page 39 indicates the fan efficiency = 66.4%, quantity = 104,100 cfm, and brake horsepower = 55.8 x 23.61/29.92 = 44.1 H.P.

The measured static pressure at No. 3 fan was 2.36" w.g. This becomes 3.08" w.g. when corrected for natural ventilation and barometric pressure. From the characteristic curve on page 40, the fan efficiency = 65.1%, quantity = 99,600 cfm, and brake horsepower = 73.7 x 23.64/29.92 = 58.3 H.P.

POWER COSTS

No. 2 Fan

Corrected H.P. = 44.1/.95 x .99 = 46.0 H.P.

46.0 H.P. x 0.746 KW/HP = 34.3 KW Demand

$$34.3 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 660$$

$$34.3 \text{ KW} \times \frac{24\text{-hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW - Hr.}} = \$\ 1,880$$

TOTAL = $ 2,540

No. 3 Fan

Corrected H.P. = 58.3/.95 x .99 = 60.8 H.P.

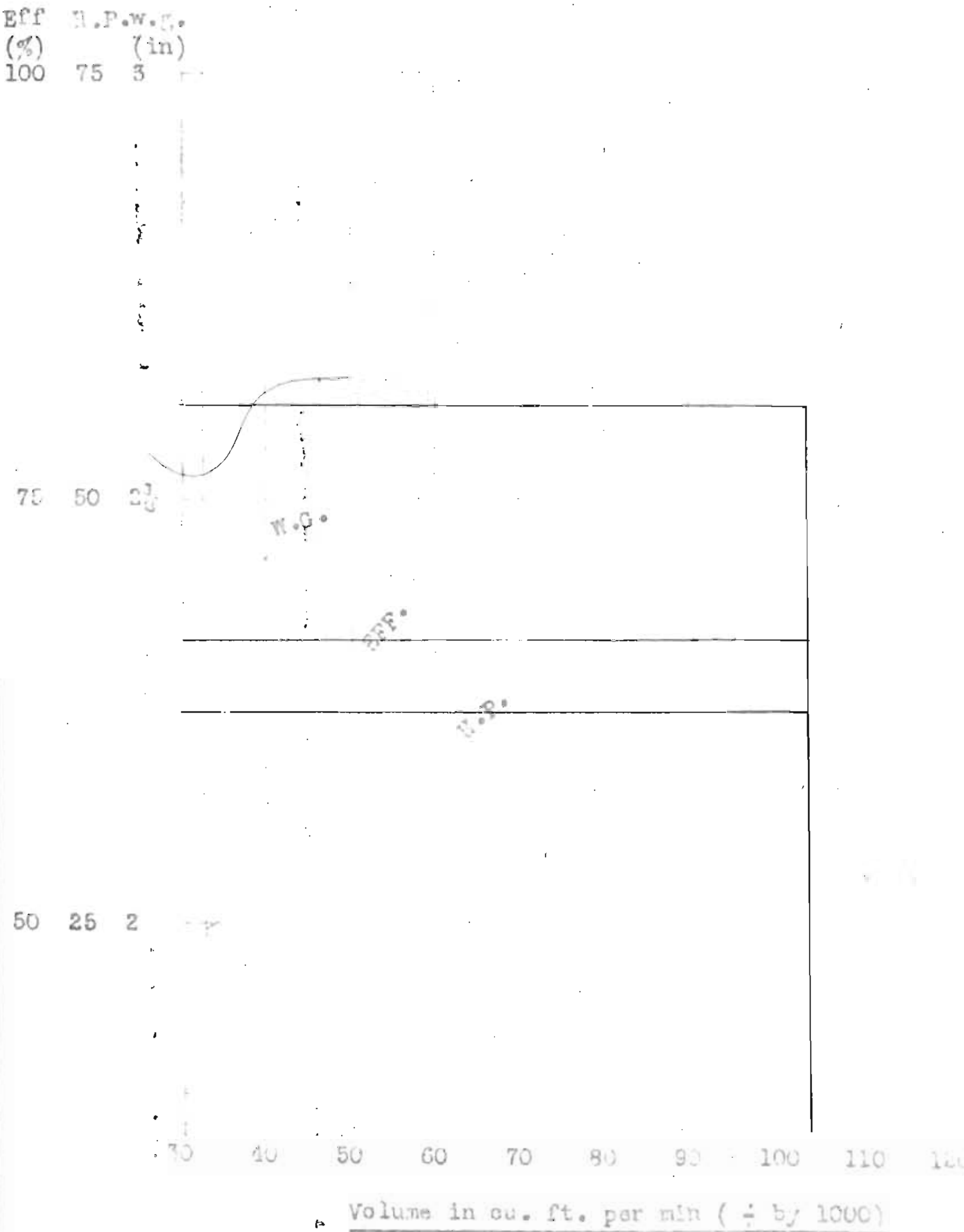
60.8 H.P. x 0.746 KW/HP = 45.4 KW Demand

$$45.4 \text{ KW Demand} \times \frac{\$\ 1.60}{\text{KW Demand Month}} \times \frac{12\text{-month}}{\text{Year}} = \$\ 870$$

$$45.4 \text{ KW} \times \frac{24\text{-Hr.}}{\text{Day}} \times \frac{365\text{-day}}{\text{Year}} \times \frac{\$\ 0.00625}{\text{KW-Hr.}} = \$\ 2,480$$

TOTAL = $ 3,350

Total power costs, two fans = $ 2,540 + $ 3,350 = $ 5,890



Performance curve for Jeffrey 7' x 3' centrifugal fan

Fan speed = 220 RPM. Weight of air = 0.075 lb per c

Fan Serial #10502

FIGURE NUMBER 15

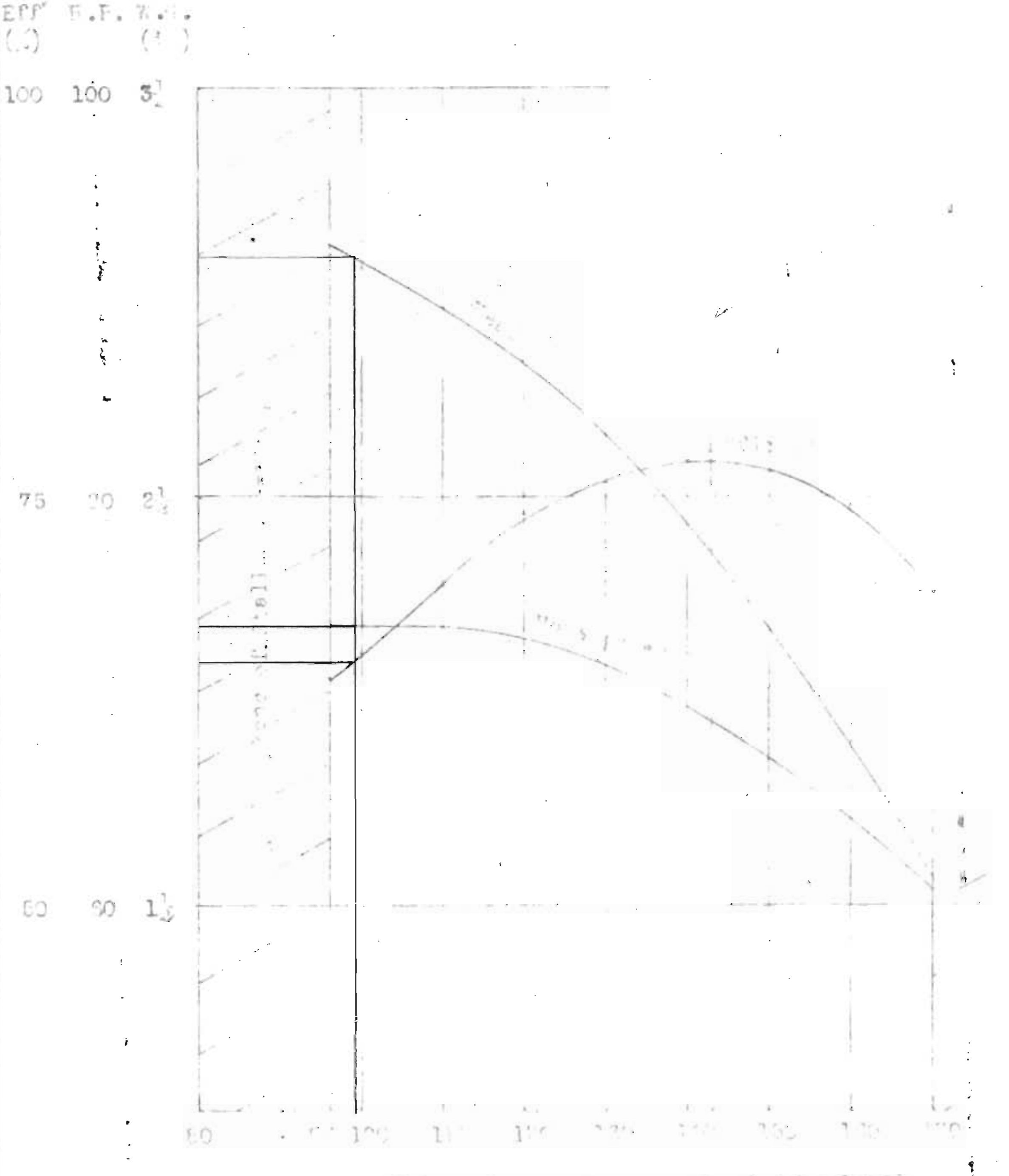


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FIGURE NUMBER 16

Total quantity of air delivered by two fans ..... 203,700 cfm

Total quantity of air required to operate .... 142,000 cfm

Fugitive air .... 61,700 cfm

Effective air = $\frac{142,000}{203,700} \times 100 = 70\%$

Power costs wasted per year = \$ 5,890 x 0.30 = \$ 1,760

The amount of air which will flow through a mine at a given water gage is dependent upon the area, the rubbing surface, and the coefficient K. K may be found experimentally and the area and rubbing surface measured, or K, S and A may be combined and treated as a single value, KS/A^3. The formula $P = \frac{KSQ^2}{A^3}$ may then be written as $P = Q^2 \frac{KS}{A^3}$, or $P = Q^2 r$.

Heretofore, when dealing with fan charts, static pressure has been used because the fan curves are based on static pressure. The actual pressure necessary to overcome mine resistance is total pressure, or a summation of static and velocity pressure. With an exhaust-type fan such as is used at Kenilworth, the static pressure in the mine is below atmospheric pressure and is, therefore, a negative value. Velocity pressure is always a positive value. For an exhaust-type fan: TP = -SP + VP. Knowing the quantity of air flowing past a known area, the velocity pressure may be calculated:

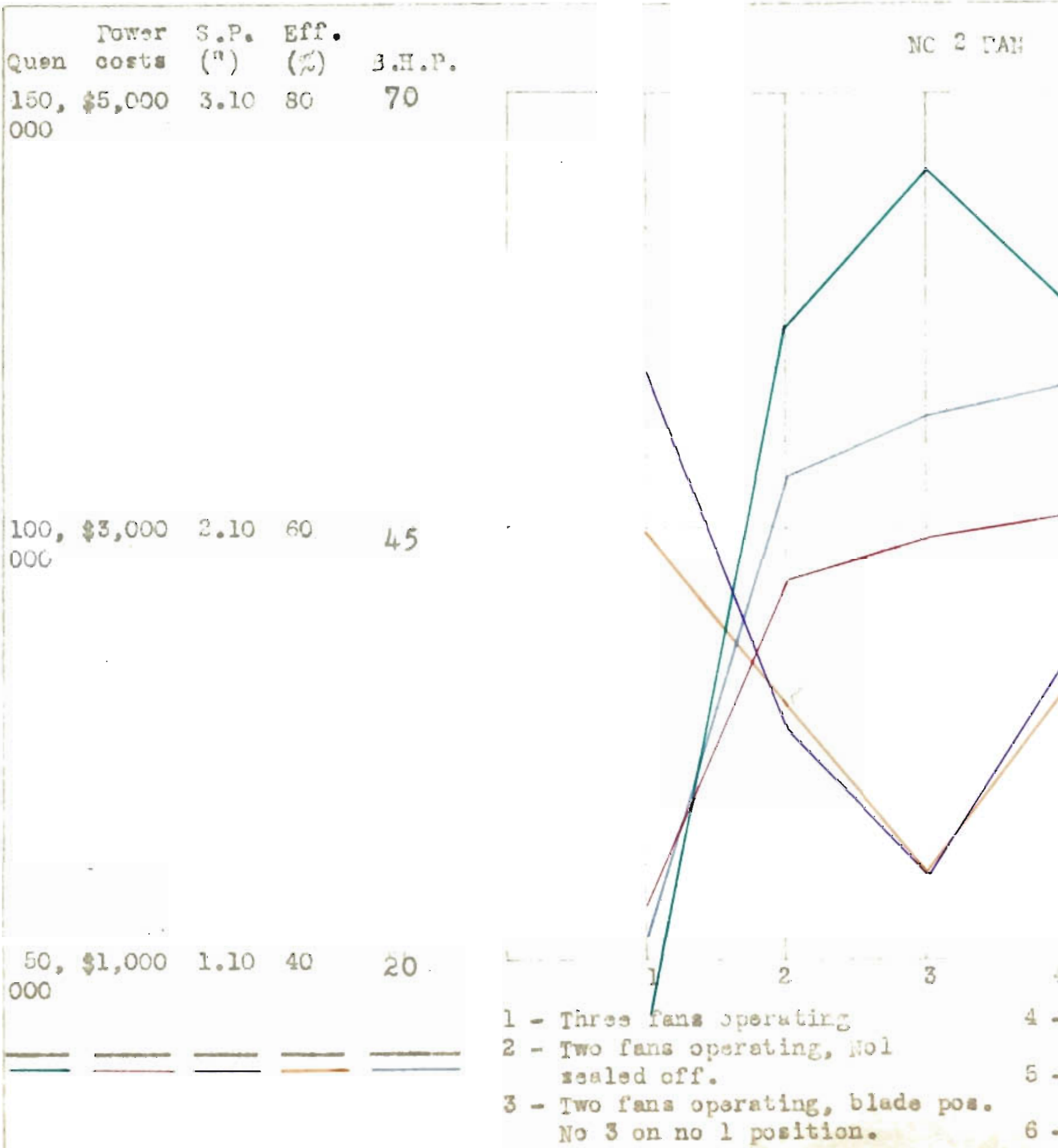
$V = \sqrt{2gh}$ where V = velocity in ft./sec.; g = 32.2 ft./sec.^{2}; h = height from which body falls.

1" w.g. = 5.2 #/ft.^{2}. A cubic foot of air at 7,200 ft. elevation, temp. = 55° F., barometer = 23", weighs 0.05926 #/ft.^{3}. 5.2/0.05926 = 87.75 ft. Therefore, the weight of an air column 87.75 ft. high = 1" w.g., and $V = \sqrt{2 \times 32.2 \times 87.75}$ = 75.2 ft./sec. or 4,512 ft./min., a velocity of 4,512, say 4,500 ft./min. = 1" w.g.

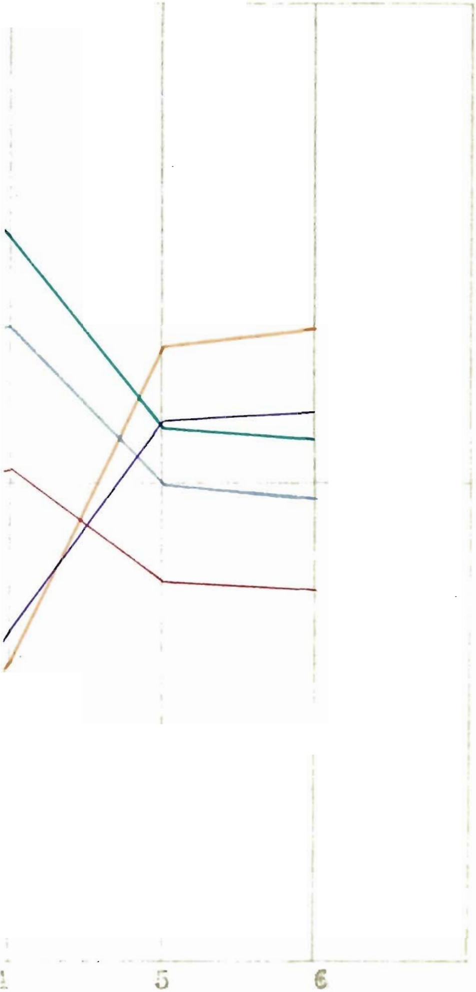
MINE CHARACTERISTIC

$$r = P/Q^2$$

Fan	SP	VP	TP	Quantity	r
			I		
1	-2.92	0.17	-2.75	1.157	2.06
2	-2.45	0.10	-2.35	0.437	12.3
3	-3.02	0.19	-2.83	1.047	2.58
			II		
2	-1.63	0.27	-1.36	1.233	0.89
3	-2.74	0.23	-2.51	1.250	1.61
			III		
2	-1.30	0.31	-0.99	1.411	0.50
3	-2.10	0.22	-1.88	1.192	1.32
			IV		
2	-1.80	0.28	-1.52	1.257	0.96
3	-2.48	0.20	-2.28	1.064	2.01
			V		
2	-2.22	0.23	-1.99	1.056	1.79
3	-2.62	0.18	-2.44	0.994	2.48
			VI		
2	-2.24	0.23	-2.01	1.041	1.85
3	-3.08	0.18	-2.90	0.996	2.92

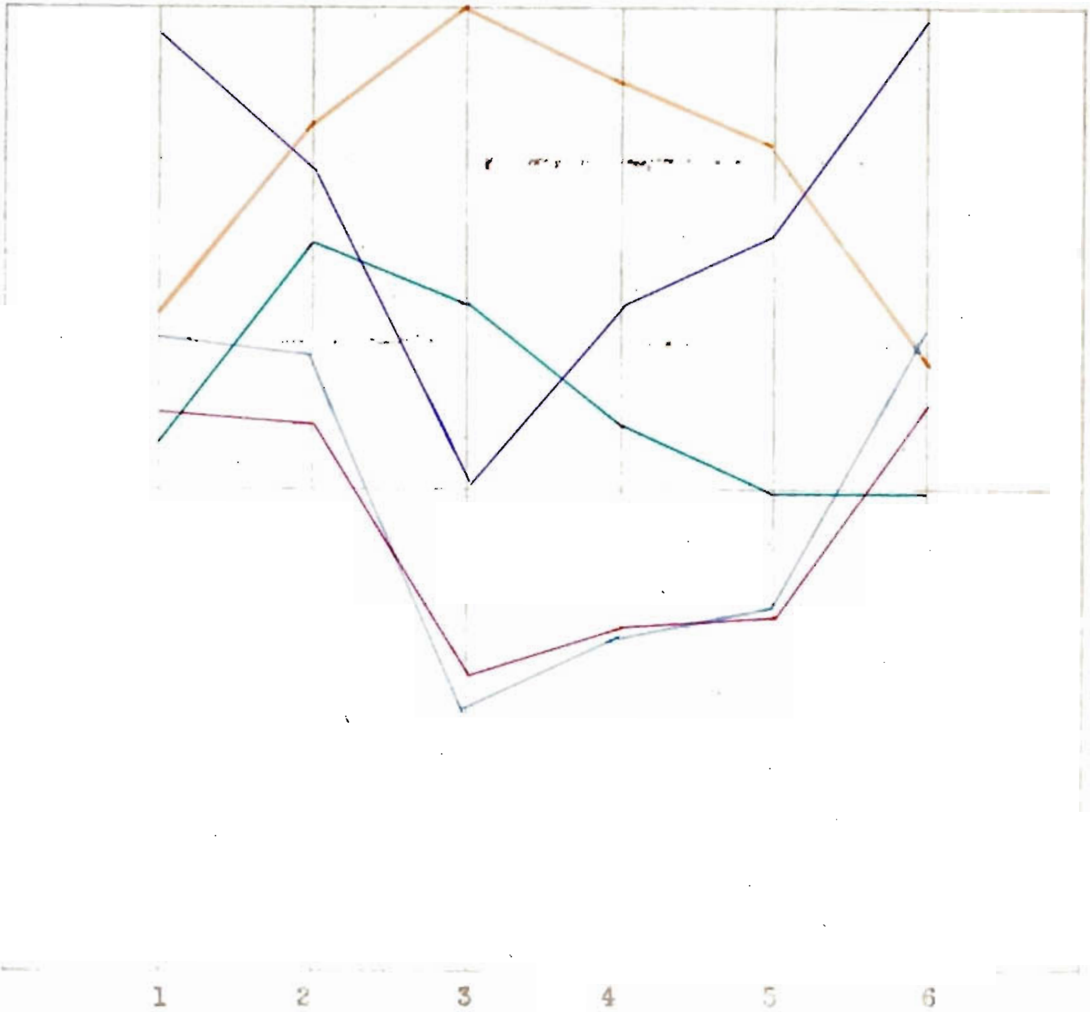


NC 2 FAN
Quan
Power costs
S.P. (")
Eff. (%)
B.H.P.
150,000 $5,000 3.10 80 70
100,000 $3,000 2.10 60 45
50,000 $1,000 1.10 40 20
1
2
3
1 - Three fans operating
2 - Two fans operating, No1 sealed off.
3 - Two fans operating, blade pos. No 3 on no 1 position.
4 -
5 -
6 -



- Two fans operating, No 4 slope sealed off.
- Two fans operating, No 5 raise intakes sealed off.
- Two fans operating, blade pos. No 3 on no 4 position.

NO 3 FAN

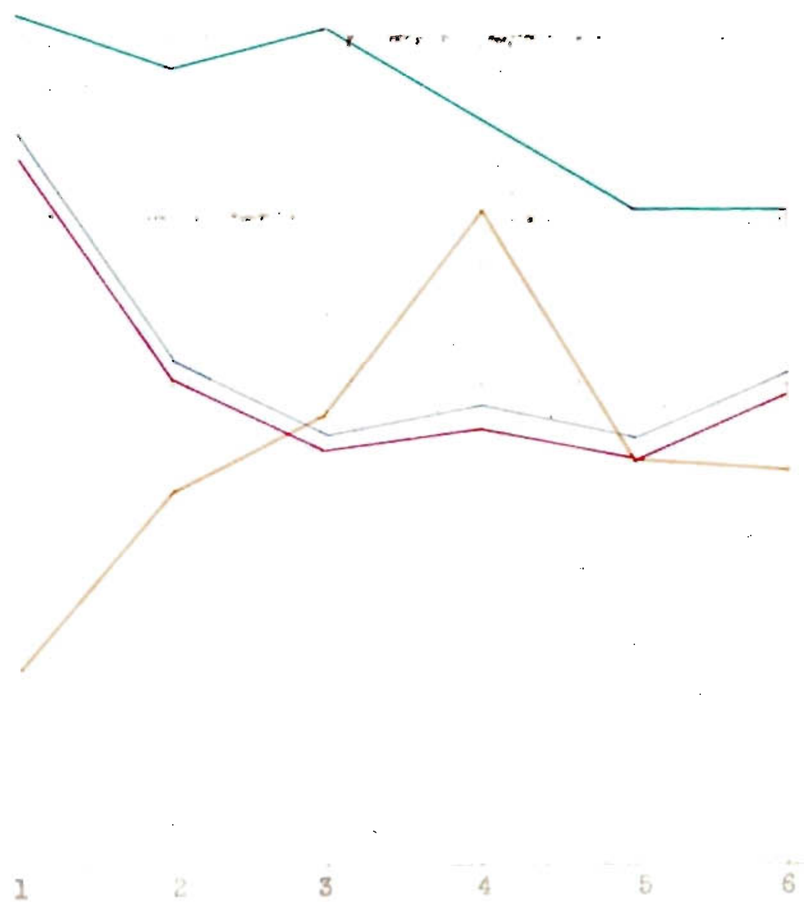


1 - Three fans operating
2 - Two fans operating, No 1 sealed off.
3 - Two fans operating, blade pos. No 3 on no 1 position.
4 - Two fans operating, No 4 slope sealed off.
5 - Two fans operating, No 5 raise intakes sealed off.
6 - Two fans operating, blade pos. No 3 on no 4 position.

FIGURE NUMBER 18

Quan	Power costs	S.P. (")	Eff. (%)	B.H.P.
150,000	$5,000	3.10	80	75
100,000	$3,000	2.10	60	50
50,000	$1,000	1.10	40	25

TOTAL ALL FANS



1 - Three fans operating
2 - Two fans operating, No 1 sealed off.
3 - Two fans operating, blade pos. No 3 on no 1 position.
4 - Two fans operating, No 4 slope sealed off.
5 - Two fans operating, No 5 raise intakes sealed off.
6 - Two fans operating, blade pos. No 3 on no 4 position.

Quan	Power cost	B.H.P.	Fug. Air.
300,000	$12,000	200	150,000
150,000	$ 6,000	100	75,000
0	0	0	0

SUMMARY AIR CHANGES

Date	Fan	Quantity	Yearly Power Costs	Static Pressure	Eff.	BHP	Fug. Air
			I				
	1	115,700	$ 4,270	2.92"	56.8	72.5	
	2	43,700	1,260	2.45"	59.8	21.9	
June, 1957	3	104,700	3,320	3.02"	67.2	57.9	
TOTAL		264,100	$ 8,850			152.3	30,600
			II				
	2	123,300	$ 2,760	1.63"	51.7	48.0	
May, 1958	3	125,000	3,270	2.74"	75.0	56.9	
TOTAL		248,300	$ 6,030			104.9	58,300
			III				
	2	141,100	$ 2,950	1.30"	44.1	51.4	
May, 1958	3	119,200	2,220	2.10"	80.0	38.6	
TOTAL		260,300	$ 5,170			90.0	70,300
			IV				
	2	125,700	$ 3,050	1.80"	52.6	53.1	
Nov, 1958	3	106,400	2,430	2.48"	76.8	42.4	
TOTAL		232,100	$ 5,480			95.5	102,100
			V				
	2	105,600	$ 2,580	2.22"	65.6	44.8	
Dec, 1958	3	99,400	2,460	2.62"	74.1	43.9	
TOTAL		205,000	$ 5,040			88.7	63,000
			VI				
	2	104,100	$ 2,540	2.24"	66.4	44.1	
Dec, 1958	3	99,600	3,350	3.08"	65.1	58.3	
TOTAL		203,700	$ 5,890			102.4	61,700

MINE HOISTING

Since the first coal was mined, its transportation from the working face to the point of consumption has presented problems. Coal is usually moved by several mediums before it is burned. From the mine portal it may be hauled by railroad cars, trucks, barges or even pipe lines. Moving the coal from the working face to the mine portal is usually accomplished by means of track haulage, rubber-tired haulage, or belt conveyors. This portion of the thesis is concerned with efficient track haulage on a slope of a pitching seam.

Standard gage for coal mine track is 42". The size of the rails used and the spacing of cross ties depends upon the load which the rails must carry. The height of the coal seam determines, to a large extent, the size of mine cars that will be used. The mine output in tons per shift determines, along with other factors, the number of cars per trip. The number of cars per trip, along with the grade of the haulage road, determines the size rope which must be used on the hoist and also the size motors which must be used.

The most important single fact to remember about track in a coal mine is: THE ENTRY SHOULD BE DRIVEN TO FIT THE TRACK; NEVER THE TRACK MADE TO FIT THE ENTRY. This is especially applicable to hoisting where partings are installed.

Once the size trip is determined, the amount of coal which may be pulled up a slope is governed by the speed of the hoist and the time spent switching at the end point and at the mid-point of the hoisting cycle. A properly-installed and graded parting will save at least ten seconds per trip in switching time over an ungraded parting. This is easily converted to dollars and cents:

10 sec./trip x 15 trip/shift x 200 shift/year x 1 hr./3600 sec.

= 8.34 hr./year. 8.34 hr./yr. x $200/hr. = $ 1,668/yr.

The following cases indicate the effect of the speed of the hoist and the distance of the parting from the slope:

Given: length of trip...... 135 feet
length of slope ....1000 feet
acceleration .... 30 seconds
deceleration .... 20 seconds

Case I - parting next to slope.

hoist speed .... 1,000 ft./min.

Up trip - $\frac{1{,}000 \text{ ft.}}{2 \text{ min.}} \times \underline{30 \text{ sec.}} \times \frac{1 \text{ min.}}{60 \text{ sec.}}$ = 250 ft. acc.

$\frac{1{,}000 \text{ ft.}}{2 \text{ min.}} \times \underline{20 \text{ sec.}} \times \frac{1 \text{ min.}}{60 \text{ sec.}}$ = 167 ft. dec.

1,000 - (250 + 167) = 583 ft. full speed

583 ft. x $\frac{1 \text{ min.}}{1000 \text{ ft.}} \times \frac{60 \text{ sec.}}{\text{min.}}$ = 35 sec.

time = 30 + 20 + 35 = 85 sec.

To parting - $\frac{215 \text{ ft.}}{460 \text{ ft./min.}} \times \frac{60 \text{ sec.}}{\text{min.}}$ = 30 sec.

Change rope top and bottom = 30 sec. each

Total time, round trip = 85 + 85 + 30 + 30 + 30 + 30 = 290 sec.

= 4 min. 50 sec.

Case II - parting next to slope.

hoist speed .... 500 ft./min.

Up trip -

$$\frac{500\text{ ft.}}{2\text{ min.}} \times \underline{30\text{ sec.}} \times \frac{1\text{ min.}}{60\text{ sec.}} = 125\text{ ft. acc.}$$

$$\frac{500\text{ ft.}}{2\text{ min.}} \times \underline{20\text{ sec.}} \times \frac{1\text{ min.}}{60\text{ sec.}} = 84\text{ ft. dec.}$$

$$1{,}000 - (125 + 84) = 791\text{ ft. full speed}$$

$$791\text{ ft.} \times \frac{1\text{ min.}}{500\text{ ft.}} \times \frac{60\text{ sec.}}{1\text{ min.}} = 95\text{ sec.}$$

$$\text{time} + 30 + 20 + 95 = 145\text{ sec.}$$

To parting -

$$\frac{215\text{ ft.}}{330\text{ ft./min.}} \times \frac{60\text{ sec.}}{\text{min.}} = 40\text{ sec.}$$

Change rope top and bottom = 30 sec. each

Total time, round trip = 95 + 95 + 40 + 40 + 60 = 530 sec.

= <u>8 min. 50 sec.</u>

Case III - parting 450 ft. from slope.

hoist speed ..... 1,000 ft./min.

Up trip -

$$\frac{1{,}000\text{ ft.}}{2\text{ min.}} \times \underline{30\text{ sec.}} \times \frac{1\text{ min.}}{60\text{ sec.}} = 250\text{ ft. acc.}$$

$$\frac{1{,}000\text{ ft.}}{2\text{ min.}} \times \underline{20\text{ sec.}} \times \frac{1\text{ min.}}{60\text{ sec.}} = 167\text{ ft. dec.}$$

$$1{,}000 - (250 + 167) = 583\text{ ft. full speed}$$

$$\text{time} = 30 + 20 + 35 = 85\text{ sec.}$$

To parting -

$$630 - (250 + 167) = 213\text{ ft. full speed}$$

$$213\text{ ft.} \times \frac{1\text{ min.}}{1000\text{ ft.}} \times \frac{60\text{ sec.}}{\text{min.}} = 13\text{ sec.}$$

$$\text{time} = 30 + 20 + 13 = 63\text{ sec.}$$

Change rope top and bottom = 30 sec. each

Total time, round trip = 85 + 85 + 63 + 63 + 60 = 356 sec.

= 5 min. 56 sec.

If the parting is next to the slope and the speed of the hoist is cut in half, the time required per trip is increased 82.8%. If the parting is moved away from the slope and the speed remains the same, the time required per trip is increased 22.8%. In other words, in Case III, with the parting moved 450 feet away from the slope, the productivity time of the hoist was cut by nearly one-fourth.

In the spring of 1956, the author recommended and, subsequently, planned the grading of a section of slope, and the construction of two partings on No. 2 slope, Kenilworth mine. A grade of about 15% on the slope just above what is now 8th West parting would have proved the limiting factor in the number of cars per trip which the hoist would have handled. Bottom was shot and the grade reduced to 12.4%. The 8th East and 8th West partings were installed to engineered specifications and have since proved to be first-class partings. The author has seen a rope trip go into 8th West parting at full speed and not derail. The hoist has pulled as many as 38 nine-car trips from the two partings in a seven-hour shift. Twenty-two trips were pulled from the 8th West parting in one seven-hour shift. The high tonnage which both entries have maintained has been due, in part, to excellent partings that have helped to supply a flow of empty cars to the loaders.

The size of the rope is dependent upon the maximum pull exerted by the trip on the slope. The horsepower and speed of the hoist and the size of the drum are dependent upon the rope pull, size of rope, and length of slope.

The following problem concerns the present situation of the Kenilworth No. 2 slope and hoist:

Empty car weight	2.8 tons
Car capacity	5 tons
Rope size	1-1/4 inch
Type rope	6 x 19 improved plow steel right regular lay
Drum size	90" x 84" overwind
Motor size	Two 500 H.P., 600 RPM
Drum speed	Up trip - 52 RPM Down trip - 55 RPM

Slope profile (top to bottom):

1	350'	11.0%	
2	200'	2.0%	
3	245'	8.2%	
4	160'	14.0%	
5	120'	7.8%	
6	490'	11.9%	
7	180'	6.7%	
8	120'	3.9%	
9	100'	4.5%	
10	140'	8.1%	
11	210'	17.5%	
12	460'	13.9%	
13	60'	8.9%	
14	280'	10.3%	
15	100'	7.3%	
16	830'	9.1%	
17	290'	10.7%	
18	590'	12.3%	
19	300'	7.0%	
20	115'	13.9%	
21	180'	6.7%	
22	390'	12.4%	(8th West)
22	600'	12.4%	(8th East)

Total ..... 6,120'

Top of slope to main parting:

a - 350' - 4.0%

The first step is to select the proper size trip for the rope used. The maximum grade is 17.5%.

$$\text{Grade resistance} = \frac{7.8 \text{ ton}}{\text{car}} \times \frac{20\ \#}{\text{ton/\% grade}} \times 17.5\% \quad = \quad 2{,}730\ \#$$

$$\text{Grade resistance rope} = \frac{2{,}600 \times 2.45}{2{,}000} \times 11\% \times 20 \quad = \quad 286\ \#$$

$$\text{Rolling resistance} = \frac{7.8 \text{ ton}}{\text{car}} \times \frac{14\ \#}{\text{ton}} \quad = \quad 110\ \#$$

$$\text{Rope resistance} = 100\ \#/\text{ton} = \frac{100}{2{,}000} \times (2{,}600 \times 2.45\ \#/\text{ft.}) \quad = \quad 32\ \#$$

Total car resistance = 2,840 #

Total rope resistance = 318 #

Breaking strength of rope = 69 tons. Safety factor of 5 is used.

$$\frac{69 \text{ tons}}{5} \times \frac{2{,}000\ \#}{\text{ton}} = 27{,}600\ \# \qquad \frac{27{,}600 - 318}{2{,}840} = 9 \text{ plus cars per trip.}$$

Critical Points

Up Trip

1 - at bottom. time = 0 sec. distance travelled = 0 feet.

2 - at end of acceleration. time = 20 sec. distance = 219 feet.

3 - beginning of full speed. time = 20 sec. distance = 219 feet.

4 - at end of full speed. time = 284 sec. distance = 6,010 feet.

5 - beginning of deceleration. time = 284 sec. distance = 6,010 feet.

6 - at top. time = 294 sec. distance = 6,120 feet.

To Parting

1 - at top. time = 0 sec. distance = 0 feet.

2 - at end of acceleration. time = 20 sec. distance = 231 feet.

3 - beginning of full speed. time = 20 sec. distance = 231 feet.

4 - end of full speed. time = 20 sec. distance = 234 feet.

5 - beginning of deceleration. time = 20 sec. distance = 234 feet.

6 - at parting. time = 30 sec. distance = 350 feet.

From Parting

1 - at parting. time = 0 sec. distance = 0 feet.

2 - at end of acceleration. time = 20 sec. distance - 219 feet.

3 - beginning of full speed. time = 20 sec. distance = 219 feet.

4 - end of full speed. time = 21 sec. distance = 240 feet.

5 - beginning of deceleration. time = 21 sec. distance = 240 feet.

6 - at top. time = 31 sec. distance = 350 feet.

Down Trip

1 - at top. time = 0 sec. distance = 0 feet.

2 - at end of acceleration. time = 20 sec. distance = 231 feet.

3 - beginning of full speed. time = 20 sec. distance = 231 feet.

4 - end of full speed. time = 269 sec. distance = 6,004 feet.

5 - beginning of deceleration. time = 269 sec. distance = 6,004 feet.

6 - at bottom. time = 279 sec. distance = 6,120 feet.

Average speed of hoist.

Up trip .... 1,315 ft. per min.
Down trip ...... 1,390 ft. per min.

Acceleration.

Up trip - $\frac{1,315 \text{ ft.} \times 1 \text{ min.}}{20 \text{ sec. min. } 60 \text{ sec.}} = 1.096 \text{ ft./sec.}^2$

Down trip - $\frac{1,390 \text{ ft.} \times 1 \text{ min.}}{20 \text{ sec. min. } 60 \text{ sec.}} = 1.158 \text{ ft./sec.}^2$

Deceleration.

Up trip - $\frac{1,315 \text{ ft.} \times 1 \text{ min.}}{10 \text{ sec. min. } 60 \text{ sec.}} = 2.192 \text{ ft./sec.}^2$

Down trip - $\frac{1,390 \text{ ft.} \times 1 \text{ min.}}{10 \text{ sec. min. } 60 \text{ sec.}} = 2.316 \text{ ft./sec.}^2$

Distance traveled.

Accelerating

Up trip - $\frac{1,315 \text{ ft.} \times 20 \text{ sec.}}{2 \text{ min.} \times 60 \text{ sec./min.}} = 219 \text{ feet}$

Down trip - $\frac{1,390 \text{ ft.} \times 20 \text{ sec.}}{2 \text{ min.} \times 60 \text{ sec./min.}} = 231 \text{ feet}$

Decelerating

Up trip - $\frac{1,315 \text{ ft.} \times 10 \text{ sec.}}{2 \text{ min.} \times 60 \text{ sec./min.}} = 110 \text{ feet}$

Down trip - $\frac{1,390 \text{ ft.} \times 10 \text{ sec.}}{2 \text{ min.} \times 60 \text{ sec./min.}} = 116 \text{ feet}$

STATIC FORCES Trip - Up

Point 1	Time (sec.) 0		Distance (ft.) 0
Grade Resistance	77.85 x 20 x 12.4%	=	19,300
Rolling Resistance	70.2 x 14	=	983
	7.65 x 100	=	765
	Total Resistance	=	21,048
Points 2 & 3	Time (sec.) 20		Distance (ft.) 219
Grade Resistance	77.58 x 20 x 12.4%	=	19,240
Rolling Resistance	70.2 x 14	=	983
	7.38 x 100	=	738
	Total Resistance	=	20,961
Points 4 & 5	Time (sec.) 37.4		Distance (ft.) 600
Grade Resistance	77.10 x 20 x 6.7%	=	10,331
Rolling Resistance	70.2 x 14	=	983
	6.9 x 100	=	690
	Total Resistance	=	12,004
Points 6 & 7	Time (sec.) 45.6		Distance (ft.) 780
Grade Resistance	76.88 x 20 x 13.9%	=	21,373
Rolling Resistance	70.2 x 14	=	983
	6.68 x 100	=	668
	Total Resistance	=	23,024
Points 8 & 9	Time (sec.) 50.8		Distance (ft.) 895
Grade Resistance	76.73 x 20 x 7%	=	10,742
Rolling Resistance	70.2 x 14	=	983
	6.53 x 100	=	653
	Total Resistance	=	12,378

STATIC FORCES   Trip - Up

Points 10 & 11   Time (sec.) 64.5   Distance (ft.) 1,195

Grade Resistance	76.36 x 20 x 12.3%	=	18,785
Rolling Resistance	70.2 x 14	=	983
	6.16 x 100	=	616
	Total Resistance	=	20,384

Points 12 & 13   Time (sec.) 91.5   Distance (ft.) 1,785

Grade Resistance	75.62 x 20 x 10.7%	=	16,183
Rolling Resistance	70.2 x 14	=	983
	5.42 x 100	=	542
	Total Resistance	=	17,708

Points 14 & 15   Time (sec.) 104.7   Distance (ft.) 2,075

Grade Resistance	75.26 x 20 x 9.1%	=	13,697
Rolling Resistance	70.2 x 14	=	983
	5.06 x 100	=	506
	Total Resistance	=	15,186

Points 16 & 17   Time (sec.) 142.8   Distance (ft.) 2,905

Grade Resistance	74.22 x 20 x 7.3%	=	10,836
Rolling Resistance	70.2 x 14	=	983
	4.02 x 100	=	402
	Total Resistance	=	12,221

Points 18 & 19   Time (sec.) 147.0   Distance (ft.) 3,005

Grade Resistance	74.09 x 20 x 10.3%	=	15,563
Rolling Resistance	70.2 x 14	=	983
	3.89 x 100	=	389
	Total Resistance	=	16,655

STATIC FORCES — Trip - Up

Points 20 & 21	Time (sec.) 160.1		Distance (ft.) 3,285
Grade Resistance	73.74 x 20 x 8.9%	=	13,126
Rolling Resistance	70.2 x 14	=	983
	3.54 x 100	=	354
	Total Resistance	=	14,463
Points 22 & 23	Time (sec.) 162.9		Distance (ft.) 3,345
Grade Resistance	73.67 x 20 x 13.9%	=	20,480
Rolling Resistance	70.2 x 14	=	983
	3.47 x 100	=	347
	Total Resistance	=	21,810
Points 24 & 25	Time (sec.) 183.9		Distance (ft.) 3,805
Grade Resistance	73.09 x 20 x 17.5%	=	25,581
Rolling Resistance	70.2 x 14	=	983
	2.89 x 100	=	289
	Total Resistance	=	26,853
Points 26 & 27	Time (sec.) 193.0		Distance (ft.) 4,015
Grade Resistance	72.83 x 20 x 8.1%	=	11,798
Rolling Resistance	70.2 x 14	=	983
	2.63 x 100	=	263
	Total Resistance	=	13,044
Points 28 & 29	Time (sec.) 200.0		Distance (ft.) 4,155
Grade Resistance	72.66 x 20 x 4.5%	=	6,539
Rolling Resistance	70.2 x 14	=	983
	2.46 x 100	=	246
	Total Resistance	=	7,768

STATIC FORCES   Trip - Up

Points 30 & 31	Time (sec.) 204.2	Distance (ft.)	4,255
Grade Resistance	72.53 x 20 x 3.9%	=	5,657
Rolling Resistance	70.2 x 14	=	983
	2.33 x 100	=	233
	Total Resistance	=	6,873

Points 32 & 33	Time (sec.) 209.8	Distance (ft.)	4,375
Grade Resistance	72.38 x 20 x 6.7%	=	9,699
Rolling Resistance	70.2 x 14	=	983
	2.18 x 100	=	218
	Total Resistance	=	10,900

Points 34 & 35	Time (sec.) 218.0	Distance (ft.)	4,555
Grade Resistance	72.16 x 20 x 11.9%	=	17,174
Rolling Resistance	70.2 x 14	=	983
	1.96 x 100	=	196
	Total Resistance	=	18,353

Points 36 & 37	Time (sec.) 241.0	Distance (ft.)	5,045
Grade Resistance	71.54 x 20 x 7.8%	=	11,160
Rolling Resistance	70.2 x 14	=	983
	1.34 x 100	=	134
	Total Resistance	=	12,277

Points 38 & 39	Time (sec.) 245.5	Distance (ft.)	5,165
Grade Resistance	71.39 x 20 x 14%	=	19,989
Rolling Resistance	70.2 x 14	=	983
	1.19 x 100	=	119
	Total Resistance	=	21,091

STATIC FORCES Trip - Up

Points 40 & 41	Time (sec.) 253.0		Distance (ft.) 5,325
Grade Resistance	71.19 x 20 x 8.2%	=	11,675
Rolling Resistance	70.2 x 14	=	983
	0.99 x 100	=	99
	Total Resistance	=	12,757

Points 42 & 43	Time (sec.) 264.1		Distance (ft.) 5,570
Grade Resistance	70.89 x 20 x 2%	=	2,836
Rolling Resistance	70.2 x 14	=	983
	0.69 x 100	=	69
	Total Resistance	=	3,888

Points 44 & 45	Time (sec.) 273.5		Distance (ft.) 5,770
Grade Resistance	70.64 x 20 x 11%	=	15,541
Rolling Resistance	70.2 x 14	=	983
	0.44 x 100	=	44
	Total Resistance	=	16,568

Points 46 & 47	Time (sec.) 284.5		Distance (ft.) 6,010
Grade Resistance	70.34 x 20 x 11%	=	15,475
Rolling Resistance	70.2 x 14	=	983
	0.14 x 100	=	14
	Total Resistance	=	16,472

Point 48	Time (sec.) 294.5		Distance (ft.) 6,120
Grade Resistance	70.2 x 20 x 11%	=	15,444
Rolling Resistance	70.2 x 14	=	983
	Total Resistance	=	16,427

STATIC FORCES   Trip - To parting.

Point 1	Time (sec.) 0		Distance (ft.) 0
Grade Resistance	70.2 x 20 x -4%	=	-5,616
Rolling Resistance	70.2 x 14	=	983
	Total Resistance	=	-4,633
Points 2 & 3	Time (sec.) 20		Distance (ft.) 231
Grade Resistance	70.49 x 20 x -4%	=	-5,639
Rolling Resistance	70.2 x 14	=	983
	0.29 x 100	=	29
	Total Resistance	=	-4,627
Point 4	Time (sec.) 30		Distance (ft.) 350
Grade Resistance	70.2 x 20 x -4%	=	-5,616
Rolling Resistance	70.2 x 14	=	983
	0.44 x 100	=	44
	Total Resistance	=	-4,589

STATIC FORCES — Trip - From parting.

Point 1	Time (sec.) 0		Distance (ft.) 0
Grade Resistance	25.64 x 20 x 4%	=	2,051
Rolling Resistance	25.2 x 14	=	353
	0.44 x 100	=	44
	Total Resistance	=	2,448

Points 2 & 3	Time (sec.) 20		Distance (ft.) 219
Grade Resistance	25.36 x 20 x 4%	=	2,029
Rolling Resistance	25.2 x 14	=	353
	0.16 x 100	=	16
	Total Resistance	=	2,398

Points 4 & 5	Time (sec.) 21		Distance (ft.) 240
Grade Resistance	25.34 x 20 x 4%	=	2,027
Rolling Resistance	25.2 x 14	=	353
	0.14 x 100	=	14
	Total Resistance	=	2,394

Point 6	Time (sec.) 31		Distance (ft.) 350
Grade Resistance	25.2 x 20 x 4%	=	2,016
Rolling Resistance	25.2 x 14	=	353
	Total Resistance	=	2,369

STATIC FORCES   Trip - Down

Point 1   Time (sec.) 0   Distance (ft.) 0

Grade Resistance	25.2 x 20 x -11%	=	- 5,544
Rolling Resistance	25.2 x 14	=	353
	Total Resistance	=	- 5,191

Points 2 & 3   Time (sec.) 20   Distance (ft.) 231

Grade Resistance	25.49 x 20 x -11%	=	- 5,608
Rolling Resistance	25.2 x 14	=	353
	0.29 x 100	=	29
	Total Resistance	=	- 5,226

Points 4 & 5   Time (sec.) 25.1   Distance (ft.) 350

Grade Resistance	25.64 x 20 x -2%	=	- 1,026
Rolling Resistance	25.2 x 14	=	353
	0.44 x 100	=	44
	Total Resistance	=	- 629

Points 6 & 7   Time (sec.) 33.7   Distance (ft.) 550

Grade Resistance	25.89 x 20 x -8.2%	=	- 4,246
Rolling Resistance	25.2 x 14	=	353
	0.69 x 100	=	69
	Total Resistance	=	- 3,824

Points 8 & 9   Time (sec.) 44.3   Distance (ft.) 795

Grade Resistance	26.19 x 20 x -14%	=	- 7,333
Rolling Resistance	25.2 x 14	=	353
	0.99 x 100	=	99
	Total Resistance	=	- 6,881

STATIC FORCES — Trip - Down

Points 10 & 11	Time (sec.) 51.2		Distance (ft.) 955
Grade Resistance	26.39 x 20 x -7.8%	=	- 4,117
Rolling Resistance	25.2 x 14	=	353
	1.19 x 100	=	119
	Total Resistance	=	- 3,645

Points 12 & 13	Time (sec.) 56.3		Distance (ft.) 1,075
Grade Resistance	26.54 x 20 x -11.9%	=	- 6,317
Rolling Resistance	25.2 x 14	=	353
	1.34 x 100	=	134
	Total Resistance	=	- 5,830

Points 14 & 15	Time (sec.) 77.5		Distance (ft.) 1,565
Grade Resistance	27.16 x 20 x -6.7%	=	- 3,639
Rolling Resistance	25.2 x 14	=	353
	1.96 x 100	=	196
	Total Resistance	=	- 3,090

Points 16 & 17	Time (sec.) 85.2		Distance (ft.) 1,745
Grade Resistance	27.38 x 20 x -3.9%	=	- 2,136
Rolling Resistance	25.2 x 14	=	353
	2.18 x 100	=	218
	Total Resistance	=	- 1,565

Points 18 & 19	Time (sec.) 90.4		Distance (ft.) 1,865
Grade Resistance	27.53 x 20 x -4.5%	=	- 2,478
Rolling Resistance	25.2 x 14	=	353
	2.33 x 100	=	233
	Total Resistance	=	- 1,892

STATIC FORCES Trip - Down

Points 20 & 21 Time (sec.) 94.7 Distance (ft.) 1,965

Grade Resistance	27.66 x 20 x -8.1%	=	- 4,481
Rolling Resistance	25.2 x 14	=	353
	2.46 x 100	=	246
	Total Resistance	=	- 3,882

Points 22 & 23 Time (sec.) 100.8 Distance (ft.) 2,105

Grade Resistance	27.83 x 20 x -17.5%	=	- 9,740
Rolling Resistance	25.2 x 14	=	353
	2.63 x 100	=	263
	Total Resistance	=	- 9,124

Points 24 & 25 Time (sec.) 109.7 Distance (ft.) 2,315

Grade Resistance	28.09 x 20 x -13.9%	=	- 7,809
Rolling Resistance	25.2 x 14	=	353
	2.89 x 100	=	289
	Total Resistance	=	- 7,167

Points 26 & 27 Time (sec.) 129.5 Distance (ft.) 2,775

Grade Resistance	28.67 x 20 x -8.9%	=	- 5,103
Rolling Resistance	25.2 x 14	=	353
	3.47 x 100	=	347
	Total Resistance	=	- 4,403

Points 28 & 29 Time (sec.) 132.1 Distance (ft.) 2,835

Grade Resistance	28.74 x 20 x -10.3%	=	- 5,920
Rolling Resistance	25.2 x 14	=	353
	3.54 x 100	=	354
	Total Resistance	=	- 5,213

STATIC FORCES Trip - Down

Points 30 & 31	Time (sec.) 144.1	Distance (ft.)	3,115
Grade Resistance	29.09 x 20 x -7.3%	=	- 4,247
Rolling Resistance	25.2 x 14	=	353
	3.89 x 100	=	389
	Total Resistance	=	- 3,505

Points 32 & 33	Time (sec.) 148.5	Distance (ft.)	3,215
Grade Resistance	29.22 x 20 x -9.1%	=	- 5,318
Rolling Resistance	25.2 x 14	=	353
	4.02 x 100	=	402
	Total Resistance	=	- 4,563

Points 34 & 35	Time (sec.) 184.1	Distance (ft.)	4,045
Grade Resistance	30.26 x 20 x -10.7%	=	- 6,476
Rolling Resistance	25.2 x 14	=	353
	5.06 x 100	=	506
	Total Resistance	=	- 5,617

Points 36 & 37	Time (sec.) 196.6	Distance (ft.)	4,335
Grade Resistance	30.62 x 20 x -12.3%	=	- 7,533
Rolling Resistance	25.2 x 14	=	353
	5.42 x 100	=	542
	Total Resistance	=	- 6,638

Points 38 & 39	Time (sec.) 222.2	Distance (ft.)	4,925
Grade Resistance	31.36 x 20 x -7%	=	- 4,925
Rolling Resistance	25.2 x 14	=	353
	6.16 x 100	=	616
	Total Resistance	=	- 3,421

STATIC FORCES Trip - Down

Points 40 & 41	Time (sec.) 235.0		Distance (ft.) 5,225
Grade Resistance	31.73 x 20 x -13.9%	=	- 8,821
Rolling Resistance	25.2 x 14	=	353
	6.53 x 100	=	653
	Total Resistance	=	- 7,815

Points 42 & 43	Time (sec.) 240.0		Distance (ft.) 5,340
Grade Resistance	31.88 x 20 x -6.7%	=	- 4,272
Rolling Resistance	25.2 x 14	=	353
	6.68 x 100	=	668
	Total Resistance	=	- 3,251

Points 44 & 45	Time (sec.) 248.0		Distance (ft.) 5,520
Grade Resistance	32.1 x 20 x -12.4%	=	- 7,961
Rolling Resistance	25.2 x 14	=	353
	6.90 x 100	=	690
	Total Resistance	=	- 6,918

Points 46 & 47	Time (sec.) 268.8		Distance (ft.) 6,004
Grade Resistance	32.71 x 20 x -12.4%	=	- 8,112
Rolling Resistance	25.2 x 14	=	353
	7.51 x 100	=	751
	Total Resistance	=	- 7,008

Point 48	Time (sec.) 278.8		Distance (ft.) 6,120
Grade Resistance	32.85 x 20 x -12.4%	=	- 8,147
Rolling Resistance	25.2 x 14	=	353
	7.65 x 100	=	765
	Total Resistance	=	- 7,029

Hoist Friction (efficiency = 80%)

Up Trip

$$\text{Average static force} = \frac{396,784}{25} = 15,871\ \#$$

$$\frac{15,871}{0.80} = 19,839\ \#$$

$$19,839 - 15,871 = \underline{3,968\ \#} = \text{hoist friction}$$

Down Trip

$$\text{Average static force} = \frac{125,378}{25} = 5,015\ \#$$

$$\frac{5,015}{0.80} = 6,269\ \#$$

$$6,269 - 5,015 = \underline{1,254\ \#} = \text{hoist friction}$$

Estimated horsepower.

15,622 + 3,968 = 19,590 # = Average full speed force up trip.

4,920 - 1,254 = 3,666 # = Average full speed force down trip.

$$HP = \frac{\text{force x velocity}}{33,000} = \frac{(19,590 + 3,666) \text{ x } 1,353 \text{ x } 125\%}{2 \text{ x } 33,000} = \underline{\underline{596 \text{ H. P. est.}}}$$

Trip - Up

6-7	8-9	10-11	12-13	14-15	16-17
45.6	50.8	64.5	91.5	104.7	142.8
780	895	1,195	1,785	2,075	2,905
23,024	12,378	20,384	17,708	15,186	12,221
3,968	3,968	3,968	3,968	3,968	3,968
26,992	16,346	24,352	21,676	19,154	16,189
1,075	651	970	863	763	644

26-27	28-29	30-31	32-33	34-35	36-37
193.0	200.0	204.2	209.8	218.0	241.0
4,015	4,155	4,255	4,375	4,555	5,045
13,044	7,768	6,873	10,900	18,353	12,277
3,968	3,968	3,968	3,968	3,968	3,968
17,012	11,736	10,841	14,868	22,321	16,645
678	467	432	591	889	647

46	47	48
284.5	284.5	284.5
6,010	6,010	6,010
16,472	16,472	16,458
3,968	3,968	3,968
	-17,790	-17,790
20,440	2,650	2,636
816	105.5	105

SUMMATION

Point	1	2	3	4-5
Time (sec.)	0	20	20	37.4
Distance Traveled	0	219	219	600
Static Force (#)	21,048	20,961	20,961	12,004
Friction (#)	3,968	3,968	3,968	3,968
Acc. & Dec. (#)	9,410	9,410		
Total Force (#)	34,426	34,339	24,929	15,972
Horsepower	1,372	1,368	994	636

Point	18-19	20-21	22-23	24-25
Time (sec.)	147.0	160.1	162.9	183.9
Distance Traveled	3,005	3,285	3,345	3,805
Static Force (#)	16,655	14,463	21,810	26,853
Friction (#)	3,968	3,968	3,968	3,968
Acc. & Dec. (#)				
Total Force (#)	20,623	18,431	25,778	30,821
Horsepower	822	735	1,026	1,228

Point	38-39	40-41	42-43	44-45
Time (sec.)	245.5	253.0	264.1	273.5
Distance Traveled	5,165	5,325	5,570	5,770
Static Force (#)	21,091	12,757	3,888	16,568
Friction (#)	3,968	3,968	3,968	3,968
Acc. & Dec. (#)				
Total Force	25,059	16,725	7,856	20,536
Horsepower	998	666	313	819

SUMMATION

Point	1	2	3
Time (sec.)	0	20	20
Distance Traveled	0	231	231
Static Force (#)	-4,633	-4,627	-4,627
Friction (#)	1,254	1,254	1,254
Acc. & Dec. (#)	9,380	9,380	-12,380
Total Force (#)	6,001	6,007	-15,753
Horsepower	252.5	252.5	- 664

Trip - To Parting

4
30
350
-4,624
1,254
-12,380
-15,750
- 664

SUMMATION

Point	1	2	3
Time (sec.)	0	20	20
Distance Traveled	0	219	219
Static Force (#)	2,448	2,398	2,398
Friction (#)	3,968	3,968	3,968
Acc. & Dec. (#)	5,860	5,860	
Total Force (#)	12,276	12,226	6,366
Horsepower	489	488	254

Trip - From Parting

4	5	6
21	21	31
240	240	350
2,394	2,394	2,369
3,968	3,968	3,968
	-11,660	-11,660
3,362	- 5,298	- 5,323
254	- 211	- 212

SUMMATION Trip - Down

Point	1	2	3	4-5	6-7	8-9	10-11	12-13	14-15	16-17
Time (sec.)	0	20	20	25.1	33.7	44.3	51.2	56.3	77.5	85.2
Distance Traveled	0	231	231	350	550	795	955	1,075	1,565	1,745
Static Force (#)	-5,191	-5,226	-5,226	- 629	-3,824	-6,881	-3,645	-5,830	-3,090	-1,565
Friction (#)	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254
Acc. & Dec. (#)	6,160	6,160								
Total Force (#)	2,223	2,188	-3,972	625	-2,570	-5,627	-2,391	-4,576	-1,836	- 311
Horsepower	93.6	92.1	-167.2	26.3	-108.2	- 237	-100.9	- 193	- 77.3	- 13.1

Point	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37
Time (sec.)	90.4	94.7	100.8	109.7	129.5	132.1	144.1	148.5	184.1	196.6
Distance Traveled	1,865	1,965	2,105	2,315	2,775	2,835	3,115	3,215	4,045	4,335
Static Force (#)	-1,892	-3,882	-9,124	-7,167	-4,403	-5,213	-3,505	-4,563	-5,617	-6,638
Friction (#)	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254
Acc. & Dec. (#)										
Total Force (#)	- 638	-2,628	-7,870	-5,913	-3,149	-3,959	-2,251	-3,309	-4,363	-5,384
Horsepower	- 26.9	-110.8	- 332	- 249	-132.5	-166.7	- 94.9	-139.2	- 184	- 227

Point	38-39	40-41	42-43	44-45	46	47	48
Time (sec.)	222.2	235.0	240.0	248.0	268.8	268.8	278.8
Distance Traveled	4,925	5,225	5,340	5,520	6,004	6,004	6,120
Static Force (#)	-3,421	-7,815	-3,251	-6,918	-7,008	-7,008	-7,029
Friction (#)	1,254	1,254	1,254	1,254	1,254	1,254	1,254
Acc. & Dec. (#)						-19,900	-19,900
Total Force (#)	-2,167	-6,561	-1,997	-5,664	-5,754	-25,654	-25,675
Horsepower	- 91.3	-276.5	- 84	- 239	-242.5	- 1,082	- 1,083

Up Trip

Area				
1 - 2	$1/2\ (1,372^2 + 1,368^2)$	x 20	=	37,538,080
3 - 4	$1/3\ (994^2 + 636^2 + 994 \times 636)$	x 17.4	=	11,743,347
5 - 6	$1/3\ (636^2 + 1,075^2 + 636 \times 1,075)$	x 8.2	=	6,133,108
7 - 8	$1/3\ (1,075^2 + 651^2 + 1,075 \times 651)$	x 5.2	=	3,950,700
9 - 10	$1/3\ (651^2 + 970^2 + 651 \times 970)$	x 13.7	=	9,115,843
11 - 12	$1/3\ (970^2 + 863^2 + 970 \times 863)$	x 27.0	=	22,705,002
13 - 14	$1/3\ (863^2 + 763^2 + 863 \times 763)$	x 13.2	=	8,735,786
15 - 16	$1/3\ (763^2 + 644^2 + 763 \times 644)$	x 38.1	=	18,901,105
17 - 18	$1/3\ (644^2 + 822^2 + 644 \times 822)$	x 4.2	=	2,267,702
19 - 20	$1/3\ (822^2 + 735^2 + 822 \times 735)$	x 13.1	=	7,947,678
21 - 22	$1/3\ (735^2 + 1,026^2 + 735 \times 1,026)$	x 2.8	=	2,190,544
23 - 24	$1/3\ (1,026^2 + 1,228^2 + 1,026 \times 1,228)$	x 21.0	=	26,744,109
25 - 26	$1/3\ (1,228^2 + 678^2 + 1,228 \times 678)$	x 9.1	=	8,494,095
27 - 28	$1/3\ (678^2 + 467^2 + 678 \times 467)$	x 7.0	=	2,320,262
29 - 30	$1/3\ (467^2 + 432^2 + 467 \times 432)$	x 4.2	=	849,038
31 - 32	$1/3\ (432^2 + 591^2 + 432 \times 591)$	x 5.6	=	1,476,938
33 - 34	$1/3\ (591^2 + 889^2 + 591 \times 889)$	x 8.2	=	4,551,000
35 - 36	$1/3\ (889^2 + 647^2 + 889 \times 647)$	x 23.0	=	13,601,533
37 - 38	$1/3\ (647^2 + 998^2 + 647 \times 998)$	x 4.5	=	3,075,480
39 - 40	$1/3\ (998^2 + 666^2 + 998 \times 666)$	x 8.5	=	5,961,977
41 - 42	$1/3\ (666^2 + 313^2 + 666 \times 313)$	x 11.1	=	2,774,933
43 - 44	$1/3\ (313^2 + 819^2 + 313 \times 819)$	x 8.4	=	2,870,213
45 - 46	$1/3\ (819^2 + 816^2 + 819 \times 816)$	x 11.0	=	7,351,377
47 - 48	$1/2\ (105.5^2 + 105^2)$	x 10		110,780

To Parting

Area				
1 - 2	$1/2\ (252.5^2 + 252.5^2)$	x 20.0	=	1,275,120
3 - 4	$1/2\ (-664^2 + -664^2)$	x 10.0	=	4,408,960

From Parting to Top

Area				
1 - 2	$1/2\ (489^2 + 488^2)$	x 20.0	=	4,772,640
3 - 4	$1/3\ (254^2 + 254^2 + 254 \times 254)$	x 1.0	=	64,516
5 - 6	$1/2\ (-211^2 + -212^2)$	x 10.0	=	447,320

Down Trip

Area			
1 - 2	$1/2\ (93.6^2 + 92.1^2)$	x 20.0 =	172,420
3 - 4	$1/3\ (-167.2^2 + 26.3^2 + -167.2 \times 26.3)$	x 5.1 =	41,228
5 - 6	$1/3\ (26.3^2 + -108.2^2 + 26.3 \times -108.2)$	x 8.6 =	27,417
7 - 8	$1/3\ (-108.2^2 + -237^2 + -108.2 \times -237)$	x 10.6 =	330,434
9 - 10	$1/3\ (-237^2 + -100.9^2 + -237 \times -100.9)$	x 6.9 =	207,607
11 - 12	$1/3\ (-100.9^2 + -193^2 + -100.9 \times -193)$	x 5.1 =	113,735
13 - 14	$1/3\ (-193^2 + -77.3^2 + -193 \times -77.3)$	x 21.2 =	410,877
15 - 16	$1/3\ (-77.3^2 + -13.1^2 + -77.3 \times -13.1)$	x 7.7 =	18,380
17 - 18	$1/3\ (-13.1^2 + -26.9^2 + -13.1 \times -26.9)$	x 5.2 =	2,163
19 - 20	$1/3\ (-26.9^2 + -110.8^2 + -26.9 \times -110.8)$	x 4.3 =	22,906
21 - 22	$1/3\ (-110.8^2 + -332^2 + -110.8 \times -332)$	x 6.1 =	323,886
23 - 24	$1/3\ (-332^2 + -249^2 + -332 \times -249)$	x 8.9 =	756,180
25 - 26	$1/3\ (-249^2 + -132.5^2 + -249 \times -132.5)$	x 19.8 =	742,837
27 - 28	$1/3\ (-132.5^2 + -166.7^2 + -132.5 \times 166.7)$	x 2.6 =	58,443
29 - 30	$1/3\ (-166.7^2 + -94.9^2 + -166.7 \times -94.9)$	x 12.0 =	210,456
31 - 32	$1/3\ (-94.9^2 + -139.2^2 + -94.9 \times -139.2)$	x 4.4 =	61,002
33 - 34	$1/3\ (-139.2^2 + -184^2 + -139.2 \times -184)$	x 35.6 =	935,639
35 - 36	$1/3\ (-184^2 + -227^2 + -184 \times -227)$	x 12.5 =	529,800
37 - 38	$1/3\ (-227^2 + -91.3^2 + -227 \times -91.3)$	x 25.6 =	687,693
39 - 40	$1/3\ (-91.3^2 + -276.5^2 + -91.3 \times -276.5)$	x 12.8 =	469,466
41 - 42	$1/3\ (-276.5^2 + -84^2 + -276.5 \times -84)$	x 5.0 =	177,890
43 - 44	$1/3\ (-84^2 + -239^2 + -84 \times -239)$	x 8.0 =	224,672
45 - 46	$1/3\ (-239^2 + - 242.5^2 + -239 \times -242.5)$	x 20.8 =	1,205,610
47 - 48	$1/2\ (-1,082^2 + -1,083^2)$	x 10.0 =	11,718,070

Total H. P. sec. = 241,827,997

Total effective time = Acc. 80 sec.
Dec. 40 sec.

Total ..... 120 sec. x 1/2 = 60.0 sec.

Rest ...... 75 sec. x 1/4 = 18.75 sec.

Full speed .... = 514.5 sec.

TOTAL = 593.25 sec.

Root mean square rating of motors = $\sqrt{\frac{241,827,997}{593.25}} = \sqrt{357,250}$

= 598 H. P. total, or 299 H. P. each motor.

Two 300-H.P. motors may be used. A pull-out torque of at least

$\frac{1,372}{600}$ = 2.29 times that at the rated H. P. is required.

In any operation in coal mining it is desirable to keep two words foremost in mind: Comparable accuracy. It is clearly seen that the hoist on No. 2 slope has more power than is required.

If the slope had been graded from the curve to 8th East at a uniform slope of 10-1/2 per cent, the following situation would exist:

Data: 11 car trips
10-1/2% grade
1-1/4" rope

Grade Resistance:

93.45 tons x 20 #/ton/%grade x 10.5% = 19,625 #

Rolling Resistance:

85.8 tons x 14 #/ton = 1,201 #

7.65 tons x 100 #/ton = 765 #

Acceleration:

$$F = MA = \frac{93.45 \times 2,000}{32.2} \times 1.096 \text{ ft./sec.}^2 = 6,360 \#$$

TOTAL = 27,951 #

$$\text{Safety factor of rope} = \frac{69 \text{ tons} \times 2,000 \#/\text{ton}}{27,951} = 4.94$$

STATIC FORCES Trip - Up

Point 1 Time (sec.) 0 Distance (ft.) 0

Grade Resistance	93.29 x 20 x 10.5%	=	19,591
Rolling Resistance	85.8 x 14	=	1,201
	7.49 x 100	=	749
	Total Resistance	=	21,541

Points 2 & 3 Time (sec.) 20 Distance (ft.) 219

Grade Resistance	93.02 x 20 x 10.5%	=	19,534
Rolling Resistance	85.8 x 14	=	1,201
	7.22 x 100	=	722
	Total Resistance	=	21,457

Points 4 & 5 Time (sec.) 258.5 Distance (ft.) 5,440

Grade Resistance	86.49 x 20 x 2%	=	3,460
Rolling Resistance	85.8 x 14	=	1,201
	0.69 x 100	=	69
	Total Resistance	=	4,730

Points 6 & 7 Time (sec.) 267.6 Distance (ft.) 5,640

Grade Resistance	86.24 x 20 x 11%	=	18,973
Rolling Resistance	85.8 x 14	=	1,201
	0.44 x 100	=	44
	Total Resistance	=	20,218

Points 8 & 9 Time (sec.) 278.6 Distance (ft.) 5,880

Grade Resistance	85.94 x 20 x 11%	=	18,907
Rolling Resistance	85.8 x 14	=	1,201
	0.14 x 100	=	14
	Total Resistance	=	20,122

Point 10 Time (sec.) 288.6 Distance (ft.) 5,990

Grade Resistance	85.8 x 20 x 20%	=	18,876
Rolling Resistance	85.8 x 14	=	1,201
	Total Resistance	=	20,077

STATIC FORCES — Trip - To Parting

Point 1 — Time (sec.) 0 — Distance (ft.) 0

Grade Resistance	85.8 x 20 x -4%	=	- 6,864
Rolling Resistance	85.8 x 14	=	1,201
	Total Resistance	=	- 5,663

Points 2 & 3 — Time (sec.) 20 — Distance (ft.) 231

Grade Resistance	86.09 x 20 x -4%	=	- 6,887
Rolling Resistance	85.8 x 14	=	1,201
	0.29 x 100	=	29
	Total Resistance	=	- 5,657

Point 4 — Time (sec.) 30 — Distance (ft.) 350

Grade Resistance	86.24 x 20 x -4%	=	- 6,899
Rolling Resistance	85.8 x 14	=	1,201
	0.44 x 100	=	44
	Total Resistance	=	- 5,654

STATIC FORCES Trip - From Parting

Point 1	Time (sec.) 0		Distance (ft.)	0
Grade Resistance	31.24 x 20 x 4%	=	2,499	
Rolling Resistance	30.8 x 14	=	431	
	0.44 x 100	=	44	
	Total Resistance	=	2,974	
Points 2 & 3	Time (sec.) 20		Distance (ft.)	219
Grade Resistance	30.96 x 20 x 4%	=	2,477	
Rolling Resistance	30.8 x 14	=	431	
	0.16 x 100	=	16	
	Total Resistance	=	2,924	
Points 4 & 5	Time (sec.) 21		Distance (ft.)	240
Grade Resistance	30.94 x 20 x 4%	=	2,475	
Rolling Resistance	30.8 x 14	=	431	
	0.14 x 100	=	14	
	Total Resistance	=	2,920	
Point 6	Time (sec.) 31		Distance (ft.)	350
Grade Resistance	30.8 x 20 x 4%	=	2,464	
Rolling Resistance	30.8 x 14	=	431	
	Total Resistance	=	2,895	

STATIC FORCES   Trip - Down

Point 1	Time (sec.) 0		Distance (ft.) 0
Grade Resistance	30.8 x 20 x -11%	=	- 6,776
Rolling Resistance	30.8 x 14	=	431
	Total Resistance	=	- 6,345
Points 2 & 3	Time (sec.) 20		Distance (ft.) 231
Grade Resistance	31.09 x 20 x -11%	=	- 6,840
Rolling Resistance	30.8 x 14	=	431
	0.29 x 100	=	29
	Total Resistance	=	- 6,380
Points 4 & 5	Time (sec.) 25.1		Distance (ft.) 350
Grade Resistance	31.24 x 20 x -2%	=	- 1,250
Rolling Resistance	30.8 x 14	=	431
	0.44 x 100	=	44
	Total Resistance	=	- 775
Points 6 & 7	Time (sec.) 33.7		Distance (ft.) 550
Grade Resistance	31.49 x 20 x -10.5%	=	- 6,613
Rolling Resistance	30.8 x 14	=	431
	0.69 x 100	=	69
	Total Resistance	=	- 6,113
Points 8 & 9	Time (sec.) 263.7		Distance (ft.) 5,874
Grade Resistance	38.00 x 20 x -10.5%	=	- 7,980
Rolling Resistance	30.8 x 14	=	431
	7.20 x 100	=	720
	Total Resistance	=	- 6,829
Point 10	Time (sec.) 273.7		Distance (ft.) 5,990
Grade Resistance	38.29 x 20 x -10.5%	=	- 8,041
Rolling Resistance	30.8 x 14	=	431
	7.49 x 100	=	749
	Total Resistance	=	- 6,861

Hoist Friction (efficiency = 80%)

Up Trip

Average static force = $\frac{108,145}{6}$ = 18,024 #

$\frac{18,024}{0.80}$ = 22,530 #

22,530 - 18,024 = 4,506 # = hoist friction

Down Trip

Average static force = $\frac{33,303}{6}$ = 5,550 #

$\frac{5,550}{0.80}$ = 6,938 #

6,938 - 5,550 = 1,388 # = hoist friction

Estimated Horsepower

16,582 + 4,506 = 21,088 # = Average full speed force up trip.

5,024 - 1,388 = 3,636 # = Average full speed force down trip.

$$HP = \frac{\text{force x velocity}}{33,000} = \frac{(21,088 + 3,636) \times 1,353 \times 125\%}{2 \times 33,000} = 634 \text{ H.P. est.}$$

Trip - Up

6-7	8	9	10
267.6	278.6	278.6	288.6
5,880	5,880	5,990	
20,218	20,122	20,122	20,077
4,506	4,506	4,506	4,506
		-19,920	-19,920
24,724	24,628	4,708	4,663
984	982	188	186

SUMMATION

Point	1	2	3	4-5
Time (sec.)	0	20	20	258.5
Distance Traveled	0	219	219	5,440
Static Force (#)	21,541	21,457	21,457	4,730
Friction (#)	4,506	4,506	4,506	4,506
Acc. & Dec. (#)	10,480	10,480		
Total Force (#)	36,527	36,443	25,963	9,236
Horsepower	1,455	1,452	1,034	368

SUMMATION

Trip - To parting

Point	1	2	3	4
Time (sec.)	0	20	20	30
Distance Traveled	0	231	231	350
Static Force (#)	-5,663	-5,657	-5,657	-5,654
Friction (#)	1,388	1,388	1,388	1,388
Acc. & Dec. (#)	10,520	10,520	-13,190	-13,190
Total Force (#)	6,245	6,251	-17,459	-17,456
Horsepower	263	264	- 736	- 736

SUMMATION Trip - From Parting

Point	1	2	3	4	5	6
Time (sec.)	0	20	20	21	21	31
Distance Traveled	0	219	219	240	240	350
Static Force (#)	2,974	2,924	2,924	2,920	2,920	2,895
Friction (#)	4,506	4,506	4,506	4,506	4,506	4,506
Acc. & Dec. (#)	6,240	6,240			-12,420	-12,420
Total Force (#)	13,720	13,670	7,430	7,426	-4,994	-5,019
Horsepower	547	544	296	296	199	200

SUMMATION Trip - Down

Point	1	2	3	4-5	6-7	8	9	10
Time (sec.)	0	20	20	25.1	33.7	263.8	263.7	273.7
Distance Traveled	0	231	231	350	550	5,874	5,874	5,990
Static Force (#)	-6,345	-6,380	-6,380	- 775	-6,113	-6,829	-6,829	-6,861
Friction (#)	1,388	1,388	1,388	1,388	1,388	1,388	1,388	1,388
Acc. & Dec. (#)	6,550	6,550					-22,150	-22,150
Total Force (#)	1,593	1,558	-4,992	613	-4,725	-5,441	-27,591	-27,623
Horsepower	67.1	65.5	- 210	25.8	- 199	- 229	- 1,160	- 1,162

Up Trip

Area				
1 - 2	$1/2\ (1{,}455^2 + 1{,}452^2)$	x 20.0	=	42,253,290
3 - 4	$1/3\ (1{,}034^2 + 368^2 + 1{,}034 \times 368)$	x 238.5	=	126,014,814
5 - 6	$1/3\ (368^2 + 984^2 + 368 \times 984)$	x 9.1	=	4,446,233
7 - 8	$1/3\ (984^2 + 982^2 + 984 \times 982)$	x 11.0	=	10,629,179
9 - 10	$1/2\ (188^2 + 186^2)$	x 10.0	=	349,700

To Parting

1 - 2	$1/2\ (263^2 + 264^2)$	x 20.0	=	1,388,650
3 - 4	$1/2\ (-736^2 + -736^2)$	x 10.0	=	5,416,960

From Parting

1 - 2	$1/2\ (547^2 + 544^2)$	x 20.0	=	5,951,145
3 - 4	$1/3\ (296^2 + 296^2 + 296 \times 296)$	x 1.0	=	87,616
5 - 6	$1/2\ (199^2 + 200^2)$	x 10.0	=	398,000

Down Trip

1 - 2	$1/2\ (67.1^2 + 65.5^2)$	x 20.0	=	87,920
3 - 4	$1/3\ (-210^2 + 25.8^2 + -210 \times 25.8)$	x 5.1	=	66,892
5 - 6	$1/3\ (25.8^2 + -199^2 + 25.8 \times -199)$	x 8.6	=	100,715
7 - 8	$1/3\ (-199^2 + -299^2 + -199 \times -299)$	x 230.0	=	10,550,330
9 - 10	$1/2\ (-1{,}160^2 + -1{,}162^2)$	x 10.0	=	13,479,220

Total H.P. sec. = 221,220,664

Total H. P. sec. = 221,220,664

Total effective time =	Acc.	80 sec.		
	Dec.	40 sec.		
	Total	120 sec. x 1/2 =		60.00 sec.
	Rest	75 sec. x 1/4 =		18.75 sec.
	Full Speed		=	503.3 sec.
		TOTAL	=	582.05 sec.

Root mean square rating of motors = $\sqrt{\frac{221,220,664}{582.05}} = \sqrt{380,072}$

= 616.5 total horsepower, or 308.3 H.P. each motor.

Two 350-H.P. motors may be used. A pull-out torque of at least

$\frac{1,455}{700}$ = 2.08 times that at the rated H. P. is required.

SUMMARY

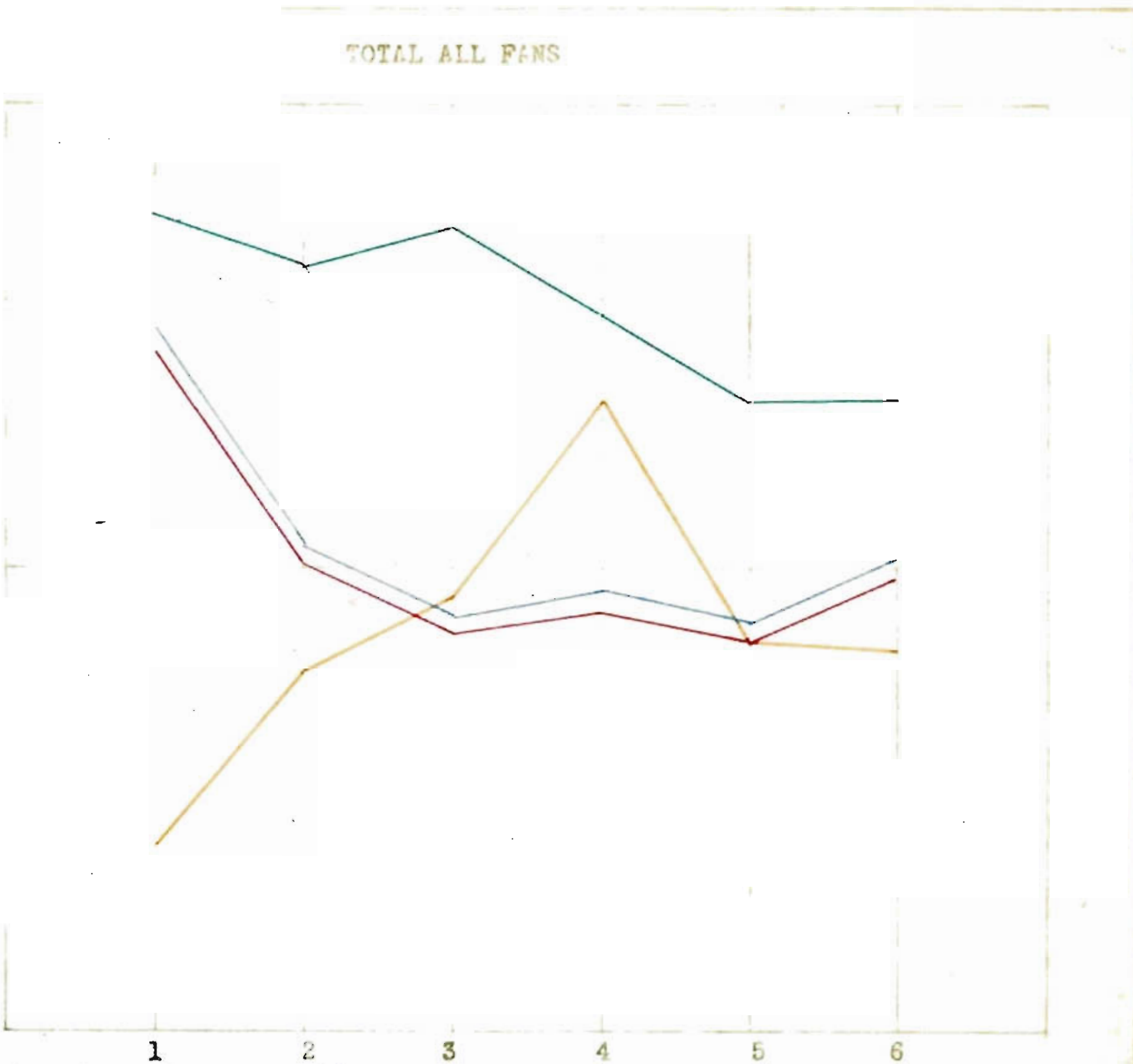
Ventilation

There are two factors which govern the choice of a ventilation system at any mine. First and foremost is the necessity to provide an adequate amount of air at each place which requires ventilation. The second, and the one most commonly overlooked, is the desirability of providing this air at the cheapest overall cost; i.e., the initial cost of the proper fan plus the power costs for the number of years which the fan is in operation balanced against the costs of driving airways in rock and in coal.

The Kenilworth mine has undergone many changes in its proposed plans of development since its inception in 1906. The section at the bottom of No. 5 Raise was to have been developed further to the East, but the encountering of low coal and the economics involved caused this area to be temporarily abandoned. No. 3 fan was installed at its present location for the purpose of ventilating this area. However, once the section was no longer in a production status, the situation required a readjustment. Fresh air was necessary inby No. 5 Raise because of a pump and a power line which entered the mine through a bore hole at this point.

The intakes at the top of No. 5 Raise were sealed off with the intention of reducing the amount of fugitive air and thereby reducing power costs. The higher water gage created as a result put the fan near its stall zone and caused it to stall occasionally.

Quan	Power cost	B.H.P.	Fug. Air.
300,000	$12,000	200	150,000
150,000	$ 6,000	100	75,000
0	0	0	0



1 - Three fans operating
2 - Two fans operating, No 1 sealed off.
3 - Two fans operating, blade pos. No 3 on no 1 position.
4 - Two fans operating, No 4 slope sealed off.
5 - Two fans operating, No 5 raise intakes sealed off.
6 - Two fans operating, blade pos. No 3 on no 4 position.

Three fans in operation produced 264,100 cfm of air at a yearly power cost of $ 8,850. Two fans in operation (Case III, page 47) produced 260,300 cfm of air at a yearly power cost of $ 5,170.

When No. 4 slope was sealed off and the air re-routed through a single airway 300 feet long, as shown on page 27, the yearly power costs rose to $ 5,480 while the quantity of air dropped to 232,100 cfm.

The result of this study was a saving in power costs because of increased ventilation efficiency of $ 3,810 per year. (See Fig. No. 18, facing page.)

A great deal of money is spent each year for fugitive air. Power costs can be reduced further and greater efficiency attained by cleaning airways and re-routing air, as shown on page 93.

A comprehensive air survey at periodic intervals will save a company a great deal of money, as has been shown in this thesis.

Hoisting

Prior to this study, eight-car trips were hoisted up No. 2 slope. As a result of this analysis an extra car was added to each trip, increasing the hoisting capacity by 190 tons per shift, giving a total of 1,710 tons per shift.

If the slope were graded in accordance with this study, eleven-car trips would be possible. Capacity would be increased to 2,100 tons per

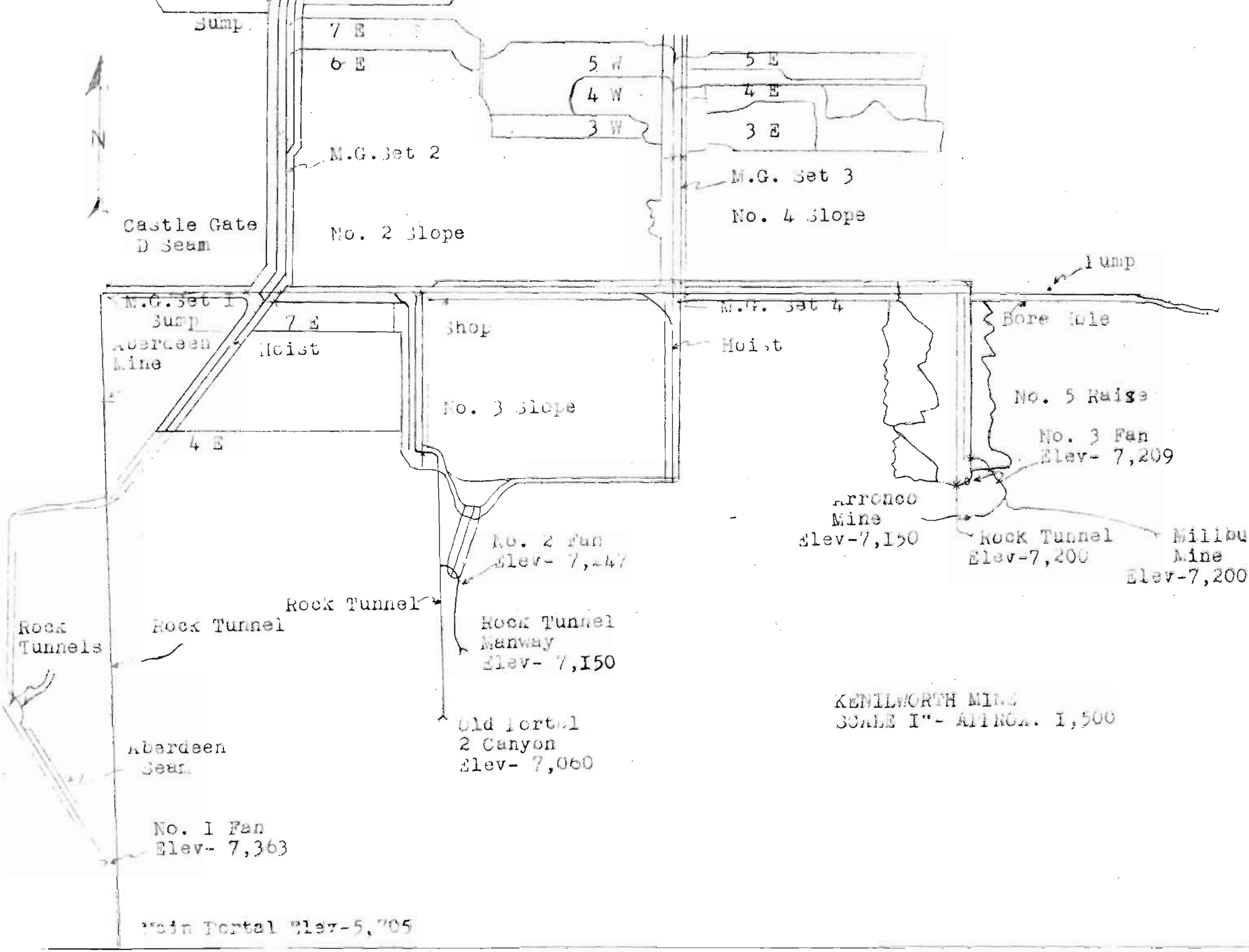


FIGURE NUMBER 20

shift, using the present hoist and rope.

Two loaders are serviced by this equipment. Each loader has produced over 1,000 tons per shift, and is averaging 800 tons per shift. Under the present system, maximum output for the area has been obtained.

Grading of the slope is not recommended at this time because of the change in haulage pattern whereby Castlegate mine will serve as the main haulageway for Kenilworth coal.

CONCLUSIONS

The study shows that careful engineering efficiency analyses can save a company a great deal of money. It is recommended that studies such as this be made of other phases of the mining operation.

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