GOVERNMENT OF CANADA

ENVIRONMENTAL ASSESSMENT REVIEW

ROGERS PASS REVIEW PANEL

REVIEW OF ROGERS PASS TUNNEL VENTILATION SYSTEM CONCEPTS

PROPOSED BY C.P. RAIL

BY KLOHN LEONOFF LTD.
CONSULTING ENGINEERS
RICHMOND, B.C.

VA 2995

April 12, 1982

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

VA 2995 April 12, 1982

1. INTRODUCTION

On July 27, 1981 C.P.Rail applied to the Canadian Transport Commission for approval of a Grade Improvement Project between Rogers, B.C. and a point approximately 3 miles west of Glacier, B.C. This grade improvement would introduce a new section of double tracking with grades limited to 1.0% and include two tunnels of approximately 9.0 miles and 1.0 mile in length near Rogers Pass, B.C. as shown in the initial Environmental Evaluation (6). This is the fourth stage of a program to reduce controlling grades and improve traffic capacity between Golden and Vancouver.

The project was approved by the Canadian Transport Commission in their decision dated March 9, 1982 (B)*. Following hearings at Revelstoke, B.C. on December 16, 17, 1981. In the course of the hearings Parks Canada submitted a Position Statement dated December 16, 1981 in which they raised various questions regarding the environmental impact of the construction of this project. In particular certain questions were raised regarding the ongoing impact of the proposed tunnel ventilation system and the exhaust. Consequently, the Minister of the Environment, on March 4, 1982, announced formation of an Environmental Assessment Panel to review the environmental and social impacts of the C.P.Rail proposal. The chairman of the panel is Mr. P.J. Paradine of the Federal Environmental Assessment Review Office (F.E.A.R.O.), who is assisted by Dr. W.A. Ross and Mr. G.D. Tench. Subsequent to the announcement of this Panel on March 10, 1982 various specialist groups were appointed to act as technical advisers to the panel. Dr. R.G. Charlwood of Klohn Leonoff Ltd. was appointed by F.E.A.R.O. to advise on the proposed ventilation system in a letter dated March 19, 1982.

---

*Figures in brackets ( ) refer to references cited.

2. OBJECTIVES OF REVIEW

This brief summarizes the findings of the review by Klohn Leonoff Ltd. of the relevant documents relating to the proposed Rogers Pass tunnel ventilation system and forms a basis for the presentation to be made to the Panel on April 13, 1982 in Vancouver.

In a letter dated March 19, 1982 to Klohn Leonoff Ltd. from Mr. Guy Riverin of F.E.A.R.O. the statement of work was specified to be:

- "To provide techncial advice on ventilation systems by reviewing the Rogers Pass Tunnel Conceptual Ventilation Study done by Parsons, Brinckerhoff, Quade and Douglas and commenting on the study in a brief to be presented to the Panel at a public meeting in Vancouver April 13, 1982 or Calgary April 16 1982. This advice will assist the Environmental Assessment Panel reviewing the project to understand the relevant engineering aspects of tunnel ventilation parts of the project."

The period of the contract was specified to be from April 1, 1982 to April 17, 1982 involve approximately 10 days of work by Dr. R.G. Charlwood and other specialists from Klohn Leonoff Ltd.

A meeting was held with Mr. Guy Riverin at Klohn Leonoff's Richmond Office on April 1, 1982 to review the scope of study and objectives. At this time, Mr. Riverin stated that the specific objectives of the Klohn Leonoff Assignment were to:

i) Review the three ventilation systems proposed by PBQD in their April 19, 1980 report and provide an opinion as to whether these are the best possible;

....

ii) review the alternative location for the ventilation shaft proposed by C.P.Rail on the east side of Highway 1 on Avalanche Mountain and to investigate the possibility of shaft location further to the west;

iii) review the proposed physical arrangement of the exhaust shaft, fans and intake and exhaust facilities;

iv) review the emission source quantities, in terms of volume, concentration, frequency and duration for use by Dr. Bruce Levelton in his review of the air quality impact outside the tunnel.

Klohn Leonoff were also asked, in general terms, to identify issues which should be looked at more closely prior to commencement of the project, and to assist the Panel in determining which particular items of work proposed by C.P.Rail for the 1982 construction season should be allowed to proceed immediately.

We note that the Parks Canada Position Statement (5) states that:

> "The tunnel vent as proposed is the most severe and unsatisfactory impact of the entire project".
>
> "The airborne emissions are likely to be more polluting and intrusive than predicted. Special pollution abatement features will be required".
>
> "CP Rail must fully outline all alternatives ...".

Consequently we have particularly addressed the need for the ventilation shaft, checked the emissions estimates and outlined all possible alternatives for review by the Panel.

3. APPROACH

Our review of the Rogers Pass ventilation system was carried out principally by Dr. R.G. Charlwood. Advise was provided by other Klohn Leonoff staff including Dr. R.P. Benson, Mr. A.R. MacDonald, Mr. J.R. Huggett and Mr. M. Walia. The ventilation analyses were checked by Mr. G. Greig and Mr. S. Kwan.

The principal subjects of review by Klohn Leonoff were the two reports on ventilation system prepared for C.P.Rail by Parsons, Brinckerhoff, Quade and Douglas Inc. (PBQD) of New York. Specifically these were:

i) "Rogers Pass Tunnel Conceptual Ventilation Study", April 19, 1980 (received by Klohn Leonoff Ltd. on March 19, 1982);

ii) "Rogers Pass Ventilation Study", October 1981 (received by Klohn Leonoff Ltd. on April 7, 1982);

Various other documents were provided to Klohn Leonoff as reference material to assist in the review of the ventilation system reports. These included:

iii) Environment Canada - Press Releases dated March 4, 5, and 17 relating to the Rogers Pass project (received by Klohn Leonoff Ltd. on March 18, 1982);

iv) C.P.Rail letter dated March 9, 1982 outlining the work plans for 1982 (received by Klohn Leonoff Ltd. on March 18, 1982);

v) Parks Canada position statement as presented to the Canadian Transport Commission dated December 16, 1981 (received by Klohn Leonoff Ltd. on March 18, 1982);

vi) "Initial Environmental Evaluation - C.P.Rail grade improvement - Rogers to Cougar Creek", C.P.Rail, January 1981 (received by Klohn Leonoff March 19, 1981);

vii) "Revised Air Quality Assessment - Rogers Pass Tunnel", E.S.L. Ltd., December 1981 (received by Klohn Leonoff March 19, 1981);

viii) Canadian Transport Commission - Railway Transport Committee Decision on the proposed C.P.Rail grade improvement project dated March 9, 1982 (received by Klohn Leonoff April 1, 1982)

A meeting was held at the F.E.A.R.O. office in Vancouver on April 1, 1982 with Mr. Guy Riverin and four of the other technical advisers to the Panel to review the project, the available data, and clarify the objectives of the review process. The technical advisers were told that they should feel free to contact C.P.Rail, Parks Canada or other parties as necessary to clarify the issues.

Consequently, R.G. Charlwood met with Mr. Mike Wakeley, Manager Special Projects C.P.Rail at the C.P.Rail office in Vancouver on April 2, 1982 to briefly discuss the ventilation system design and basic criteria. At this time Mr. Wakeley advised Klohn Leonoff of the location and arrangement of the proposed alternative locations for the shaft. The April 1980 PBQD report (1) and the IEE (6) refer to a shaft location close to the tunnel centreline surfacing to the west of Highway 1 (Referred to herein as Shaft Location 1). Subsequently, CP Rail have proposed a new location on the east side of Highway 1 surfacing on the slope of Avalanche Mountain (Referred to as Shaft Location 2).

On April 3, 1982 R.G. Charlwood visited the Rogers Pass site in the company of Mr. Bruce McKinnan of Parks Canada. At this time Mr. McKinnan assisted in the identification of the various portal sites for the proposed new tunnels and visited the portals of the existing Connaught Tunnel.

A telephone discussion (16) was held between R.G. Charlwood and Mr. J. Fox and Mr. M. Wakeley of C.P.Rail on April 7, 1982 to review the traffic forecast data, shaft construction questions, options for exhaust locations, the possibility of using modified locomotives and the feasibility of electrification.

In the preparation of this review brief we have followed the organization of the PBQD report dated April 19, 1980 on a section by section basis starting at Section 4.0 - Criteria - through to Section 7.0 - Recommended Concept.

Consequently, in Section 4 of this brief we review the basis for design, traffic forecasts, system constraints, etc. and discuss the design criteria adopted by PBQD and C.P.Rail. In addition we discuss the "Site constraints", particularly the possible locations for ventilation exhaust.

In Section 5 we review the ventilation concepts presented by PBQD and then discuss several alternatives with and without a shaft.

In Section 6 we review the ventilation analyses performed by PBQD for both the cooling and purging operations of the ventilation system. This involved independent checks of their calculations by Klohn Leonoff to confirm the need for ventilation. A summary of cycle times and emmissions is presented.

In Section 7 we review the basis for selection of concepts as presented by PBQD and their recommended concept including the arrangement of equipment and structures. In addition we summarize the other options for consideration by the Panel and comment on the dependence of C.P. Rail's proposed 1982 construction on the selection of the final ventilation system.

In our conclusions, we have not recommended a single scheme since this involves the consideration of various complex trade-offs between construction, economics, traffic management and environmental impact which require input by C.P.Rail and Parks Canada. We have attempted to provide the Panel with a summary statement of all of the principal design options.

In carrying out this review we have drawn extensively on Klohn Leonoff's data and experience gained during the conceptual studies of long tunnels prepared for Canadian National Railway in 1979 and 1980 (12) and current design and construction of two major tunnels for the British Columbia Railway (11).

4. CRITERIA

4.1 Train Operations and Traffic Forecasts

The proposed Rogers Pass Tunnel and Grade Improvement Project will in effect provide a new double track section through the Rogers Pass as shown in Figure 1.

C.P.Rail state that they intend to run all westbound traffic through the proposed Rogers Pass tunnel and all eastbound traffic through the existing Connaught tunnel during normal operations. Consequently, eastbound traffic will pass through the Connaught tunnel essentially in the idle mode or possibly with dynamic braking with minimal generation of smoke and heat. The demands on the Connaught Tunnel ventilation system and the quantities of emission from its east portal will then be reduced under normal circumstances following completion of the project. On the other hand the ventilation system for the proposed Rogers Pass Tunnel will have to satisfy the operating needs of westbound trains moving upgrade at relatively low speeds with the locomotives will be operating at or near maximum horsepower.

The passage of heavy diesel powered trains through long tunnels presents two operational ventilation problems which impact directly on train scheduling and capacity. These are:

a) ensuring an adequate supply of cooling air to the locomotives; and

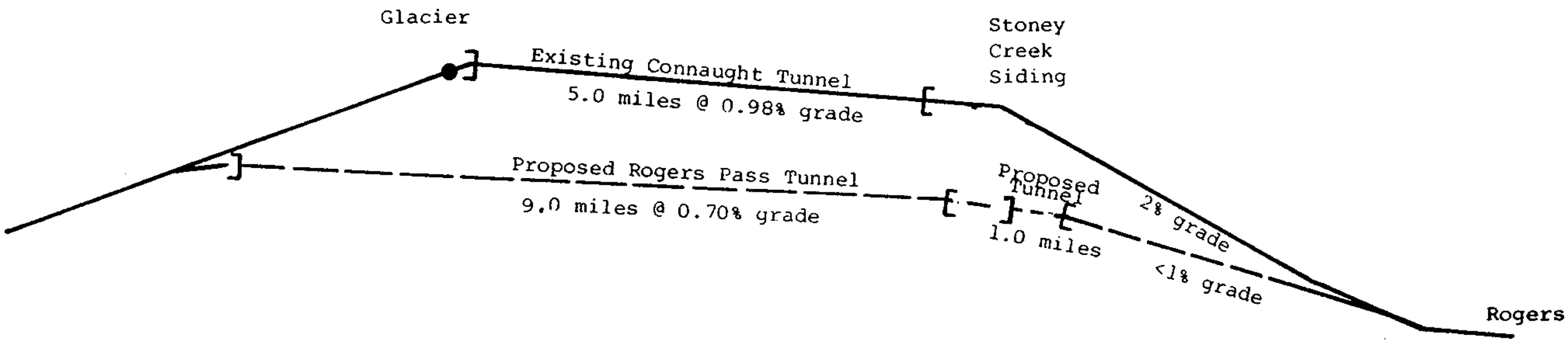
b) maintaining acceptable air quality in the tunnel.

In addition there is an increasing awareness of the need to have the capability to handle emergency situations such as fires or other equipment failures inside the tunnel through flexible use of the ventilation system to minimize the risk to personnel or damage to equipment.

The design of the ventilation system to meet these requirements depends on the forecast traffic frequency, the expected train configurations including locomotives types, consists (i.e. the location of the locomotive in the train), freight tonnage and tunnel air quality standards.

The traffic forecasts for the freight classifications used in the PBQD analyses and which were quoted in various forms in the reference documents are summarized in Table 1. Two historical sets of data are quoted for 1975 and 1980. The figures for 1986 are forecasts and the data quoted for "Design" are those used by PBQD (1) and are reportedly supplied by C.P.Rail. Our comments on this data are as follows:

i) the total number of trains per day used for design, namely 24, is quoted by PBQD (1) and was subsequently verified in discussions with Mr. J. Fox, Chief Engineer, C.P.Rail. This number of trains per day is limited by the overall railway system operational constraints including the sections of single tracking, various other grades and maintenance periods which are budgeted at 6 hours per day. This



TO BE READ WITH KLOHN LEONOFF REPORT DATED April 12, 1982

NOT TO SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: C.P. RAIL ROGERS PASS TUNNEL

TITLE: EXISTING AND PROPOSED RAIL GRADE PROFILES

DATE OF ISSUE	PROJECT No.		REV.
12 April 1982	VA 2995	FIGURE 1	
APPROVED: [signature]			

total number of trains per day, or alternatively the total daily gross tonnage, will essentially determine the total quantity of emission from the various exhausts of the tunnel ventilation system. It will also determine the size of the fans required to purge tunnel air and the need for the shaft to reduce the overall ventilation system operating cycle time. This traffic flow is taken to be the ultimate capacity of the rail system between Golden and Vancouver and thus defines the worst case for environmental impact.

ii) the 1986 forecast total of 16 trains per day is important in terms of the timing of the need for the ultimate capacity of the ventilation system. Later in the report the question of whether the construction of the shaft, or permission to exhaust through the shaft, could be postponed is discussed. C.P.Rail have indicated that the traffic forecasts for 1986/7 indicate that the full ventilation system capability will be required at about that time and therefore postponements of shaft construction or operation are not acceptable.

iii) the split of total freight between the various categories, coal, grain, potash, sulphur, merchandise and passenger trains would have a major effect on C.P.Rail operations but will not significantly affect the ventilation system design. Ventilation systems will be designed for the most severe train and locomotive consists.

Our general review of these data suggests that the 24 westbound trains per day frequency is a reasonable upper limit for impact assessment. Confirmation of this number can, in our judgment, only be supplied by C.P.Rail at this time since it involves several complex operational issues which are presently unavailable to us.

VA 2995

April 12, 1982

TABLE 1

WESTBOUND FREIGHT TRAFFIC SUMMARY
(Golden - Vancouver)

FREIGHT		1975 (a)	1980 (a)	1986 (a)	Design Values (b)
COAL	Net tons/year	11,100,000	10,500,000	30,700,000	
	Gross tons/day				120,000
	Trains/day	3.0*	2.8*	8.3	8
GRAIN POTASH SULPHUR	Net tons/year	6,000,000	7,000,000	11,100,000	
	Gross tons/day				55,000
	Trains/day	1.8*	2.1*	3.4	5
MERCHANDISE	Net tons/year	3,800,000	5,000,000	6,900,000	
	Gross tons/day				66,000
	Trains/day	2.7*	3.6*	4.7	11
TOTAL	Net tons/year	20,900,000	22,500,000	48,700,000	
	Gross tons/day			220,000*	241,000
	Trains/day	7.5*	8.5*	16.4	24

Notes:

(a) Data for 1975 and 1980 and estimates for 1986 are as quoted in the Canadian Tranport Committee decision dated March 9, 1982, File No. 50132 (Heard at Revelstoke, B.C., December 16 - 17, 1981) (8).

(b) Design Values are as quoted in the PBQD report dated April, 1980 (1).

(c) Values noted with an asterisk (*) are estimates made by Klohn Leonoff based on the CTC report of March 9, 1982 (8).

Another key criteria which is mentioned in the CTC Decision (8) is flexibility in the overall system capacity. In view of the major expenditures associated with the Rogers Pass Grade Improvement Project in total, and other possible subsequent expenditures for double tracking at other locations, it would not be prudent to build tunnels and ventilation systems which could cause unnecessary bottlenecks at some time in the future. In using the traffic forecasts it is therefore necessary to recognize that C.P.Rail may need to respond quickly to variations in freight due to changes in overseas' demand for various commodities or other reasons. These are compelling reasons for the Rogers Pass tunnel to be designed so as to maximise the rail system capacity between Golden and Vancouver.

In Table 2 we have summarized the various design trains and locomotive consists which have been analysed by PBQD in their two reports (1) and (2) plus those which we have discussed as possible alternatives later in this report. The PBQD 1980 report (1) quotes the use of the General Motors EMD SD40-2 locomotives as being the "Design locomotives." These locomotives will be used in various consists with, in some cases two, three or four locomotives in the lead position at the front of the train and sometimes, two or three locomotives placed somewhere near the middle of the train operating in the remote mode. The split locomotive arrangement is helpful in terms of minimizing the coupler loads and also assists in ventilation cooling considerations.

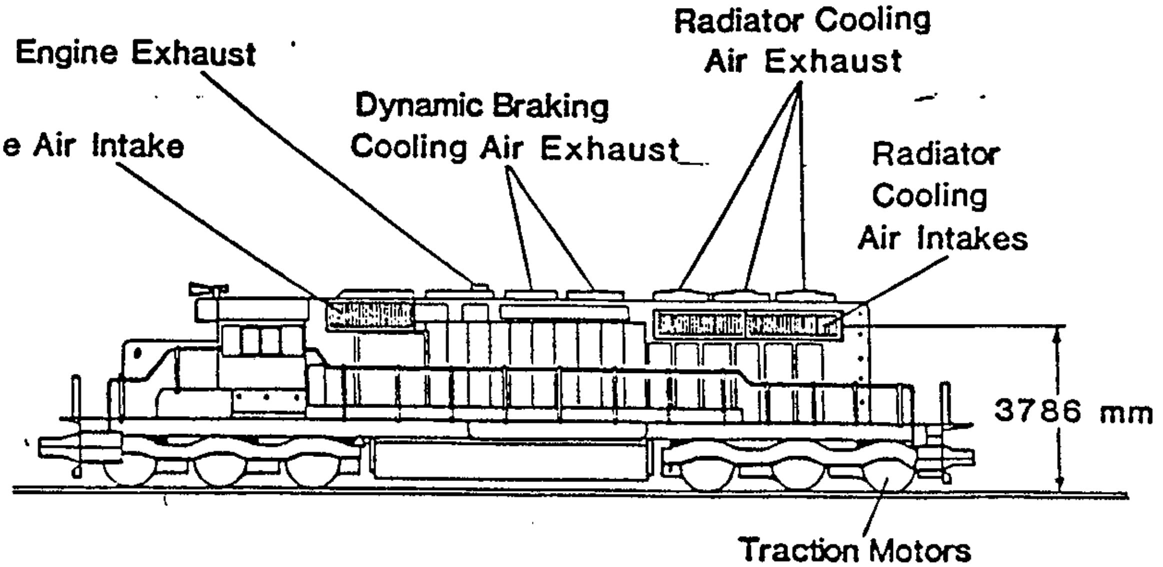
General Motors also offer the EMD SD-50 a higher horsepower locomotive. This has been considered in the PBQD 1981 (2) analyses. A modified version of SD40-2 locomotive for tunnel operations is also available. This locomotive has a lower radiator air intake location as shown in Figure 2, in order to intake cooler air in the

TABLE 2

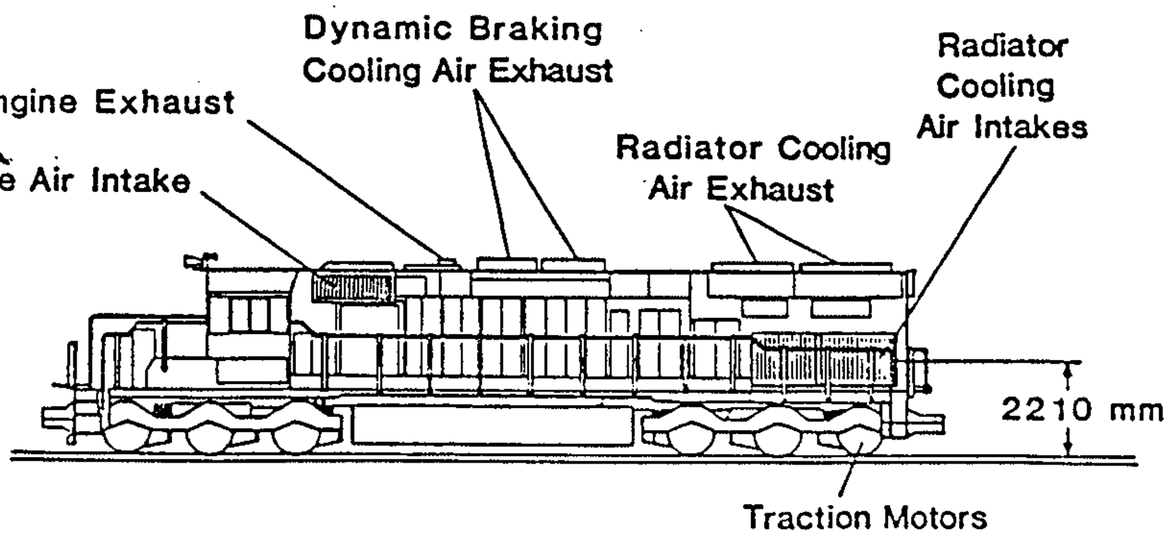
DESIGN TRAINS AND LOCOMOTIVE CONSISTS DISCUSSED

DESIGN TRAIN	FREIGHT	TRAILING TONNAGE	LOCO.	CONSIST	COMMENTS
1	Coal	15,000	SD40-2	3 + 2	PBQD April 1980 & Oct. 1981*
2	Coal		SD40-2	2 + 3	PBQD April 1980 & Oct. 1981*
3	Coal	12,000	SD40-2	4 + 0	PBQD April 1980 & Oct. 1981*
4	Grain	11,000	SD40-2	4 + 0	KL Assumed 4 + 0 locos.
5	Merchandise	6,000	SD40-2	3 + 0	KL Assumed 3 + 0 locos.
6	Merchandise	6,000	SD40-2	2 + 0	KL Assumed 2 + 0 locos.
7	Passenger	Not Specified			Not considered for Ventilation
8	Coal	15,000	SD40-2	3 + 3	PBQD Oct 1981*
9	Coal	15,000	SD50	2 + 2	PBQD Oct 1981*
10	Coal	15,000	SD50	2 + 3	PBQD Oct 1981*
11	Various	Various	SD40-2T	Various	Tunnel modified locomotives
12	Various	Various	Electric	Not Specified	Possible future Electrification

*Note: PBQD 1981 Studies also considered "Older" and "Reversed" locomotives.



"STANDARD" LOCOMOTIVE - EMD - SD40-2



"TUNNEL" LOCOMOTIVE - EMD - SD40-2T

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT	C.P. RAIL ROGERS PASS TUNNEL		
TITLE	LOCOMOTIVE INTAKE AND EXHAUST LOCATIONS		
CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE	DATE OF ISSUE 12 APRIL 1982 APPROVED	PROJECT No. VA 2995	FIGURE 2

tunnel environment. Such a locomotive is currently in use by the Denver and Rio Grande Western Railway through the Moffat Tunnel in Colorado and is under consideration by B.C.Rail and C.N.Rail for the transport of northeast B.C. coal through the Tumbler Ridge Branch Line tunnels to Prince Rupert. C.P.Rail advise (16) that this modification to SD40-2 locomotives is not acceptable to them due to potential problems of ingestion of dust and other materials through the lower intake in certain sections of their system. The impact of the use of this locomotive on the Rogers Pass Tunnel is however briefly discussed later on in this report since it does offer a potential way to minimize exhaust through the shaft.

In addition the question of electrification is raised in various instances (1, 6, 8) with respect to its potential for eliminating the need for the ventilation system. There are two major options potentially available. Option 1 would be electrification of the total route and the use of only electric locomotives. This is stated by C.P.Rail to be not a viable option (6). Option 2 would be the possible use of dual function locomotives. These, which would be from a new locomotive generation, would operate under electric power from a third rail or catenary source through the tunnel system and then revert back to diesel operation outside. However, C.P.Rail advise (16) that these locomotives would probably not be available for at least 10 years. In addition, it is clear that the use of specialty locomotives of this type would impose major logistical constraints on the system. It would be necessary to ensure that a sufficient number of this particular type of locomotive were available for operation through the tunnel and also have all the necessary maintenance and supporting services. Based on our general discussions on this issue in connection with other tunnels we tend to agree with C.P.Rail's position. However in terms of its importance to the decision on the tunnel design it may be appropriate for the Panel to request clarification of the electrification option.

4.2 Purge Time

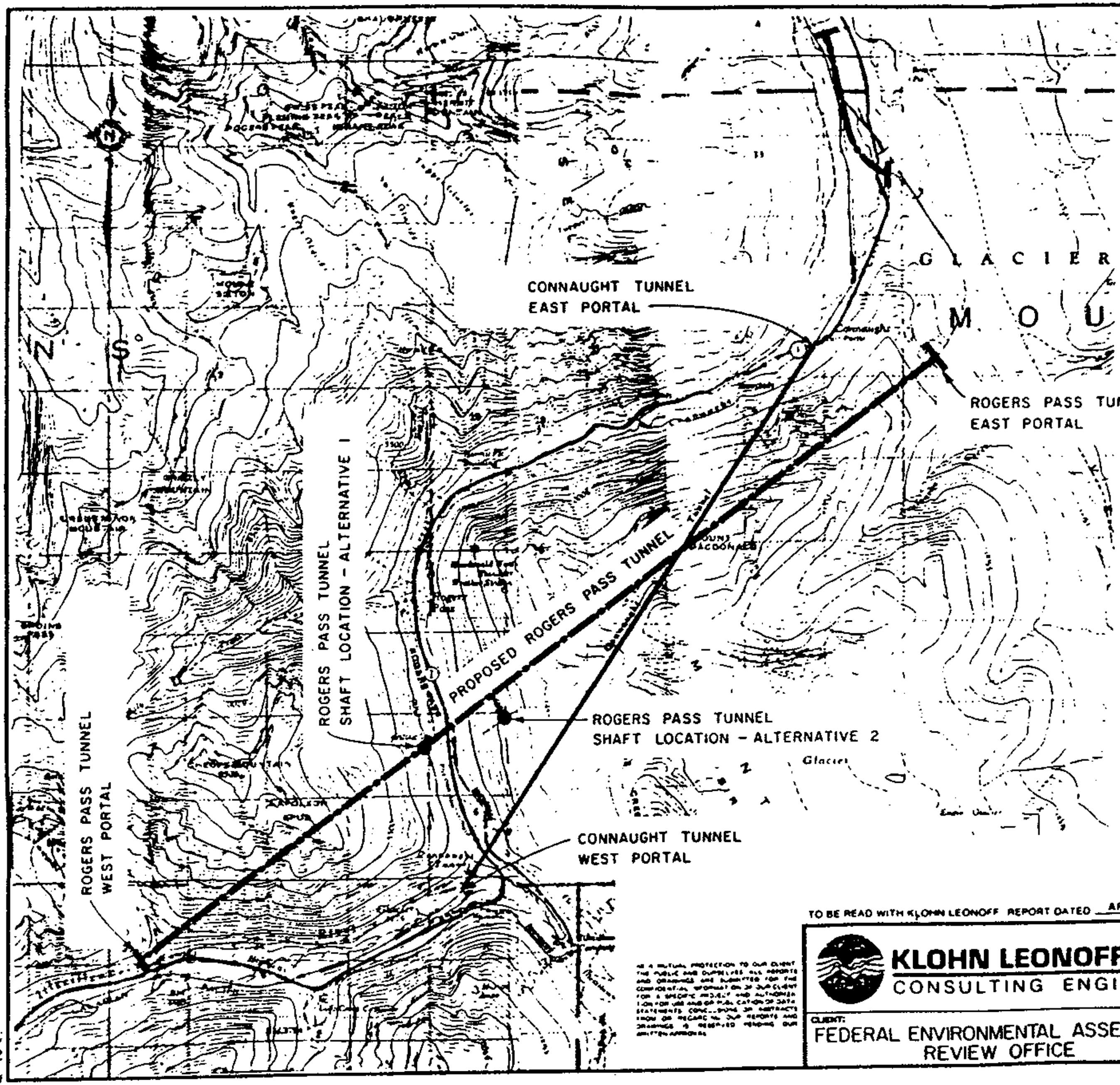
The PBQD, 1980 Report (1) discusses the required purge times. The purge time is a design parameter used to size the fans for the purging cycles. However, the overall parameter which controls the traffic flow through the tunnel is the minimum headway, which is the controlling ventilation and traffic cycle time. The use of a 15 minute purge time by PBQD would lead to reasonable system operation times and train headways, but the means to obtain it are the problem. A more detailed discussion of this is given later in Section 6.3.

4.3 Site Constraints

The PBQD Report (1) mentions that there are limits on location of ventilation shafts, and that it appears unavoidable that the shafts be located in the valley containing the Rogers Pass section of Highway 1. The Initial Environmental Evaluation (6) mentions the consideration of various other routes but we have not attempted to repeat that routing assessment. We have restricted ourselves to tunnel alignment 'B'.

Considering route 'B', we reviewed the overall opportunities for exhaust from the Rogers Pass and Connaught Tunnels during the site visit. These are listed below and shown in Figure 3. The ranking of the acceptability of these exhaust locations, from the environmental point of view, is outside our terms of reference. In assessing the range of available ventilation alternatives we have, however, considered all of these potential exhaust sites. These are as follows:

i) Rogers Pass Tunnel East Portal
ii) Connaught Tunnel East Portal
iii) Connaught Tunnel West Portal
iv) Rogers Pass Tunnel West Portal
v) Rogers Pass Tunnel Shaft Location Alternative 1
vi) Rogers Pass Tunnel Shaft Location Alternative 2



TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

SCALE

KLOHN LEONOFF LTD. CONSULTING ENGINEERS	PROJECT: CPR ROGERS PASS TUNNEL VENTILATION TITLE: POTENTIAL VENTILATION SYSTEM EXHAUST SITES
CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE	DATE OF ISSUE: APRIL 12, 1982 · APPROVED: · PROJECT No. VA2995 · FIGURE 3

We note that in the PBQD Reports (1, 2) or the IEE (6) no discussion is given regarding the possible use of the Connaught Tunnel as a means to exhaust ventilation air from the Rogers Pass Tunnel. We have considered this possibility and it is discussed in Section 5.2.

In addition, we note that PBQD (1), in discussion with C.P.Rail, excluded the possibility of exhaust from the West Portal of the Rogers Pass Tunnel due to its proximity to the TransCanada Highway. We would suggest that this not be ruled out categorically since there is in fact a choice between exhausting the purge air from the west section of the Rogers Pass Tunnel either through the West Portal or through the ventilation shaft at whichever location is selected in the Rogers Pass. Furthermore, we understand that due to construction and avalanche considerations the track will continue underneath the Highway 1 in a closed section until it almost reaches the existing C.P.Rail alignment. Consequently if the exhaust is continued through this closed section it will in fact discharge over the C.P.Rail track rather than directly on to the highway. Nevertheless, it will be very visible from the highway and the question of its dispersion due to southwesterly winds back across the highway would need to be addressed.

If the portals to the existing Connaught Tunnel could be utilized, it would appear that they may present acceptable sites for exhaust from both tunnels if the necessary ventilation system could be designed.

The Rogers Pass Tunnel East Portal location is located behind a ridge of Mount MacDonald and will not be visible from the TransCanada Highway 1. This site does not appear to be contested as a possible exhaust location (5).

5. VENTILATION CONCEPTS

5.1 PBQD Proposed Design Concepts

PBQD state (1) that in order to ensure technical feasibility the ventilation concepts considered in their studies were limited to those that are or are extensions of concepts successfully employed in existing tunnels of this type. By this we presume that they refer in particular to the Moffatt, Cascade and Flathead (17, 18, 19) railroad tunnels in the United States which handle heavy diesel traffic. The ventilation system requirements for heavy diesel trains are quite different from those associated with ventilation problems arising with either high speed trains or electric trains in other parts of the world (20a, b, c, d, e).

The three particular examples of tunnels which are directly relevant to the Rogers Pass design which are currently in operation and have formed the basis of the PBQD proposals are:

i) Moffatt Tunnel - operated by the Denver, Rio Grande and Western railroad in Colorado. This tunnel is 6.21 miles in length with a grade of +0.8% over most of its length and was built in 1928. The ventilation system is currently being upgraded although the basic concept remains the same as present.

ii) Cascade Tunnel - operated by Burlington Northern in Washington State. This tunnel is 7.79 miles in length with a grade of 1.57% and was converted for diesel operation in 1955.

iii) The Flathead Tunnel - operated by Burlington Northern in Montana. This tunnel is 7.00 miles in length with a grade of 0.6% and was built in 1970 to a design prepared by PBQD.

Rogers Pass	Canada	CPR	1985	14.2 km (8.9 mi.)
Cascade	USA	BNR	1955	12.5 km (7.8 mi.)
Connaught	Canada	CPR	1916	11.2 km (7.0 mi.)
Flathead	USA	BNR	1970	11.2 km (7.0 mi.)
Moffatt	USA	DRGW	1928	10.0 km (6.3 mi.)
Table	Canada	BCR	1983	9.0 km (5.6 mi.)
Hoosac	USA	B & M	1887	7.7 km (4.8 mi.)
Hells Gate	Canada	CNR	1985	7.7 km (4.8 mi.)
Wolverine	Canada	BCR	1983	6.0 km (3.8 mi.)
White Canyon	Canada	CNR	1985	5.9 km (3.7 mi.)

ALL
HANDLE
DIESEL
LOCOMOTIVES

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: C.P. RAIL ROGERS PASS TUNNEL

TITLE: SUMMARY OF EXISTING AND PROPOSED LONG RAILWAY TUNNELS FOR DIESEL TRAINS

DATE OF ISSUE	PROJECT No.		REV.
April 12/82 APPROVED: Mh	VA 2995	FIGURE 4	

More recently Klohn Leonoff have been involved in the design and construction of new tunnels with ventilation systems to handle heavy diesel traffic (12). These designs utilized similar design concepts to those in the above American tunnels and also included extensions of the technology (12) as follows:

iv) The Wolverine Tunnel - for the British Columbia Railway on the Tumbler Ridge branch line. This tunnel will be 3.6 miles in length with a grade of 0.7% and is currently under construction (11).

v) The Table Tunnel - for the British Columbia Railway on the Tumbler Ridge branch line. This tunnel is 5.6 miles in length with nominal grades and is currently under construction (11).

vi) Plant Expansion Program - for the Canadian National Railway as part of their double tracking program in British Columbia. These designs considered many different tunnels ranging up to a tunnel system with an overall length of 27 miles. Preliminary ventilation system designs were prepared for these tunnels and they considered the use of a sectional ventilation system of the type now proposed for the Rogers Pass Tunnel involving shafts at intermediate locations (12).

A general summary listing of existing and proposed long tunnels for diesel traffic is given in Fugure 4.

We therefore agree that the basic concept in which a gate and fan are placed at one end of the tunnel is a viable concept for tunnels up to a certain length depending on the traffic frequency expected. As mentioned above the American tunnels are operating without shafts in tunnels up to 7.7 miles in length. The need to introduce a shaft depends on many factors and is the principal question addressed in the PBQD report (1).

Based on our knowledge of current and precedent designs we have the following comments on the various design concepts proposed by PBQD.

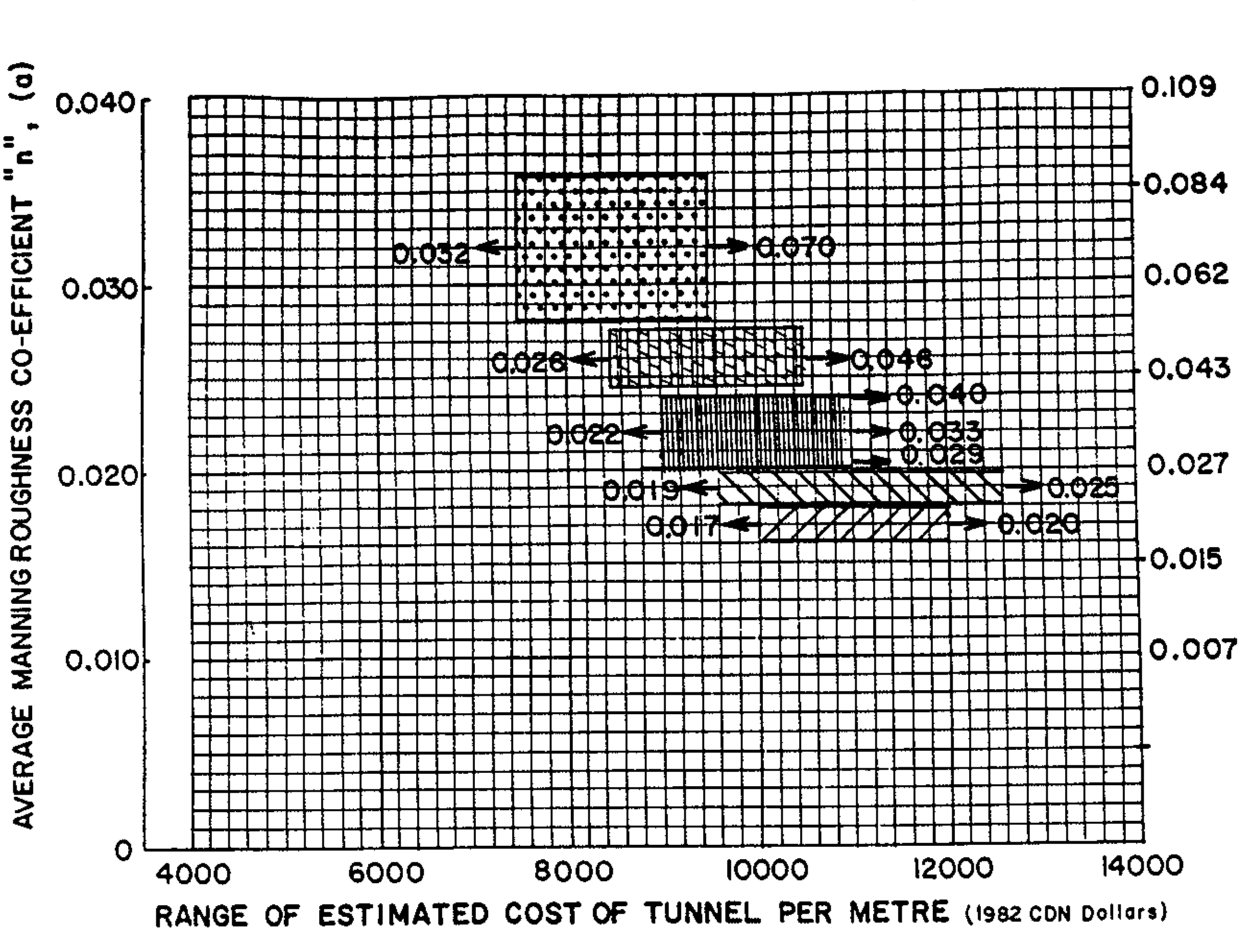
Concept 1 - No Shaft

Concept 1 involves a tunnel without air entries at intermediate locations similar to the Flathead, Moffatt and Cascade tunnels. Air flows would travel the full 9.0 mile length of the tunnel.

The PBQD discussion (1) of Concept 1 indicates that the minimum headway with this concept is approximately 60 minutes using 1,000,000 cfm maximum purge fan capacity and a shotcrete finish to a conventionally drilled and blasted tunnel. It is stated that this length of cycle time or train headway is unacceptable to C.P.Rail in terms of their future traffic volumes and therefore this concept was rejected.

We agree that "no shaft" is a technically practical concept. However, its acceptability is dependent on the minimum headway which could be achieved with reasonably sized fans and energy consumption by the fan motors, and tunnel construction. The Darcy-Weisbach friction factor $f = 0.04$ was used for the drill and blast tunnel concept.

In order to improve the performance of Concept 1, given that cooling fan air is required, it would be necessary to dramatically reduce the tunnel friction to allow much higher purging air flows at acceptable energy costs. This could be handled by providing a full concrete lining to the tunnel which would have a friction factor in the region of $f = 0.017$. Alternatively if a bored tunnel could be considered in terms of cost and construction risk points



LEGEND

(diagonal hatch)	Concrete lined (lining 25 cm thick)
(reverse diagonal hatch)	Tunnel boring machine (bolts 25% of controlled blasted rock)
(vertical hatch)	Shotcrete lined
(cross hatch)	Carefully controlled blasted rock
(dotted)	Controlled blasted rock

NOTES:

a) For use in Manning Formula

b) For use in the Darcy-Weisbach formula

c) Conversion n to f based on m = 4.92

d) Rock quality - fair to good
Provisions for pattern bolting (throughout) and steel sets (10% tunnel length) included
Mob. and demob. excluded
Friction Coefficient includes track

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT	C.P. RAIL ROGERS PASS TUNNEL
TITLE	TUNNEL FRICTION AND COST DATA
CLIENT:	FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE
DATE OF ISSUE	12 April 1982
APPROVED	
PROJECT No.	VA 2995
DWG. No.	FIGURE 5
REV.	

of view, this would also result in a much lower friction factor possibly f = 0.019. However, the costs involved in lining the tunnel or the problems with a bored tunnel must be recognized. Cost estimates for various methods of construction and lining and associated factors are summarized diagramatically in Figure 5. Using this data the incremental cost for these options can be approximately estimated.

The PBQD report quotes friction factor for a bored tunnel of f = 0.022. PBQD 1980 (1) Table 9, shows this corresponds to a doubling of the energy cost over the preferred Concept 3 with a drill and blast tunnel and shaft. This additional energy cost is approximately $350,000 per year (based on 5 cents/KW-h), but would only permit a minimum headway of 52 minutes compared to 40 minutes for Concept 3.

The technical feasibility of using tunnel boring machines at the site would have to be very carefully assessed before basing a decision on the ventilation system on a bored tunnel. In particular attention would have to be given to the in situ stress, rock conditions, and faulting in the Rogers Pass Tunnel section (11). As a illustration during the bidding in 1981 for the Wolverine Tunnel for the British Columbia Railway only one bidder out of six chose to submit on the basis of a tunnel boring machine (TBM) with a price 15% higher than the best price for a drill and blast tunnel. Another, possibly overriding question to be addressed, would be the schedule risk associated with the use of TBM. If problems were encountered, it is possible that there could be major delays compared to the conventional drill and blast approach. The unacceptability of this risk potential has tended to mitigate against the use of TBM's in similar tunnelling situations and may well be the case for the Rogers Pass Tunnel. However, we found no specific discussion of this point in the PBQD reports other, and note that the TBM option has been dropped from the PBQD 1981 Report (2). Presumably this means the TBM option has been discarded by CP Rail.

The provision of a fully lined tunnel over a shotcrete finish would incur an additional capital cost of $15-30 million approximately. However, even with a purging fan capacity of 1,500,000 cfm the minimum headway would still be 52 minutes.

In the PBQD analyses the controlling factor is that purging cannot commence until the train has left the West Portal of tunnel due to the need to supply adequate cooling air to the locomotives.

Cooling air requirements could possibly be reduced by limiting the locomotive consists to 3 + 2 (or possibly 3 + 3) and/or using the GM "Tunnel Modification" locomotives SD4D-2T in critical locations. Our approximate calcualtions suggest that using both these options it may be possible to operate the heavy trains (and others) without cooling fans but using a closed door behind the train for a "negative piston effect" to draw about 625,000 cfm air past the locomotives. However, this in itself would not affect the minimun headway.

To improve the headway by reducing the system cycle time it would be necessary to start purging while the train is still in the tunnel. This would decrease the "negative piston effect" air flows past the locomotives by an amount approximately equal to the purge flow. The amount of purging air flow which could be tolerated would therefore be small (at the most 150,000 cfm) and thus 90% of the tunnel would remain to be purged after train exits. The cycle time in this case would still be about 50-52 minutes with either very high horsepower fan motors or expensive wall treatment to reduce friction.

In summary, the lowest headway possible for the "no shaft" Concept 1 is approximately 50-52 minutes involving high energy costs and/or expensive wall treatment. The possible use of "Tunnel Modification" locomotives would not help. The basic Concept 1 with a minimum headway of about 60 minutes appears to be the best version of this concept.

Concept 2 - Single Section Shaft

PBQD show (1) that through the introduction of a shaft with various combinations of fan and gate locations, an improvement can be achieved over Concept 1. However, in order to achieve the same flush times as those under Concept 3 with a split shaft and central gate the energy costs for Concept 2 rise to uneconomic levels. Consequently the emphasis was transferred to consideration of Concept 3. We agree.

Concept 3 - Double Section Shaft with Mid-Tunnel Gate

PBQD note (1) that a common characteristic of concepts 1 and 2 is their inability to serve the ventilating needs of a train entering the tunnel until the entire tunnel is purged of the pollutants emitted by the preceding train. The time between successive trains entering the tunnel is therefore limited by these concepts unless a quite unreasonable power demand for the fans is provided. This constraint therefore lead to consideration of Concept 3 which in effect divides the tunnel into two shorter independent tunnels for ventilation purposes through the use of a split shaft and a mid-tunnel gate.

We would note that in our previous design studies for the Canadian National Railway when considering longer tunnels with high volume traffic we arrived at the same conclusion that a segmental tunnel system with split shafts and a gate was the optimum solution (12). We recommended a maximum segment length of about 6 miles.

The PBQD 1980 Report (1) describes the detailed operation of the tunnel using this concept based on emissions from the shaft at Location 1 and the East portal. We have analyzed the cycle times for the fan sizes quoted and found that this concept would allow a minimum headway, or system cycle time, for westbound heavy coal trains of 40 minutes. A cycle diagram analysis of these operations for various trains is shown in Figures 10.1 to 10.5 and discussed in more detail in Section 6 of this brief.

It should be noted that the analyses quoted by PBQD 1980 (1) and 1981 (2) are in terms of fans located at the top of the shaft. However, in discussions with CP Rail and as presented in their "Tunnel Fact Sheet" shown in Figure 6 they plan to locate the fans at the foot of the shaft. This will not materially effect the emissions from the ventilation system although it will reduce the noise at ground level.

If the shaft is moved to Location 2 on Avalanche Mountain then the cycle time or minimum headway is reduced by approximately 2 minutes to 37 minutes for the heavy coal train as shown in Figure 10.8. The final fan designs will need to be finalized by CP Rail to accommodate the proposed 606 ft long horizontal ventilation adit connecting the tunnel to the shaft.

If the shaft is moved to a location further west than location 1 on the west of Highway 1, the cycle time would increase above 40 minutes for the same purge time in the East Sections unless much higher horsepower fan motors were provided. This option does not therefore appear attractive.

Rogers Pass Grade Improvement Project

Tunnel Fact Sheet

Location: Glacier National Park, Rogers Pass, B.C.
Tunnel Length: 9.01 miles (14.5 kilometres)
Tunnel Height: 29 feet (center to floor) (8.8 metres)
Tunnel Width: 18 feet (16.4 metres)
Tunnel Elevation: east portal – 3,175 feet above sea level (967.7 metres)
west portal – 3,502 feet above sea level (1067.4 metres)

Grade through tunnel: 0.70 per cent
Purpose of Tunnel Ventilation:

(a) To provide a sufficient flow of air relative to a moving train to prevent locomotives from overheating.
(b) To remove diesel exhaust emitted by a train so that a succeeding train can be exposed to a relatively clean environment.

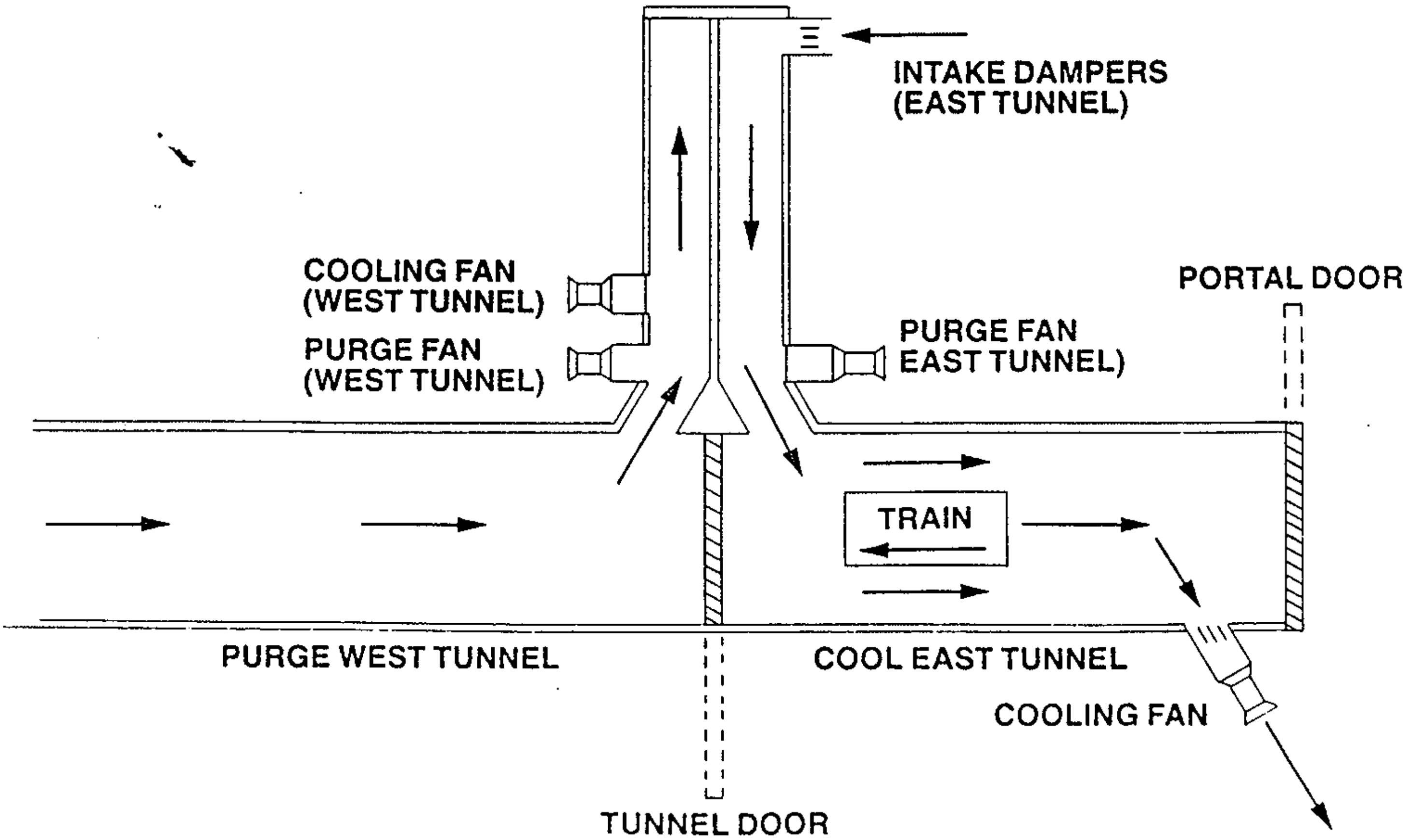
Average train speed through tunnel: 16 m.p.h. (25.7 kmph)
Ventilation shaft: 24-foot diameter (7.3 metres)
1,500-feet long (457.2 metres)

How ventilation works:
The tunnel is cleared by displacing the exhaust with outside air. Each tunnel segment, divided by a door at the center and one at the east portal, is served by one purge fan and one cooling fan.

The cooling fans are required to provide a flow of air to keep the locomotives from overheating. The purge fans, which pump air through at greater velocity, are designed to clear the tunnel of exhaust.

The purge fans serving the east tunnel are located at the base of the ventilation shaft. The cooling fan serving the east tunnel is located at the east portal and operates in exhaust. The fans serving the west tunnel are also located at the base of the shaft and normally operate in exhaust.

VENTILATION CONCEPT – COOL EAST, PURGE WEST.

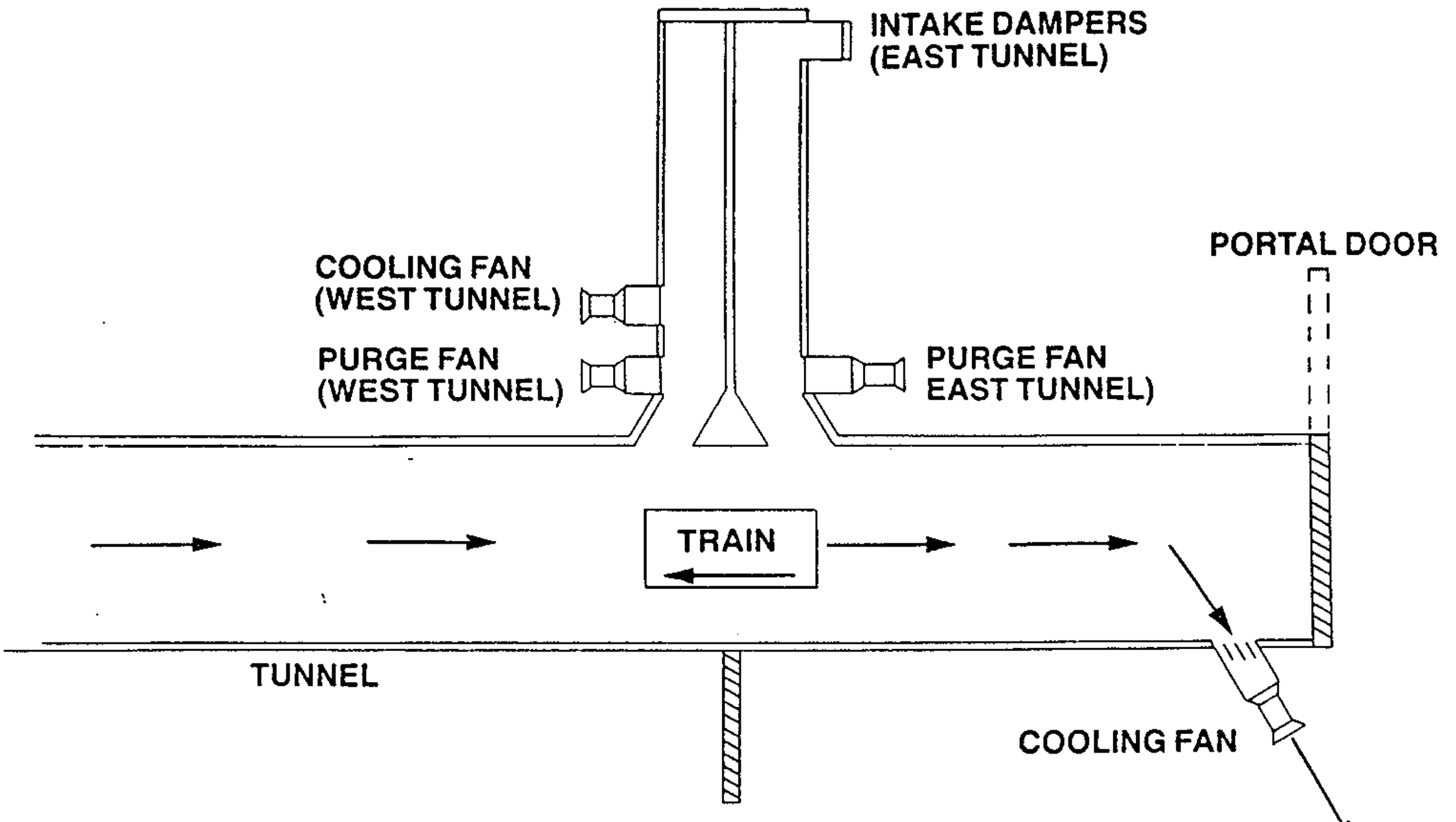


NOTE: PURGE OF WEST TUNNEL BEGINS WHEN REAR OF TRAIN EXITS TUNNEL.

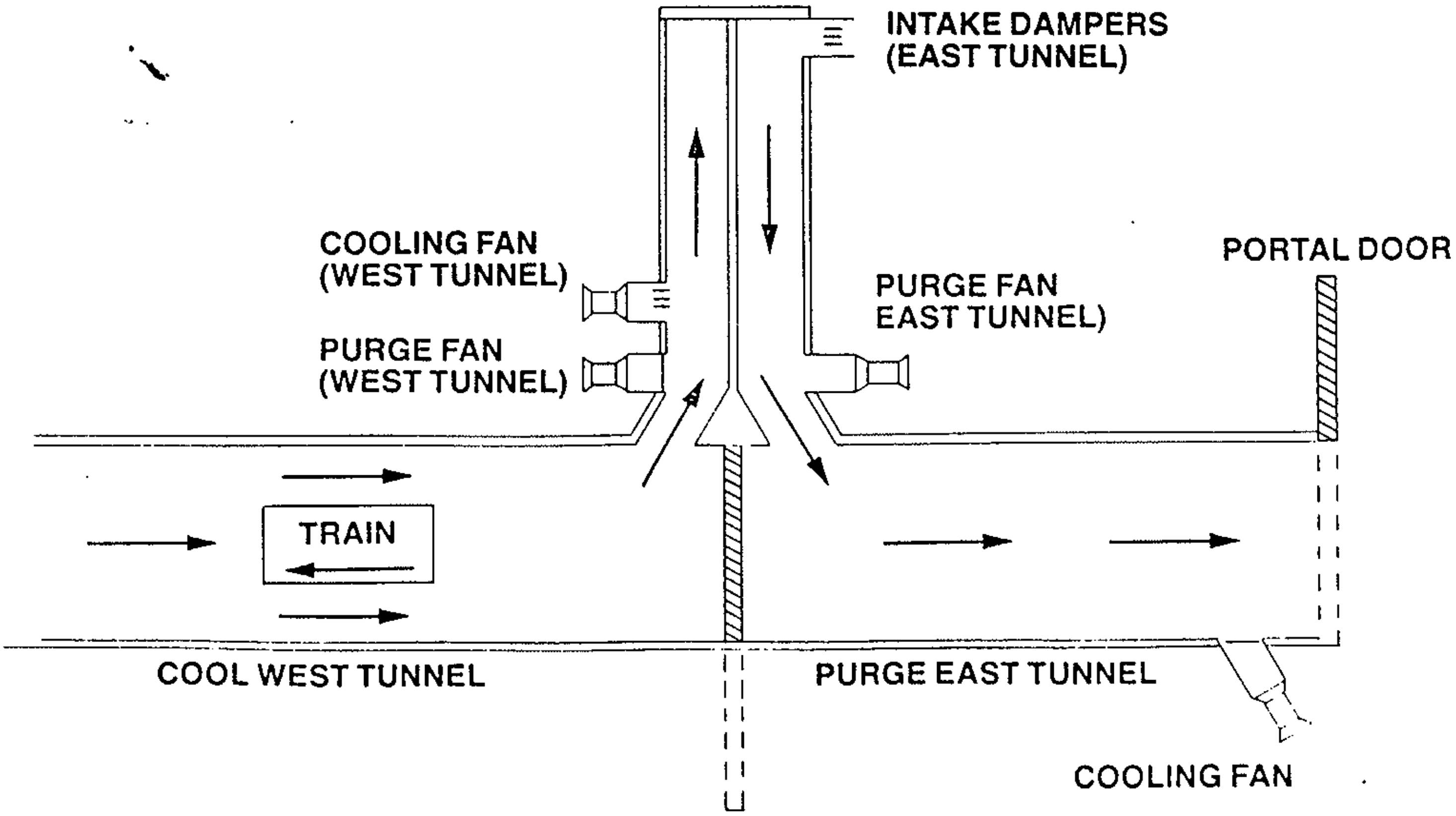
FIGURE 6A: C.P. RAIL FACT SHEET SIDE 1

CP Rail

VENTILATION CONCEPT - TRAIN TRANSITIONS FROM EAST TO WEST TUNNELS.



VENTILATION CONCEPT - PURGE EAST, COOL WEST.



NOTE: PURGE OF EAST TUNNEL BEGINS WHEN REAR OF TRAIN PASSES SHAFT AND TUNNEL DOOR IS CLOSED BEHIND IT.

FIGURE 6B: C.P. RAIL FACT SHEET SIDE 2

In summary, Concept 3 using a shaft at either location, would result in cycle times of approximately 38-40 minutes for the heavy coal trains. Certain other trains may be marginally quicker. PBQD's 1981 report (2) has confirmed these estimates having allowed for certain possible variations in conditions. We agree with their analysis of cycle times.

5.2 Alternative Concepts Considered by Klohn Leonoff

In the course of our review we considered the possible utilization of all six candidate exhaust locations as shown in Figure 3, together with other technical options. These are discussed below as Concepts 4 to 9.

Concept 4 - West Portal Exhaust

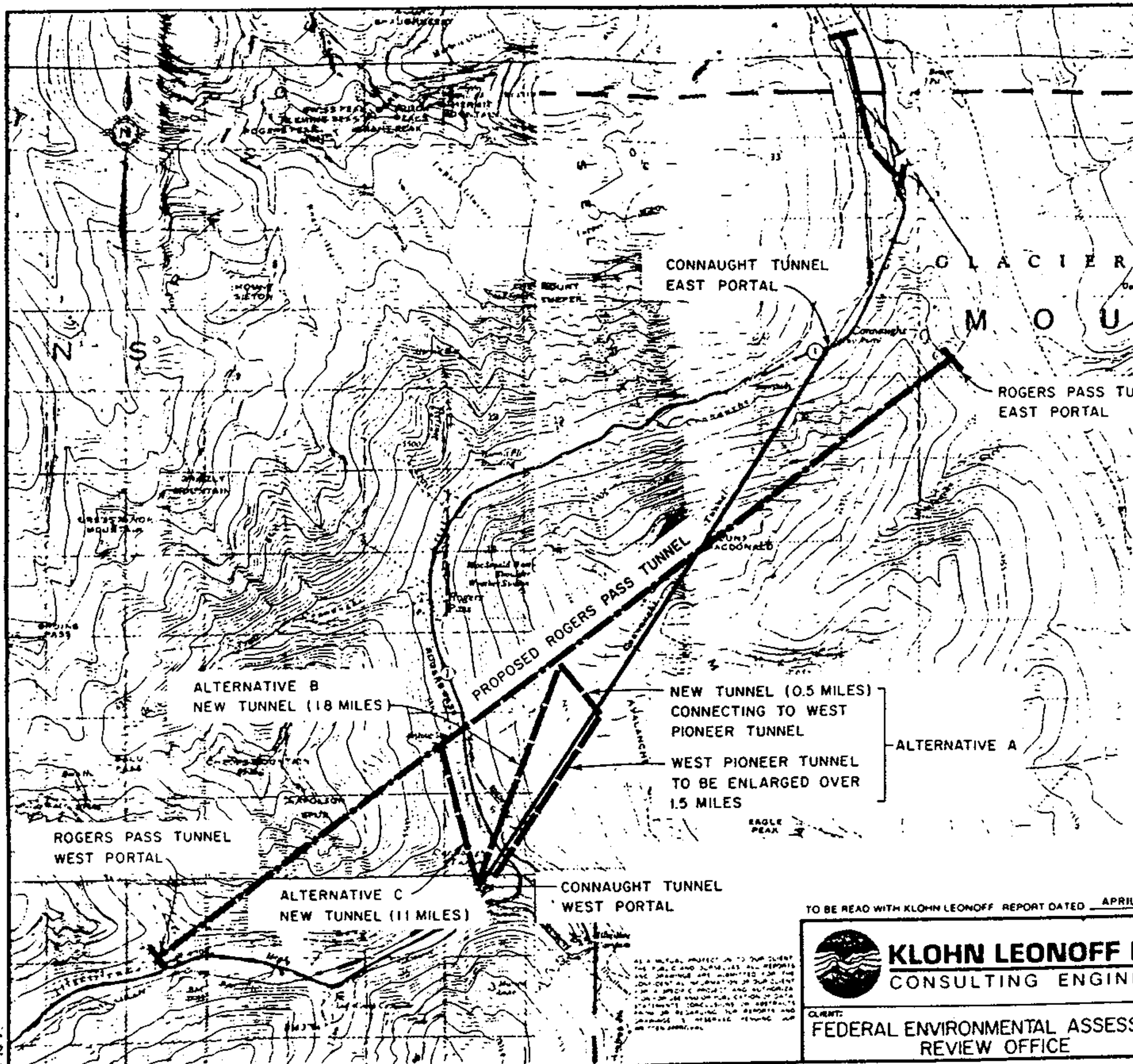
If exhaust could be tolerated from a closed extension to the proposed new west portal adjacent to Highway 1, then the total volumes of emissions from the shaft could be reduced. In this concept the operation of the east section of the tunnel would be as described in Concept 3 by PBQD (1). Also, cooling operations in the west section of the tunnel would remain as in Concept 3 with cooling air required to flow in from the West Portal exhausting via the shaft. However, once the lead locomotives have left the tunnel and the cooling requirement is complete the cooling fans could be shutdown and the purge fans operated to reverse the flow and exhaust the tunnel from the west portal. Consequently the only period with exhaust through the shaft would be during the cooling mode of train transit through the west section. Cycle times would remain the same as Concept 3.

Concept 5 - West Portal Exhaust With Tunnel Modification Locomotives

As discussed above under Concept 4, if exhaust of the west portal is acceptable, then the only exhaust from the shaft would occur during the cooling operation while the heavy trains are in the west section. Our preliminary calculations suggest that if the tunnel modification to the General Motors EMD SD40-2 locomotives are used with a low radiator air intake as shown in Figure 2 it may be possible with certain locomotive consists to avoid the use of the cooling fans and consequent exhaust via the shaft. CP Rail have advised us that the use of this type of locomotive is unacceptable in their system as a whole and therefore they cannot consider it as viable option. However, as noted before, these locomotives are in use by the Denver and Rio Grande Western Railway and are proposed for use by the Canadian National and British Columbia Railways on the Tumbler Ridge to Prince Rupert system. If the west portal exhaust is acceptable environmentally then it may be appropriate to ask CP Rail to clarify the problems with the tunnel locomotive and to consider their possible use in this manner to eliminate shaft exhausts. Cycle times would be the same as Concept 3.

Concept 6 - East Portal Exhaust Except During Queing

If the PBQD Concept 3 configuration is installed it may still be possible to minimize the exhaust from the shaft by establishing the ventilation system control logic so that normal purging or cooling exhaust is handled via the east portal fans. The operation of the exhaust from the shaft would only be achieved through an automatic control override in the event of traffic queing situations to prevent unnecessary delays. This would not eliminate shaft exhausts but might reduce the shaft exhaust quantities in the short term. It does however, introduce complexities in the railway operations which may incur additional costs.



TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

SCALE

KLOHN LEONOFF LTD. CONSULTING ENGINEERS	PROJECT: CPR ROGERS PASS TUNNEL VENTILATION	
	TITLE: ALTERNATIVE VENTILATIONS SYSTEMS LINKED TO CONNAUGHT TUNNEL	
CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE	DATE OF ISSUE: APRIL 12, 1982 / APPROVED:	PROJECT No. VA2995 / FIGURE 7 / REV

Concept 7 - Delay in Shaft Construction

A variation of Concept 6 above would be to delay the shaft construction and operate as Concept 1 for an initial period until traffic volumes require the shaft. The provision of a Concept 1 Rogers Pass tunnel will result in a considerable improvement in traffic capacity between Golden and Vancouver for this period.

The shaft would then be constructed using previously established tunnel access zones underground, leading finally to Concept 3 at a later stage. However, CP Rail advise (16) that according to their traffic forecasts they will need cycle times of approximately 40 minutes in the period of 1986 and 1987. On this basis, the demand for this facility is so soon after the initial tunnel construction that a delay would not make sense. Furthermore, although a delay may allow a better definition of the load forecast (or the possible introduction of electrification sooner than expected) it would preclude the ability of CP Rail to respond to rapid increases in demand. This lack of flexibility caused by the delay in the shaft construction could have major financial consequences which may outweigh the benefits.

Concept 8 - Use of the Connaught Tunnel Facilities

The ventilation system design for the Rogers Pass Tunnel requires a means of air entry and exit at a point as close as possible to the mid-point of the tunnel. This is required to reduce train cycle time and thereby increase capacity. Concept 3 achieves this by means of a vertical shaft.

Consideration has also been given to providing access to near central locations of the Rogers Pass Tunnel by means of a separate partitioned ventilation adit. Three cases were considered and all would have their portals in the area of the existing Connaught West Portal. The three alternatives which are shown on Figure 3 are:

Alternative 8A - Use of Pioneer Tunnel

When the Connaught Tunnel was constructed, pioneer headings were used at both ends. The west pioneer tunnel commences 700 ft east of the Connaught West Portal about 150 ft above the main line heading and 50 ft south of the main tunnel line. The tunnel is approximately 1.5 miles long and is 7 ft high and 8 ft wide. An alternative means of providing air entry and exit to the Rogers Pass Tunnel would be to construct a 0.5 mile long tunnel from the end of the pioneer tunnel to the Rogers Pass Tunnel. It would also be necessary to enlarge the pilot tunnel to approximately 21 ft wide by 21 ft high depending on the acceptable head losses during purging.

Alternative 8B - 1.8 Mile Adit

This alternative would link the centre of the Rogers Pass Tunnel directly to the Connaught Tunnel West Portal area and would be an entirely new ventilation adit approximately 1.8 miles long.

Alternative 8C - 1.1 Mile Adit

Consideration was given to minimizing the length of the new tunnel access. While it is desirable to intersect the Rogers Pass Tunnel as near to the centre as possible, this alternative considered the new tunnel joining at the same location as the Concept 3 ventilation shaft Location 1. This ventilation adit would be 1.1 miles long.

The Connaught West Portal area was chosen as a likely area for the entry to the ventilation adits, since the existing Connaught Tunnel has its fan house here.

These alternatives allow consideration of:

a) the elimination of the vertical ventilation shaft;

b) ventilation connection to the centre of the Rogers Pass Tunnel to reduce system cycle time to 34 minutes;

c) the fan house can be located near the existing Connaught Tunnel fan house which would allow -

- existing maintenance access at the portal;
- centralized power requirements;
- elimination of underground fans and motors;
- the ventilation adit would allow the possibility of constructing the Rogers Pass Tunnel using three to four headings instead of two depending on the construction scheduling.

All three schemes are feasible alternatives, which will satisfy the need to minimize train cycle time. However, their acceptability depends on economic analysis including increased initial capital cost for all components of the system and operational costs, together with allowance for the possible benefits discussed above.

Concept 9 - Emmission Control

The exhaust gases contain a number of toxic components including nitric oxide, nitrogen dioxide, sulphur dioxide and carbon monoxide. A summary discussion was given by BHRA (20c). Nitric oxide oxidises to nitrogen dioxide in the presence of sunlight (ultraviolet rays). In tunnels the ratio has been found to be approximately 20 parts of NO to 1 part NO_2 probably due to the absence of sunlight. The oxides of nitrogen produced at the engine exhaust ports are almost entirely nitric oxide (NO) due to the thermodynamics involved in the combustion process. This has been confirmed by measurements made with the mass spectrometer. In the presence of oxygen or air, nitric oxide is oxidised to nitrogen dioxide.

$$2\ NO + O_2 = 2\ NO_2$$

This oxidation can also take place in the exhaust system, particularly if air has been added to the gases at the exhaust valves in an effort to partly oxidise the unburned hydrocarbons. This oxidation is not instantaneous, but proceeds at a rate proportional to its concentration. Heavy concentrations oxidise rapidly but low concentrations take from a few minutes to twenty-four hours to oxidise completely. At higher temperatures the rate of oxidation is more rapid.

NO_2 molecules react with each other to form

N_2O_4 molecules

$NO_2 + NO_2 = N_2O_4$

Nitrogen dioxide (NO_2) and nitrogen tetroxide (N_2O_4) normally exist together, the degree of dissociation depending upon the temperature. The mixture of NO_2 and N_2O_4 shows the following colour at the different temperatures:

(1) Yellow at 10°C
(2) Reddish-brown at 21°C
(3) Red above 21°C

N_2O_4 is a colourless gas.

From the toxic point of view nitric oxide is more toxic than carbon monoxide and should be palced between CO and NO_2, and closer to NO_2 than to CO. An examination of predicted levels of tunnel gases to permissible levels shows that the exhaust component of principal concern is nitric oxide.

PBQD does not give consideration to the use of air scrubbers to remove the oxides of nitrogen. This area of work has been the subject of much recent study because of the need to reduce the amount of NO_x produced by coal fired electrical generating plants. In this application most attention has been paid to reducing the quantities of oxides of nitrogen generated. However post combustion selective catalyst reduction (SCR) and selective non catalystic reduction (SNR) are being developed. The bulk of development work has been carried out by the Japanese for thermal power plant applications. Technology for sulphur dioxide removal is available using scrubbers.

Much of the technology is new and would require further work to determine the feasibility and cost effectiveness of using scrubbers to remove NO_x and SO_2 from tunnel exhausts.

In addition to the emission of gases, particulates are also emitted. Electrostatic precipitation have been used in a Japanese road tunnel to remove particulates in a longitudinal tunnel ventilation system. Their applicability and cost effectiveness in this application would again require further study.

The installation of scrubbers and/or precipitation would involve more heavy plant being located in the Park.

6. VENTILATION ANALYSES

6.1 Scope of PBQD Analyses

PBQD carried out analyses for the cooling and purging requirements. Analyses were performed for a variety of trains to determine the more severe conditions and the ventilation equipment required.

In the April 1980 report (1) analyses were made for both a drill and blast tunnel and a bored tunnel. However, in the April 1981 report (2) only a drill and blast cross-section was considered and we presume that the bored option has been dropped.

In the cooling analyses the objective was to determine the self-cooling capability, train speeds, and engine radiator inlet air temperature for the various consists at the estimated operating speeds. The specified maximum radiator air intake temperature for General Motors EMD SD40-2 locomotives is 118°F. This was used in the initial analyses quoted in the April 1980 report (1). In the subsequent October 1981 report (2) more detailed aspects of the operations were considered including the cooling requirements to limit the maximum air intake temperature to 108°F to account for loss of efficiency and partially blocked radiators intakes. Parametric studies were also made for tunnel wall temperatures ranging between 55° and 65° together with a recommendation that this be confirmed through tests in the Connaught Tunnel.

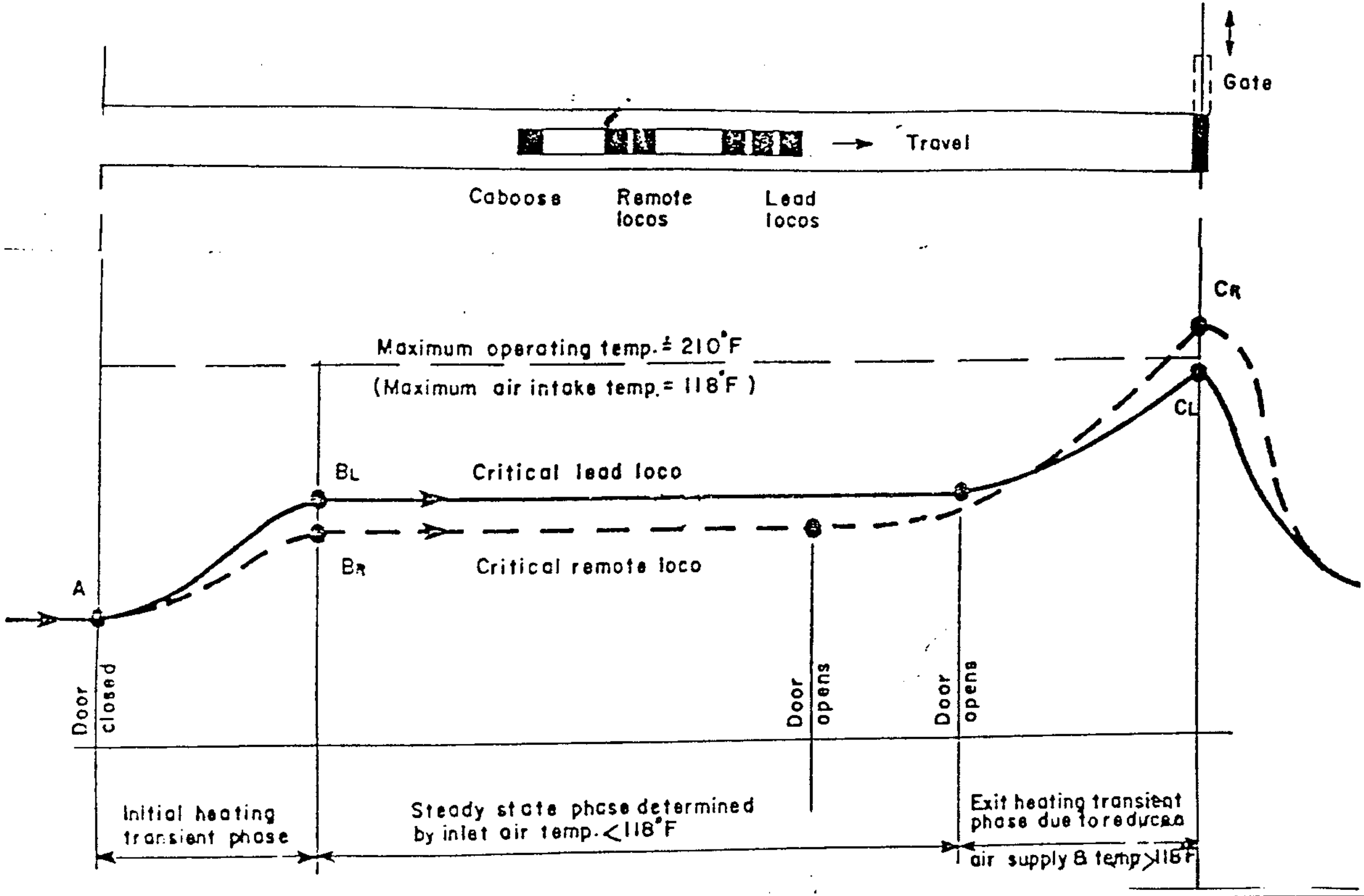
The calculations performed by PBQD indicated that for the conditions envisaged in the April 1980 report (1) a maximum cooling air capacity of 250,000 cfm would be required for the heaviest trains. In the October 1981 report (1) in which other factors were taken into account this cooling requirement was increased to 350,000 cfm. We presume that the design as proposed is based on the 350,00 cfm cooling capacity although, some variations about this general level will not have a significant effect on the environmental impact of the system.

6.2 Cooling System Analyses

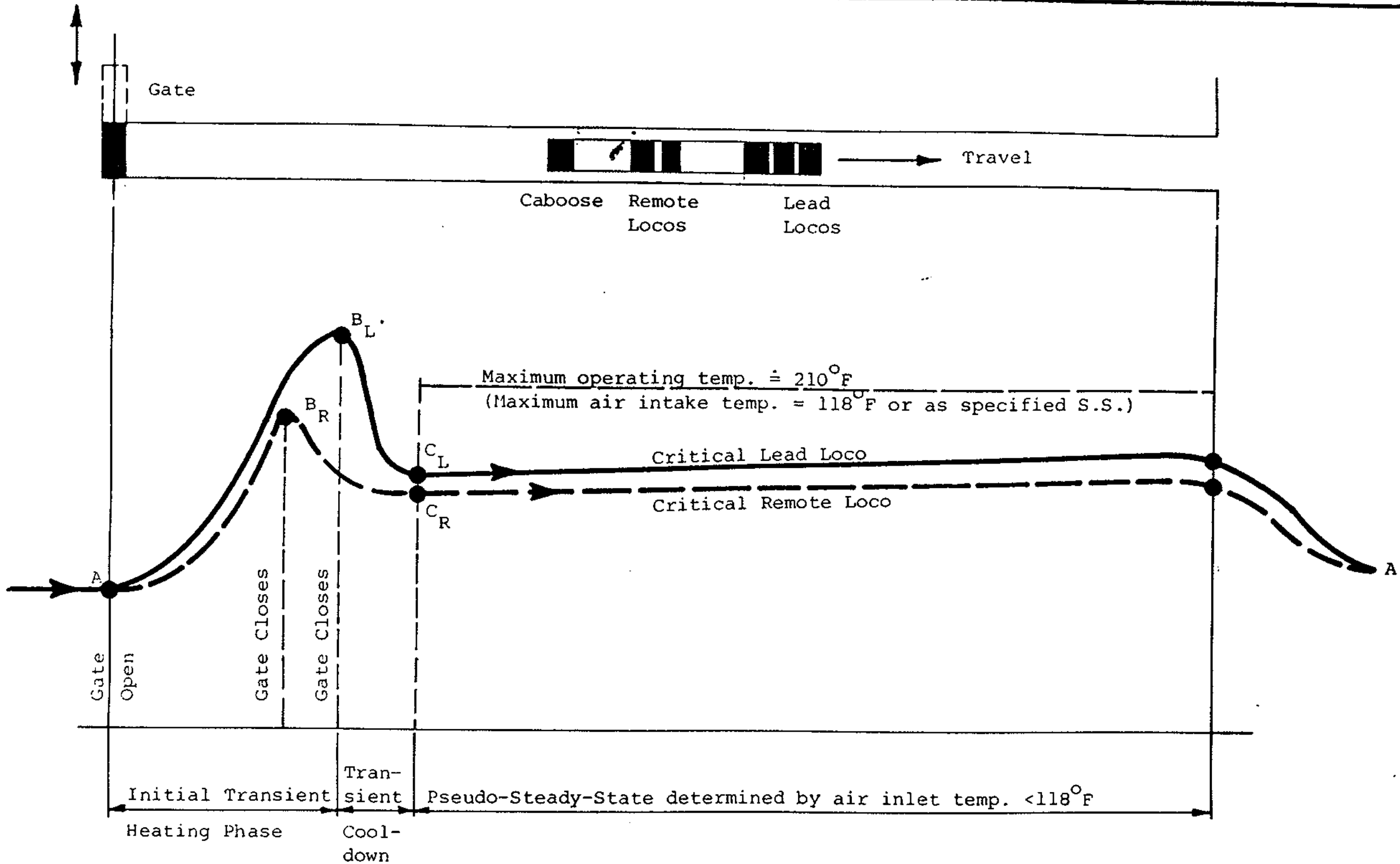
The PBQD computer programs represent the state-of-the-art of coupled aerodynamics and heat transfer analyses for this particular problem. There have been some cases where it has been possible to check the results of predictions using those programs against tunnel operations and these have generally given good results. It should be noted that PBQD calculations are for pseudo steady-state conditions in the tunnel when the train is travelling at a constant speed and the temperature conditions are steady.

However, there are in some cases, transient cooling conditions of train passage which may prove to be the critical case for consideration. Figure 8a shows an idealization of the response of the locomotive cooling system during the passage of the train through a single segment tunnel with a door ahead of the train. This illustrates the response of the critical lead and remote locomotives used on a 3 + 2 consist with gates and fans as used in the 3 American Tunnels. The highest temperatures are on exit from the tunnel in this case. In order to ensure that a door is fully open before the train exits and to allow the train to stop in the event of door failure, the actuator for the door drive is positioned some 3000 ft before the door. This means that when the full piston cooling effect of the closed door is terminated, the lead and remote locomotives are still well within the tunnel.

It can be seen from Figure 8a that when the door opens the radiator air intake temperature will rise and some overheating may occur depending on train speed, hp, etc.. The characteristics of the locomotive together with a consideration of the track geometry may then be the difference between success and failure of the train to operate satisfactorily. If the locomotive is operating at throttle 8, when the cooling water temperature reaches a critical



KLOHN LEONOFF LTD. CONSULTING ENGINEERS	PROJECT: C.P. RAIL ROGERS PASS TUNNEL	
	TITLE: IDEALIZED LOCOMOTIVE COOLING SYSTEM RESPONSE TRAVELLING TOWARDS A GATE	
CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE	DATE OF ISSUE: 12 APRIL 1982 APPROVED:	PROJECT No.: VA 2995 — FIGURE 8a — REV.



TO BE READ WITH KLOHN LEONOFF REPORT DATED ____________

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT	C.P. RAIL ROGERS PASS TUNNEL
TITLE	IDEALIZED LOCOMOTIVE COOLING SYSTEM RESPONSE TRAVELLING AWAY FROM A GATE
CLIENT:	FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE
DATE OF ISSUE	12 April 1982
APPROVED	[signature]
PROJECT No.	VA 2995
	FIGURE 8b
REV.	

value the GM SD40-2 locomotives offer an option which allows notch back to throttle setting number 6 automatically, instead of total shutdown. Total shutdown is undesirable since the sudden drop in power and operating speed could lead to increased cooling demands for other units and may cause these units to also shutdown, thereby potentially stalling the train before it is out of the tunnel. The delay in notch back can also be extended by the use of high pressure radiator caps.

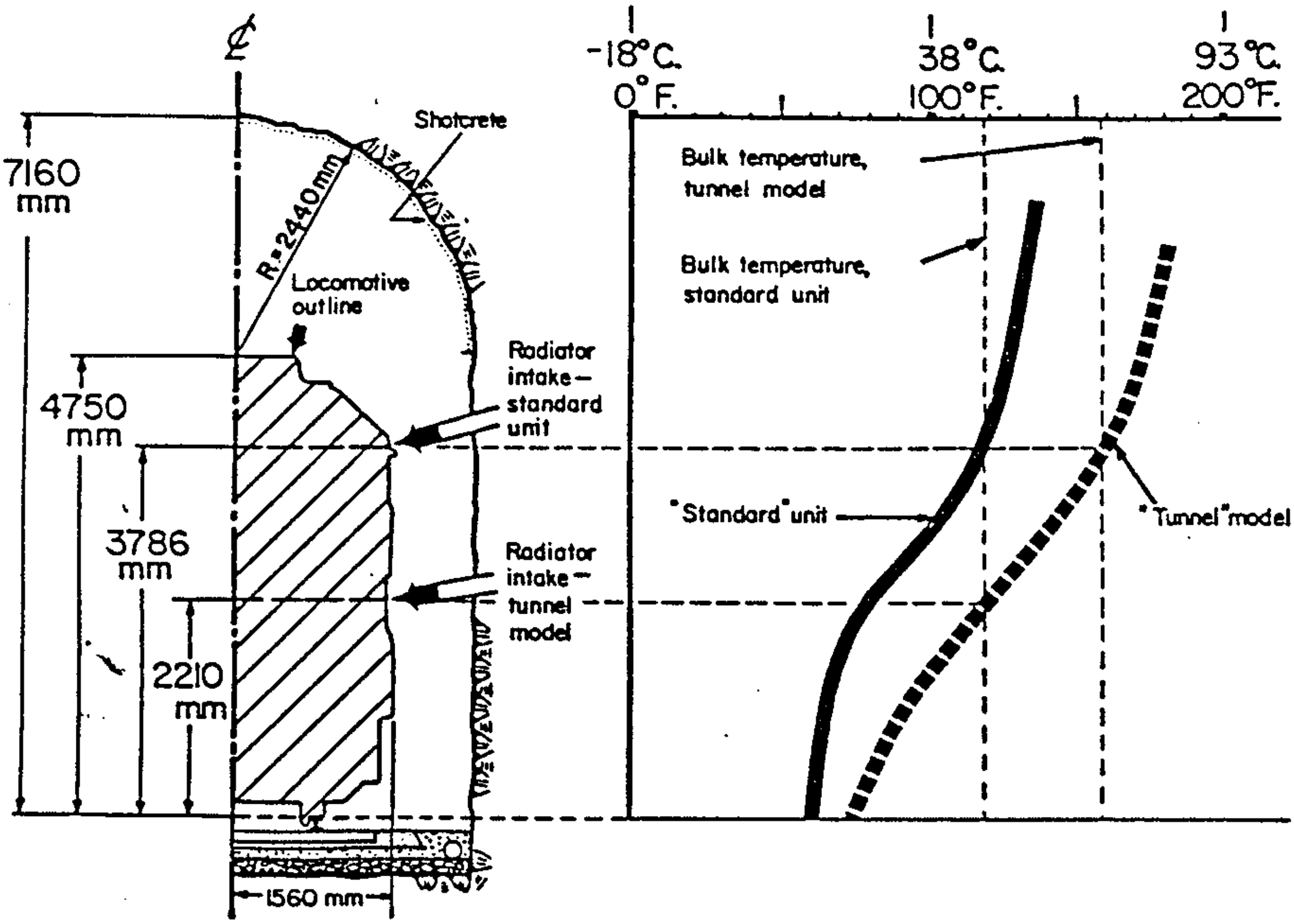
The track geometry is important since if the grade increases outside the tunnel even more power is required as the train exits the tunnel. Ideally, the grade should decrease outside the tunnel and thus, compensate for loss of some power during exit.

In Concept 1 and Concept 3 proposed by PBQD (1), doors are located at the East end of each Segment. In these cases there may be a larger thermal transient on entry if there is a delay in starting the supply of cooling air until the rear of the train has passed the fan duct as shown in Figure 8b.

The General Motors specifications for intake air are for the steady-state condition but it is known from experience in other tunnels that certain transients can also be handled. This will no doubt be checked by C.P.Rail or fan operations adjusted to handle the problem. However, these transient effects will not significantly affect the emissions from the tunnel provided that speeds are maintained.

We checked the PBQD calculation results using the design method used for the design of the British Columbia Railway Tumbler Ridge Line Tunnel ventilation systems. This method is described in the paper by Charlwood et al (11). A key aspect is the thermal

Approximate Temperature Distributions around 3000 h.p. Locomotive at Maximum Radiator Intake Temperatures



KLOHN LEONOFF LTD. CONSULTING ENGINEERS	PROJECT: C.P. RAIL ROGERS PASS TUNNEL		
	TITLE: TUNNEL AIR TEMPERATURE DISTRIBUTIONS		
CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE	DATE OF ISSUE: 12 APRIL 1982 APPROVED:	PROJECT No. VA 2995	FIGURE 9 REV.

stratification which occurs and the resulting temperatures at air intake locations. This is shown schematically in Figure 9. The calculations are based on an overall heat balance and empirical correlations between observed temperature profiles in tunnels and heat dissipation in the existing American tunnels and certain other analytical models.

The important PBQD conclusions regarding the need for ventilation cooling and the fan capacities to supply this were confirmed. In addition we performed approximate analyses for the possibility of the use of the tunnel modification to the GM EMD SD40-2 locomotives. These allow an approximately 35° to 40°F increase in the bulk air temperature in the tunnel at the critical locomotives. Our calculations suggest that the cooling air requirement could be reduced or possibly eliminated for most of the trains proposed if this modification is used. If cooling fans were eliminated it would still be necessary to operate the locomotives with closed gates in order to derive the piston cooling effects.

6.3 Purging Analyses

The purge analyses reported by PBQD are based on incompressible steady-state flow with friction factors appropriate to the construction of the tunnel walls. Their assumed factors correlate quite closely with our own data shown in Figure 5. (The train friction factors are used in the calculations of air flows and pressures during the cooling calculation.)

The purge analyses are based on an allowance for flushing 1.15 times the volume of the tunnel to allow for drag at the tunnels walls and the associated lower velocities in that region. A slightly larger number possibly as high as 1.25 has been suggested for certain other tunnel designs. However, the final decision on the purge times can best be judged once the system is in operation in terms of the residual contaminants measured.

It has been assumed that purging is required after the passage of every design train. This is highly desirable in terms of ensuring that the air quality of the crew and subsequent trains is maintained at an acceptable levels in the cab. It may be possible in certain cases to allow a subsequent train to enter the tunnel before purging is complete if it has been demonstrated that there is only limited leakage of the tunnel air into the cab during the period of tunnel transit. However, normal operation will no doubt require purging prior to train entry into the tunnel.

An additional requirement for purging fans is capability to clean the tunnel for wayside workers engaged in maintenance operations in the tunnel. In addition some capability through the use of reversable fans is highly desirable in order to be able to manage smoke and tend to control fire, should they occur within the tunnel to assist in the escape of personnel. In such circumstances any one of the fans may operate in the exhaust mode depending on the particular situation.

6.4 Air Quality Criteria for Use in The Working Environment

In this section we have provided a review of the current standards and literature used in North America when assessing permissible concentrations of toxic gases in a working environment. PBQD quote air quality standards but do not specify their source.

The following organizations publish standards, regulations or recommendations in North America concerning safe levels on noxious gases in a working environment:

a) Workers Compensation Board of British Columbia (WCB) - Industrial Health and Safety Regulations

b) American Conference of Governmental Industrial Hygenists - Threshold Limit Values (ACGIH)

c) Canada Safety Council - Occupational Safety and Health Data Sheets stratification which occurs and the resulting temperatures at air intake locations. This is shown schematically in Figure 9. The calculations are based on an overall heat balance and empirical correlations between observed temperature profiles in tunnels and heat dissipation in the existing American tunnels and certain other analytical models.

The important PBQD conclusions regarding the need for ventilation cooling and the fan capacities to supply this were confirmed. In addition we performed approximate analyses for the possible of the use of the tunnel modification to the GM EMD SD40-2 locomotives. These allow an approximately 35° to 40°F increase in the bulk air temperature in the tunnel at the critical locomotives. Our calculations suggest that the cooling air requirement could be reduced or possibly eliminated for most of the trains proposed if this modification is used. If cooling fans were eliminated it would still be necessary to operate the locomotives with closed gates in order to derive the piston cooling effects.

6.3 Purging Analyses

The purge analyses reported by PBQD are based on incompressible steady-state flow with friction factors appropriate to the construction of the tunnel walls. Their assumed factors correlate quite closely with our own data shown in Figure 5. (The train friction factors are used in the calculations of air flows and pressures during the cooling calculation.)

The purge analyses are based on an allowance for flushing 1.15 times the volume of the tunnel to allow for drag at the tunnels walls and the associated lower velocities in that region. A slightly larger number possibly as high as 1.25 has been suggested for certain other tunnel designs. However, the final decision on the purge times can best be judged once the system is in operation in terms of the residual contaminants measured.

d) U.S. Department of Labour - Occupational Safety and Health Administration (OSHA) are the U.S. regulatory authority. Their research work is conducted by U.S. Department of Health and Human Services - National Institute for Occupational Safety and Health (NIOSH)

e) National Academy of Sciences - Committee on Medical and Biological Effects of Environmental Pollutants

f) World Health Organization - Environmental Health Criteria

The Workers Compensation Board regulations are based on the recommendations of the American Conference of Governmental Industrial Hygenists and govern the operation of many industrial establishments, though their application to or authority over the CP Rail Rogers Pass Tunnel appears unclear. The Canada Safety Council have no regulatory authority, but their recommendations are based on NIOSH publications and are considerably more demanding.

The Workers Compensation Board of British Columbia (WCB) give guidance on air quality in the "Industrial Health and Safety Regulation". Permissible concentrations of substances are given for eight hour and fifteen minute exposure.

The time exposure categories are defined by WCB as follows:

a) 8 hour Exposure Limit - The time weighted average concentration for a normal 8 hour work day or a 40 hour work week;

b) 15 minute Exposure limit - The maximun concentration to which workers can be exposed for a period up to 15 minutes without suffering from irritation, chronic or irreversible tissue change, or narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that not more than four excursions per day are permitted with at least 60 minutes between exposure periods and provided that the 8 hour exposure limit is not exceeded. The 15 minute exposure limit is considered a maximum allowable concentration, or ceiling, not to be exceeded at any time during the 15 minute excursion period;

In addition to these concentrations the WCB regulations, Section 13, show the method of determining permissible concentrations when two or more substances are present and state that the oxygen content must be greater than 18% before a worker enters a confined space. Additional requirements for underground workings defined as "Any underground place of employment including a tunnel", are contained in Section 40 of WCB regulations.

The most recent exposure limits available from ACGIH are somewhat lower than present WCB regulations, but preliminary verbal enquiries suggest that WCB do not at present intend to lower their permissible levels. Table 4 summarizes the WCB maximum permissible concentrations of gases.

TABLE 3

WCB PERMISSIBLE CONCENTRATIONS OF GASES

	Permissible Concentrations			
Substance	8 Hour Limit		15 Minute Limit	
	ppm	mg/m^3	ppm	mg/m^3
CO	50	55	400	440
NO_2	5	9	5	9
NO	25	30	35	45
SO_2	5	13	5	13
CO_2	5000	9000	15000	27000

The TLV and MPC limits quoted by PBQD 1980 (1) Table 14 are generally similar to these except CO. The applicable authority and standards to be used by CP Rail are unclear.

6.5 Calculation of Emission Concentrations in the Tunnel

Emissions data for the SD40 locomotive are available from a number of sources, including:

a) data provided in Table 12 of the 1980 PBQD report (1), labelled "Manufacturer's Tests" (GM-1 data);

b) data provided in Table 12 of the 1980 PBQD report (1), labelled "EPA AP-42 Emission Factors" (EPA data);

c) test data provided by GM of Canada, Diesel Division (21) (Ref. letter June 24, 1981) (GM-2 data);

d) test data compiled by the U.S. Department of Transportation (13) (USDT data).

The emission rates quoted by these sources for a single SD40 unit at full throttle have been converted to common units, and are tabulated below:

	Emission Rate (gn/hr)			
Pollutant	GM-1	EPA	GM-2	USDT
Nitrogen Oxides	37500	25100	29160	25500
Carbon Monoxide	5320	12150	4410	9740
Hydrocarbons	1270	2125	2000	2010
Suspended Particulates	----	1890	----	----
Sulphur Dioxide	----	4330	4190	----

The GM-1 data and the EPA data have been calculated from figures quoted in the 1980 PBQD report (1), based on a fuel consumption of 167 U.S. gallons per hour per locomotive.

The 1981 PBQD report gives the fuel consumption rate as 161.4 to 169.6 U.S. gallons per hour, for a new and old unit, respectively. The GM-2 data indicate the fuel consumption as 160.7 U.S. gallons per hour.

The concentrations of nitrogen oxides (NO_x) in the tunnel exhaust were calculated by dividing the total emission rate by the total air flow past the train. The average concentration during the purge phase is slightly lower than that during the cooling phase, since approximately 115% of the tunnel volume is displaced during the purge phase. The results of our analyses for NO_x are shown on the cycle diagrams, Figures 10.1 to 10.13.

Based on the above data, the levels of various pollutants in the tunnel exhaust may be obtained by multiplying the concentration of NO_x shown on Figures 10.1 to 10.13 by the following ratios:

Pollutant	Ratio of Pollutant Concentration (ppm) to Indicated NO_x Concentration (ppm)
Nitrogen Oxides	0.67 - 1.00
Carbon Monoxide	0.14 - 0.38
Hydrocarbons	0.04 - 0.06
Suspended Particulates*	0.00 - 0.07
Sulphur Dioxide	0.00 - 0.06

* to give concentration in mg/m^3

Various estimates have been made of the proportions of NO and NO_2 in the total NO_x emissions. The GM-2 data indicate that the proportions are approximately 5% NO_2 and 95% NO, the USDT data indicate the proportions may be 10% NO_2 and 90% NO. PBQD 1980 (1) have assumed a breakdown by weight of 25% NO_2 and 75% NO.

PBQD had calculated the pollutant levels in the tunnel exhaust based on both the GM-1 data and the EPA data provided above. This is equivalent to assuming the maximum emission rate for each pollutant as quoted by the four sources listed above.

In the tunnel air follow a design train passage the critical component is NO_x which exceed the WCB criteria. The concentrations in the cab of the next train would not necessarily by exceeded. However, purging prior to each train should ensure compliance.

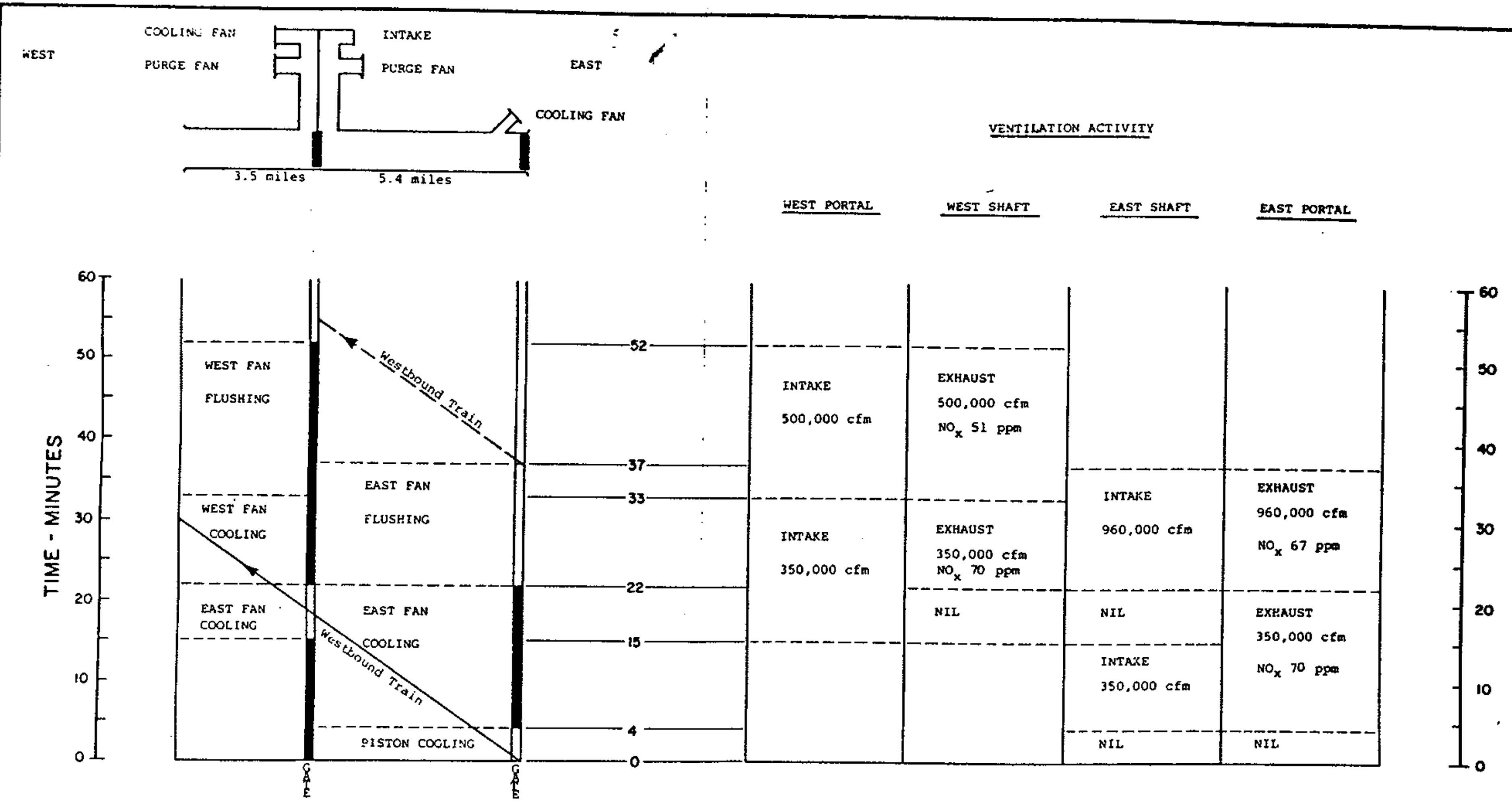
6.6 Summary Presentation of Results

The cycle diagrams Number 1 to 13 summarize the analyses of train and fan operations for the major options of interest. In addition these indicate the volumes of exhaust and concentrations of NO_x emitted during fan operations at the various locations. The concentrations of other components can be found by calculating them in proportion to the NO_x values as discussed in Section 6.5.

The cycle time diagrams were based on idependent calculations by Klohn Leonoff using the proposed operational procedures and the recommended fan sizes for the various concepts.

Cycle diagram No. 1 presents the results for the PBQD 1980 (1) Concept 3 with 350,000 cfm cooling and 2 x 480,000 cfm purging fans for the east section and 1 x 500,000 cfm purging fans for the west section. This considers shaft Location 1. This diagram shows that the overall system cycle time is 40 minutes between successive west bound 15,000 TT coal trains with a 3 + 2 consist of FD-40 locomotives.

Cycle diagram No 2 shows a cycle time of 40 minutes for a 12,000 TT west bound coal train with a 4 + 0 consist in Concept 3.



CYCLE TIME: 37 min.

COOLING FANS: 1 x 350,000 cfm (east)
1 x 350,000 cfm (west)

PURGE FANS: 2 x 480,000 cfm (east)
1 x 500,000 cfm (west)

TRAIN: Grain Train - 11,000 T. Tons
Loco Consist - 4 + 0
Speed 17.8 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

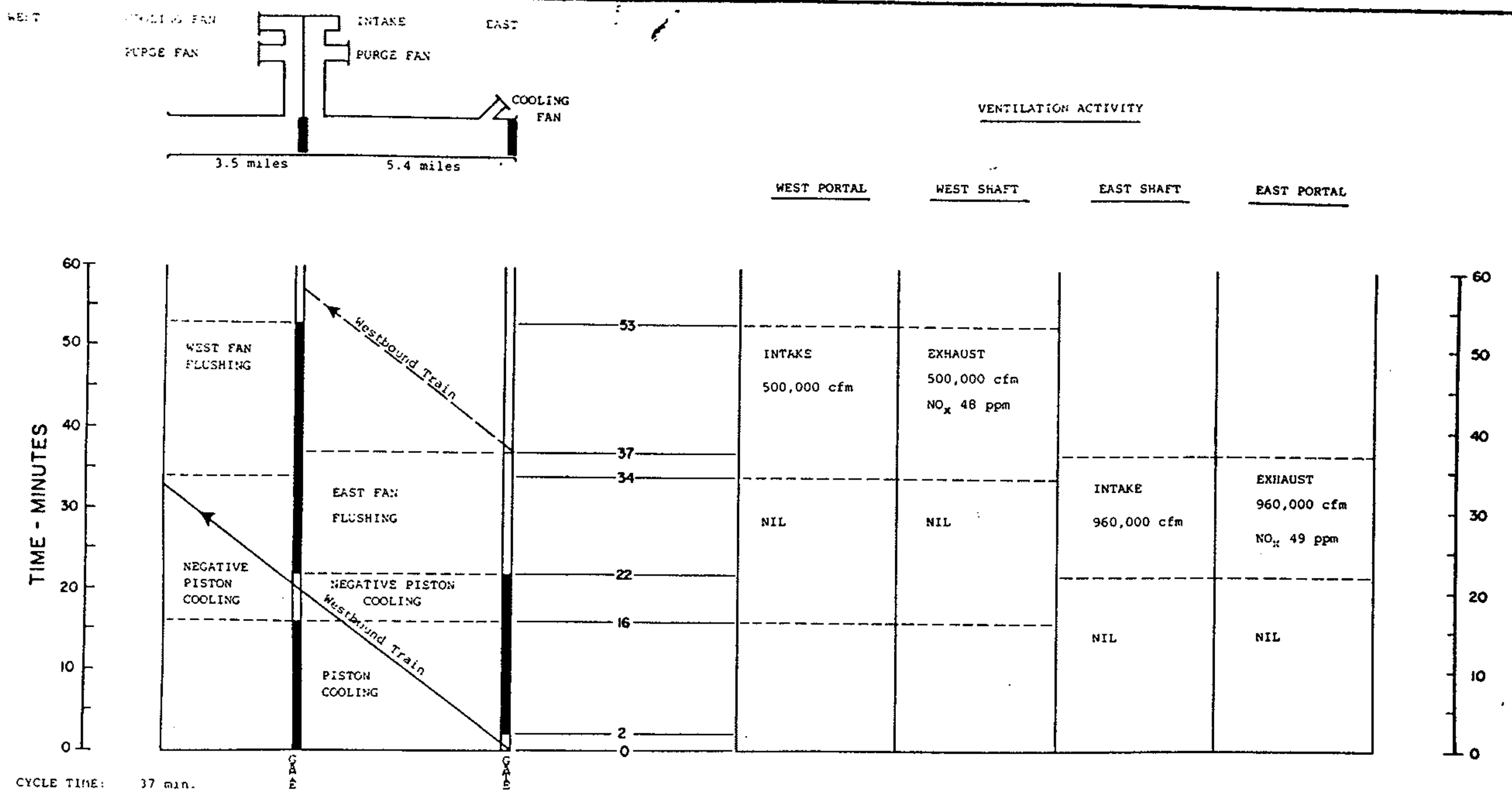
TITLE: CYCLE DIAGRAM NO. 3
Concept 3 - 11000TT Grain Train

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

DATE OF ISSUE: APRIL 12, 1982

PROJECT No.: VA 2995

FIGURE 10.3



CYCLE TIME: 37 min.

COOLING FANS: Not Required

PURGE FANS: 2 x 480,000 cfm (east)
1 x 500,000 cfm (west)

TRAIN: Merchandise - 6,000 T. Tons
Loco Consist 2 + 0
Speed 16.4 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 4
Concept 1 - 6000TT Merchandise 2+0

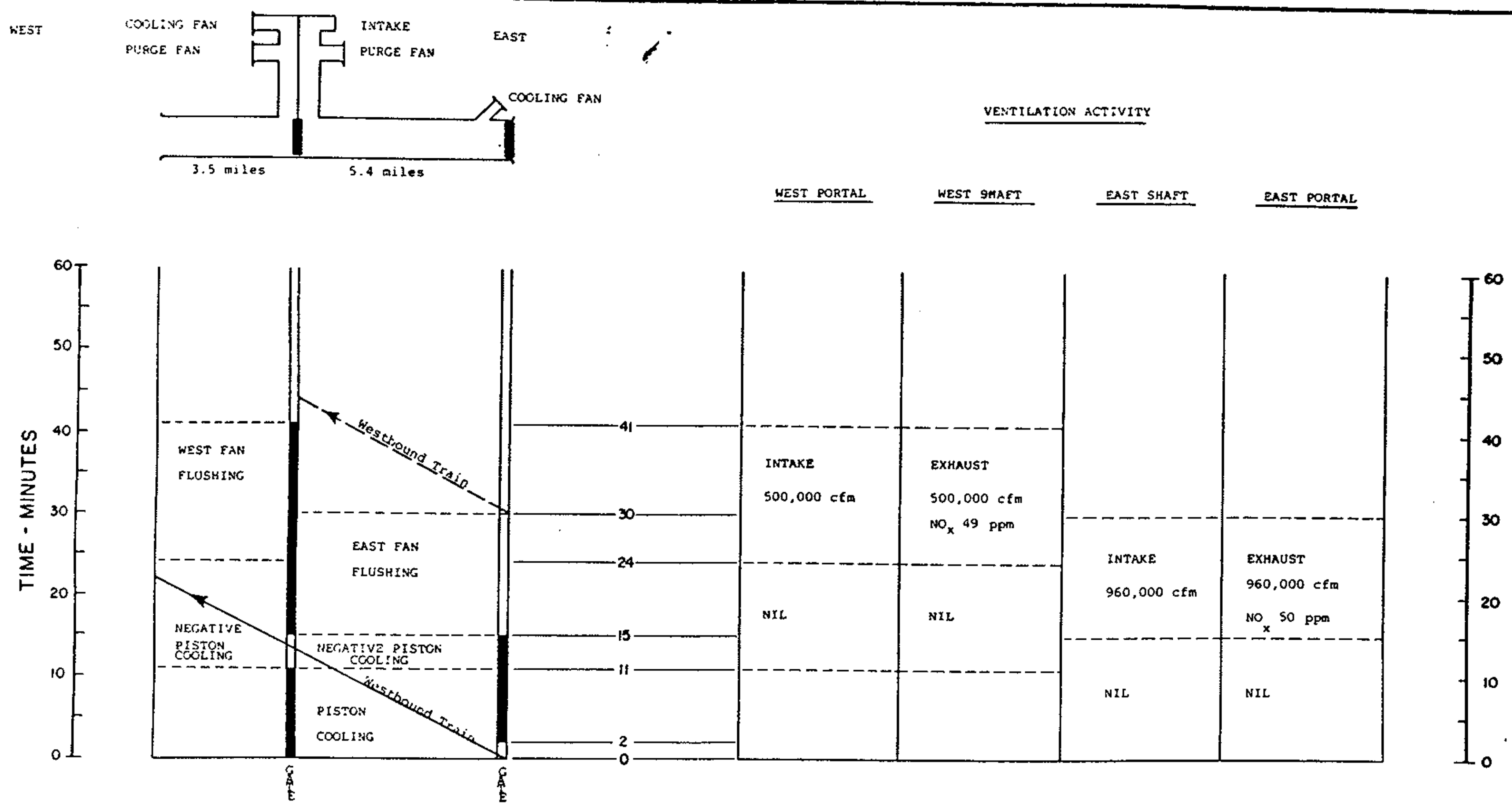
DATE OF ISSUE: APRIL 12, 1982

APPROVED:

PROJECT No. VA 2995

FIGURE 10.4

REV



CYCLE TIME: 30 min.

COOLING FANS: Not Required

PURGE FANS: 2 x 480,000 cfm (east)
1 x 500,000 cfm (west)

TRAIN: Merchandise 6,000 T. Tons
Loco Consist 3 + 0
Speed 24.0 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 5
Concept 3 - 6000TT Merchandise 3+0

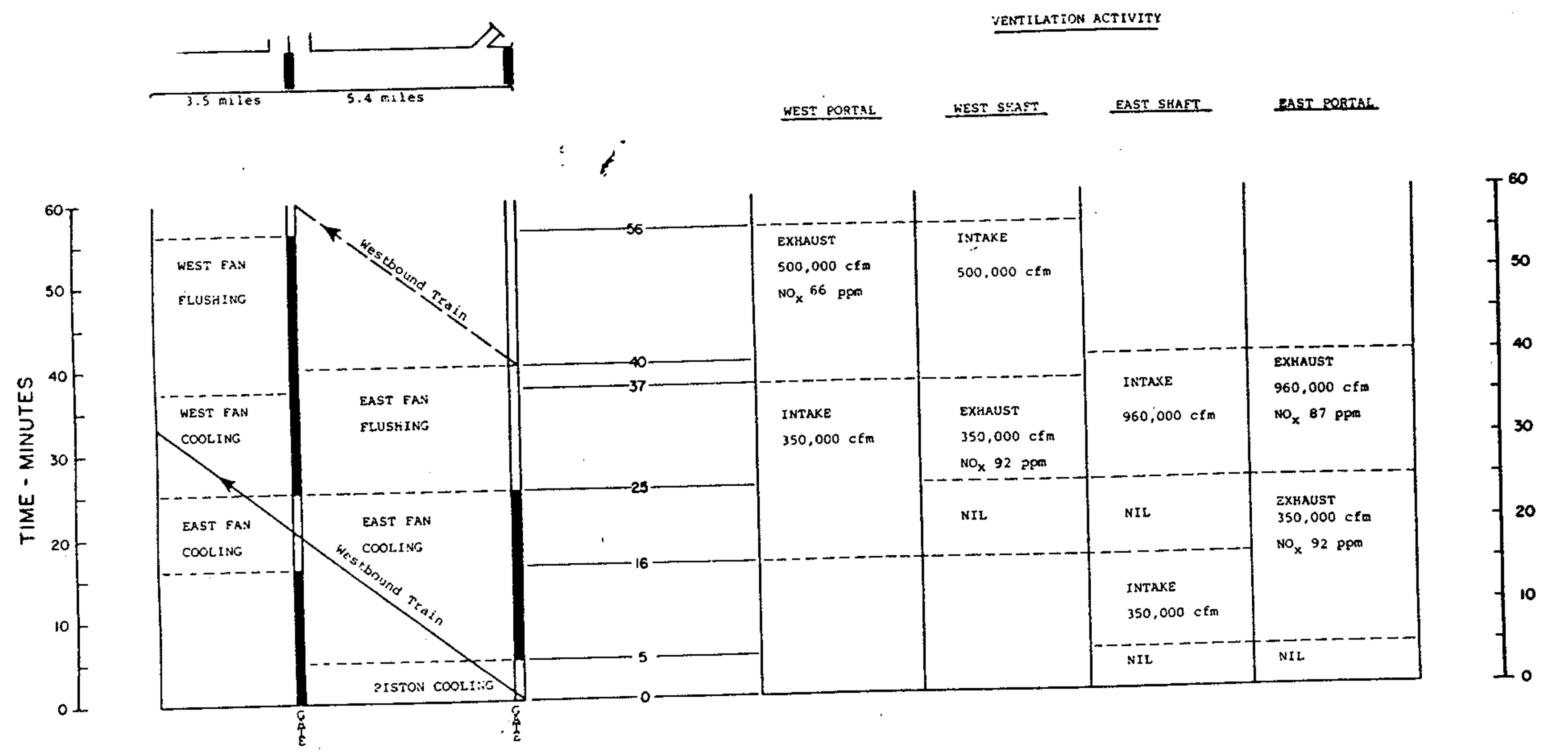
DATE OF ISSUE: APRIL 12, 1982

APPROVED:

PROJECT No. VA 2995

FIGURE 10.5

REV



CYCLE TIME: 40 min.

COOLING FANS: 1 x 350,000 (east)
1 x 350,000 (west)

PURGE FANS: 2 x 480,000 cfm (east)
1 x 500,000 cfm (west)

TRAIN: Coal Train - 15,000 T. Tons
Loco Consist 3 + 2
Speed 16.4 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

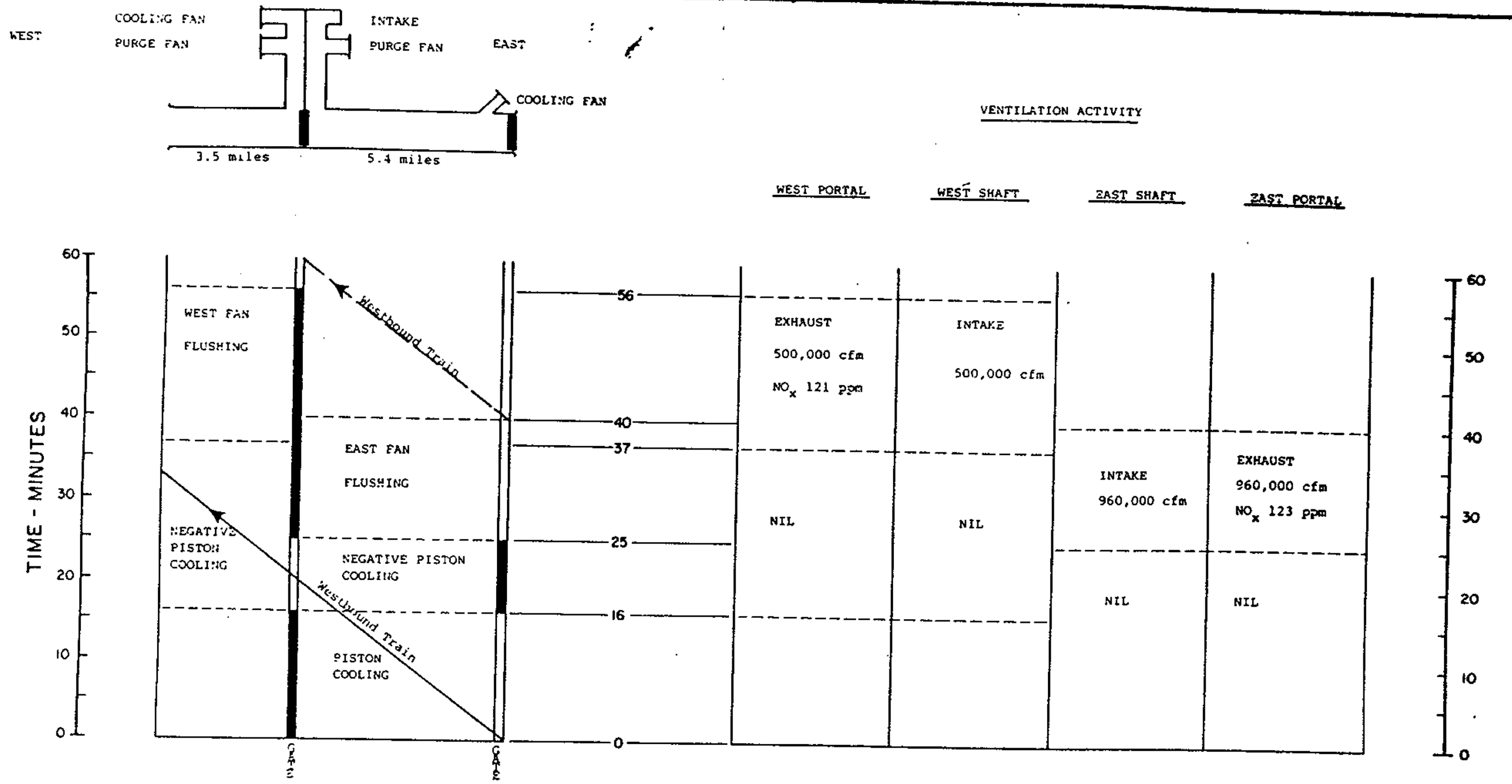
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 6
Concept 4 - 15000TT Coal Train

DATE OF ISSUE: APRIL 12, 1982
APPROVED:
PROJECT No.: VA 2995
FIGURE 10.6
REV



CYCLE TIME: 40 min.

COOLING FANS: Not required

PURGE FANS: 2 x 480,000 cfm (east)
1 x 500,000 cfm (west)

TRAIN: Coal Train - 15,000 T. Tons
Loco Consist: 3 + 2 Tunnel Type
Speed 16.4 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 7
Concept 5 - 15000TT Coal Train

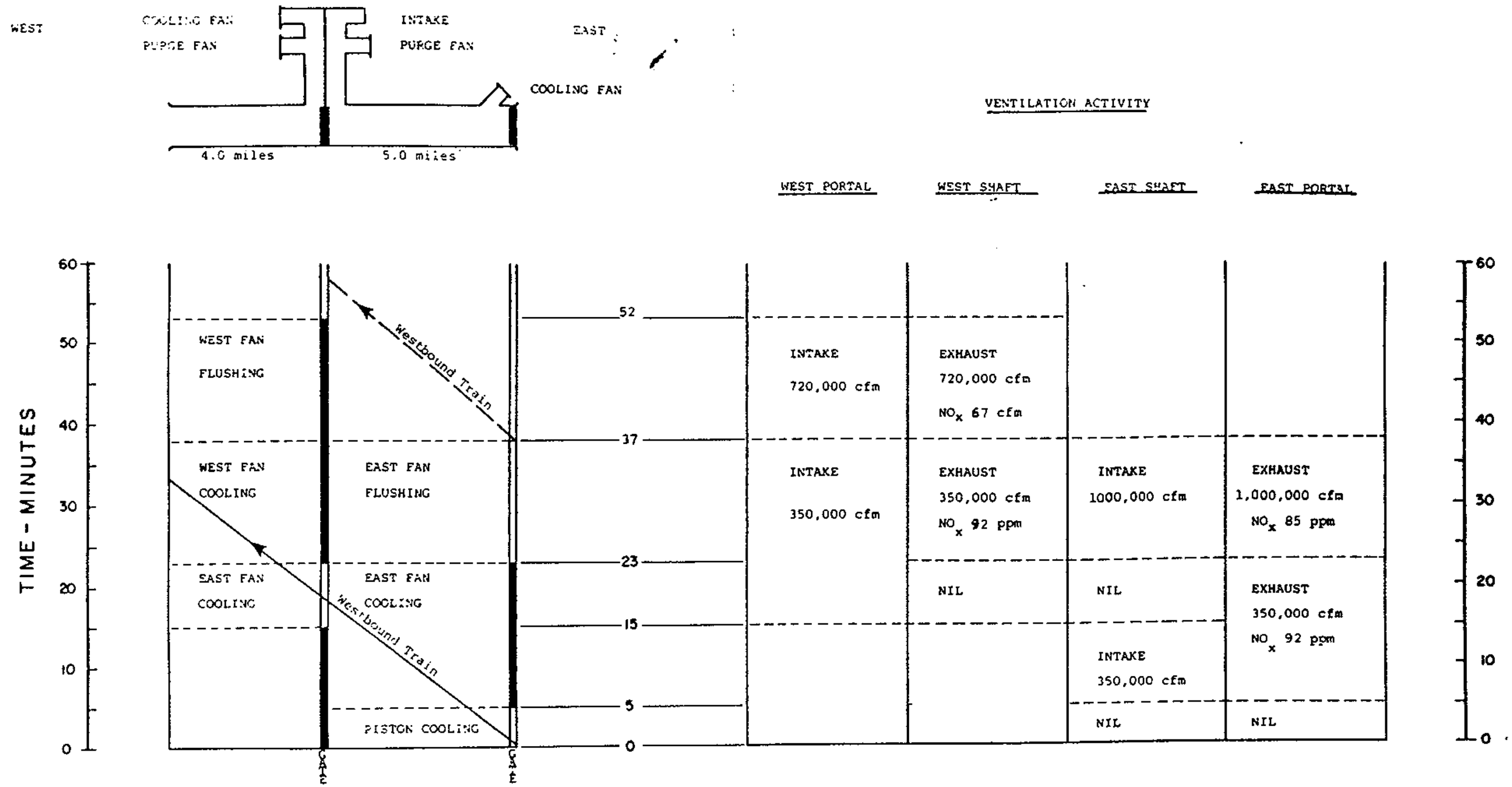
DATE OF ISSUE: APRIL 12, 1982

APPROVED:

PROJECT No. VA 2995

FIGURE 10.7

REV



CYCLE TIME: 37 min.

COOLING FANS: 1 x 350,000 cfm (east)
1 x 350,000 cfm (west)

PURGE FANS: 2 x 500,000 cfm (east)
2 x 360,000 cfm (west)

TRAIN: Coal Train 15,000 T. Tons
Loco Consist 3 + 2
Speed 16.4 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

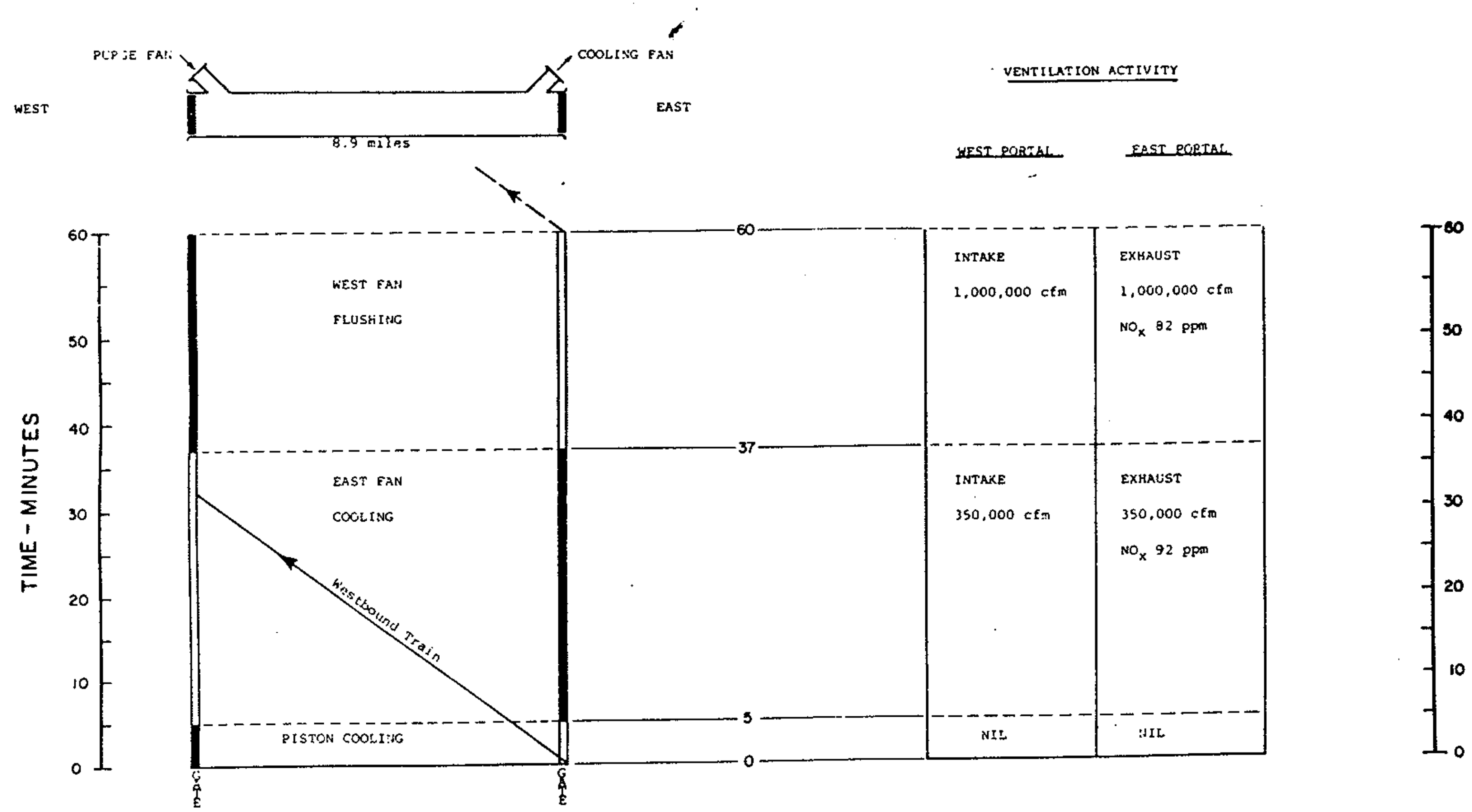
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 8
Concept 3 - Coal Train - Shaft 2

DATE OF ISSUE: APRIL 12, 1982
APPROVED: [signature]
PROJECT No. VA 2995
FIGURE 10.8
REV.



CYCLE TIME: 60 min.

COOLING FANS: 1 x 350,000 cfm

PURGE FANS: 2 x 500,000 cfm

TRAIN: Coal Train - 15000 T. Tons
Loco Consist 3 + 2
Speed 16.4 mph

TO BE READ WITH KLOHN LEONOFF · REPORT DATED APRIL 12, 1982

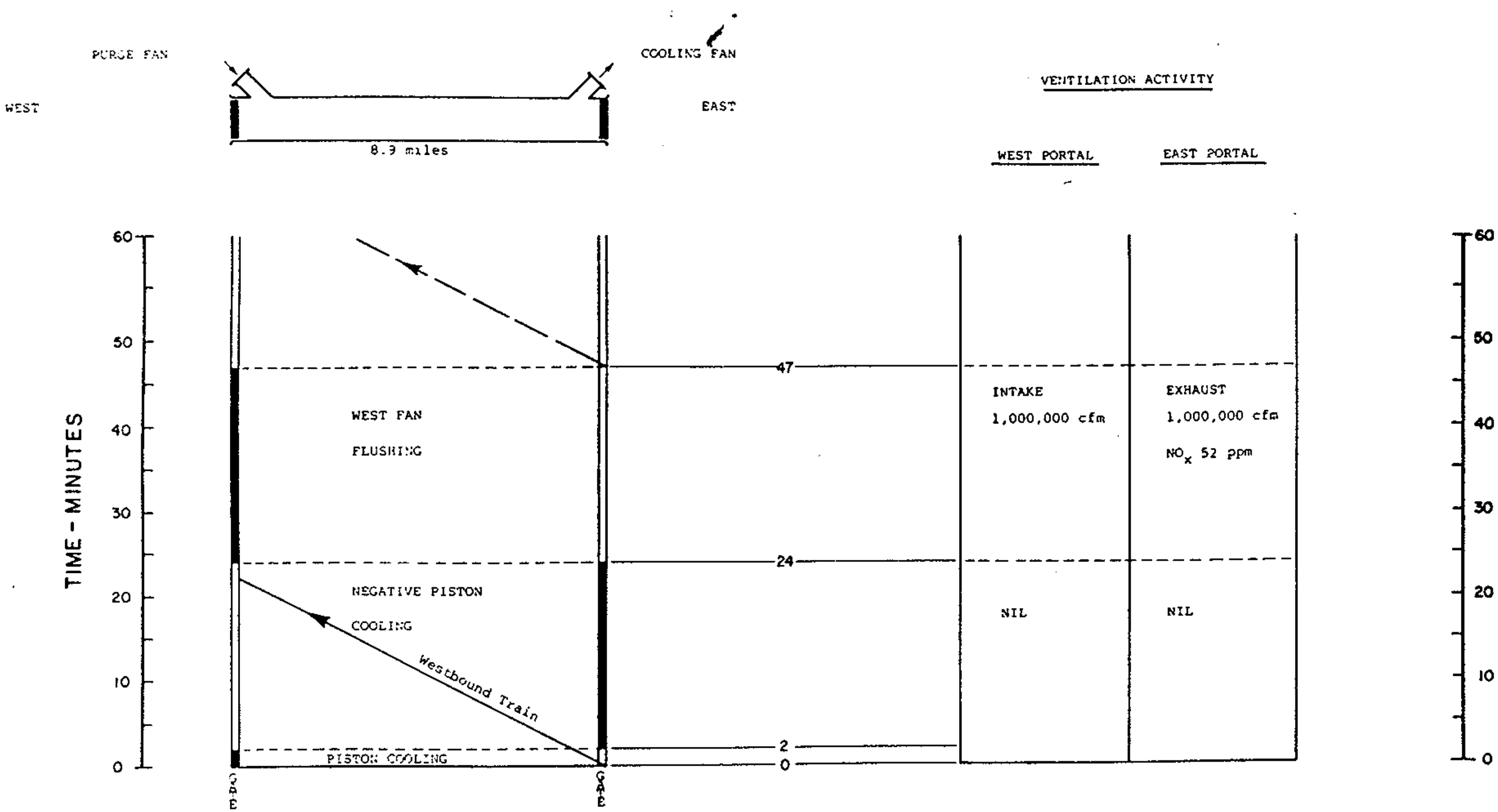
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 9
Concept 1 - 15000TT Coal Train

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

DATE OF ISSUE	PROJECT No.		REV.
APRIL 12, 1982	VA 2995	FIGURE 10.9	



CYCLE TIME: 47 min.

COOLING FANS: Not Required

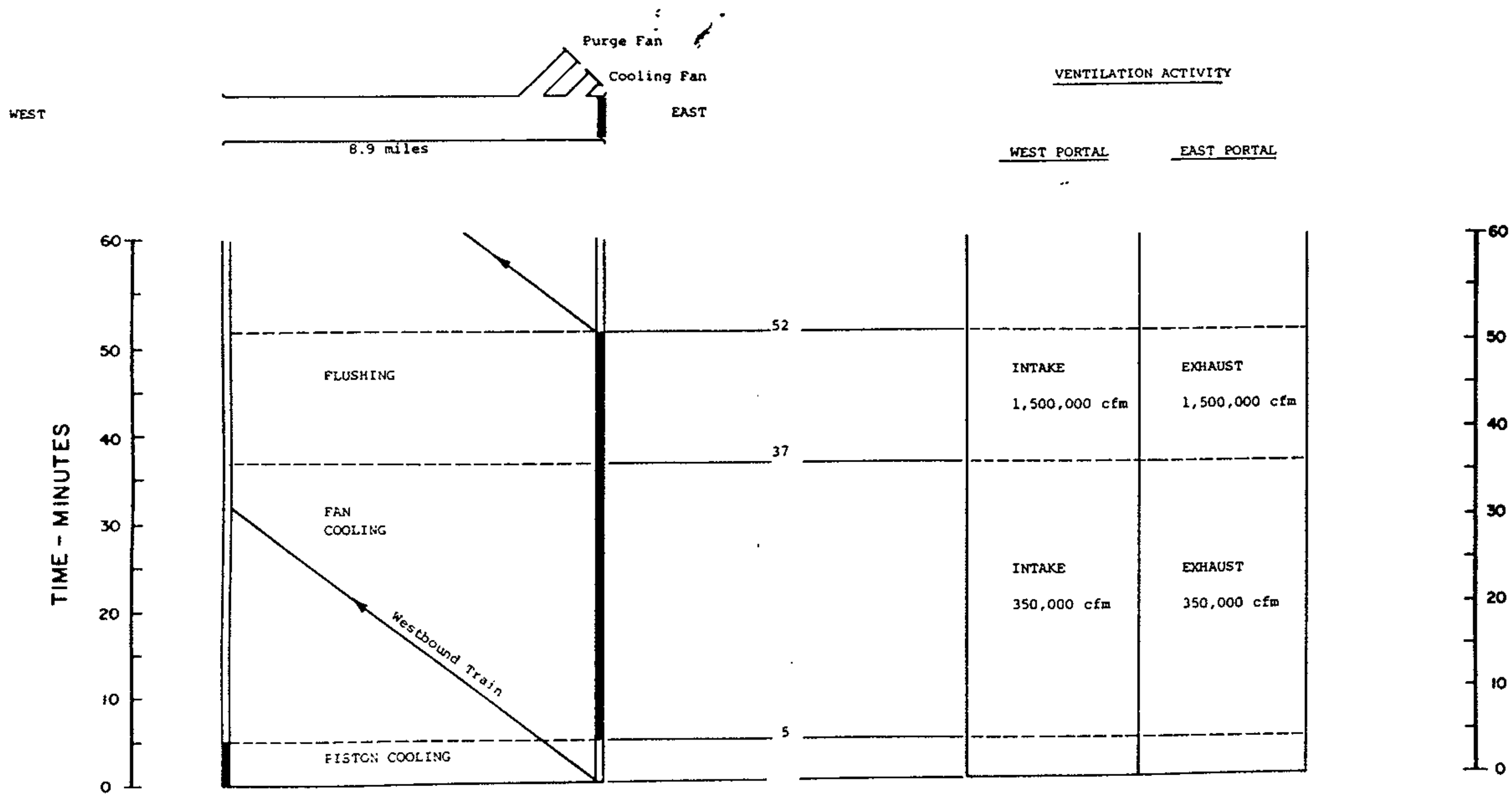
PURGE FANS: 2 x 500,000 cfm

TRAIN: Merchandise - 6,000 T. Tons
Loco Consist - 3 + 0
Speed 24.0 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

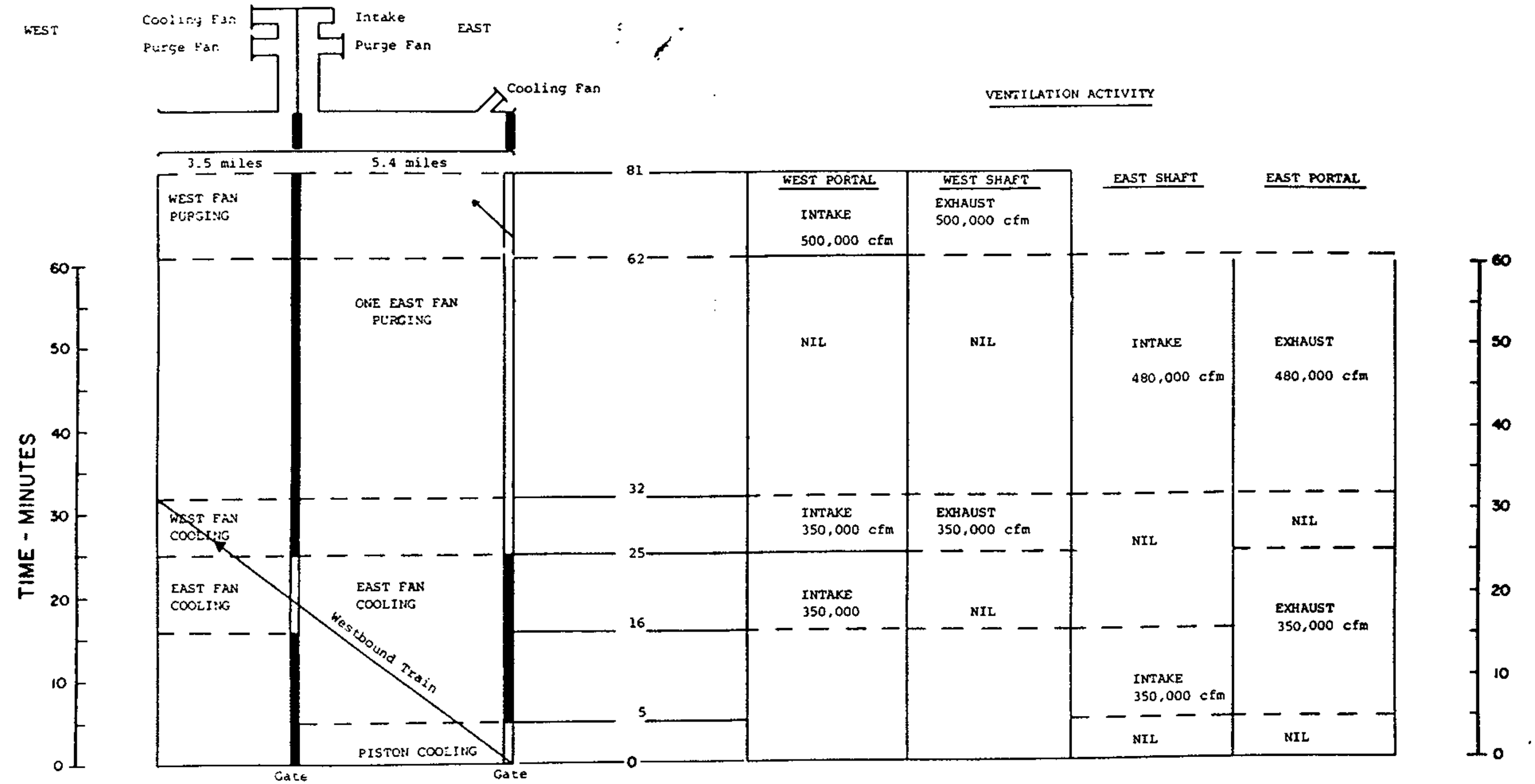
PROJECT	CPR ROGERS PASS TUNNEL VENTILATION
TITLE	CYCLE DIAGRAM NO. 10 Concept 1 - 6000TT Merchandise Train
CLIENT	FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE
DATE OF ISSUE	APRIL 12, 1982
APPROVED	
PROJECT No.	VA 2995
	FIGURE 10.10
REV.	



CYCLE TIME: 52 min.
COOLING FANS: 1 x 350,000 cfm
PURGE FANS: 3 x 500,000 cfm
TRAIN: Coal Train - 15000 T. Tons
Loco Consist 3 + 2
Speed 16.4 mps

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

KLOHN LEONOFF LTD. CONSULTING ENGINEERS	PROJECT: CPR ROGERS PASS TUNNEL VENTILATION
	TITLE: CYCLE DIAGRAM NO. 11 Concept 1 - 15000 TT Coal - Fans
CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE	DATE OF ISSUE: APRIL 12, 1982 · PROJECT No.: VA 2995 · FIGURE 10.11



CYCLE TIME: [illegible] min.
COOLING FANS: 1 x [illegible]50,000 (east)
1 x 350,000 (west)
PURGE FANS: 2 x 480,000 cfm (east)
1 x 500,000 cfm (west)
Maximum of one fan running at any time
TRAIN: Coal Train - 15,000 T. Tons
Loco. Consist 3 + 2
Speed 16.4 mph

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

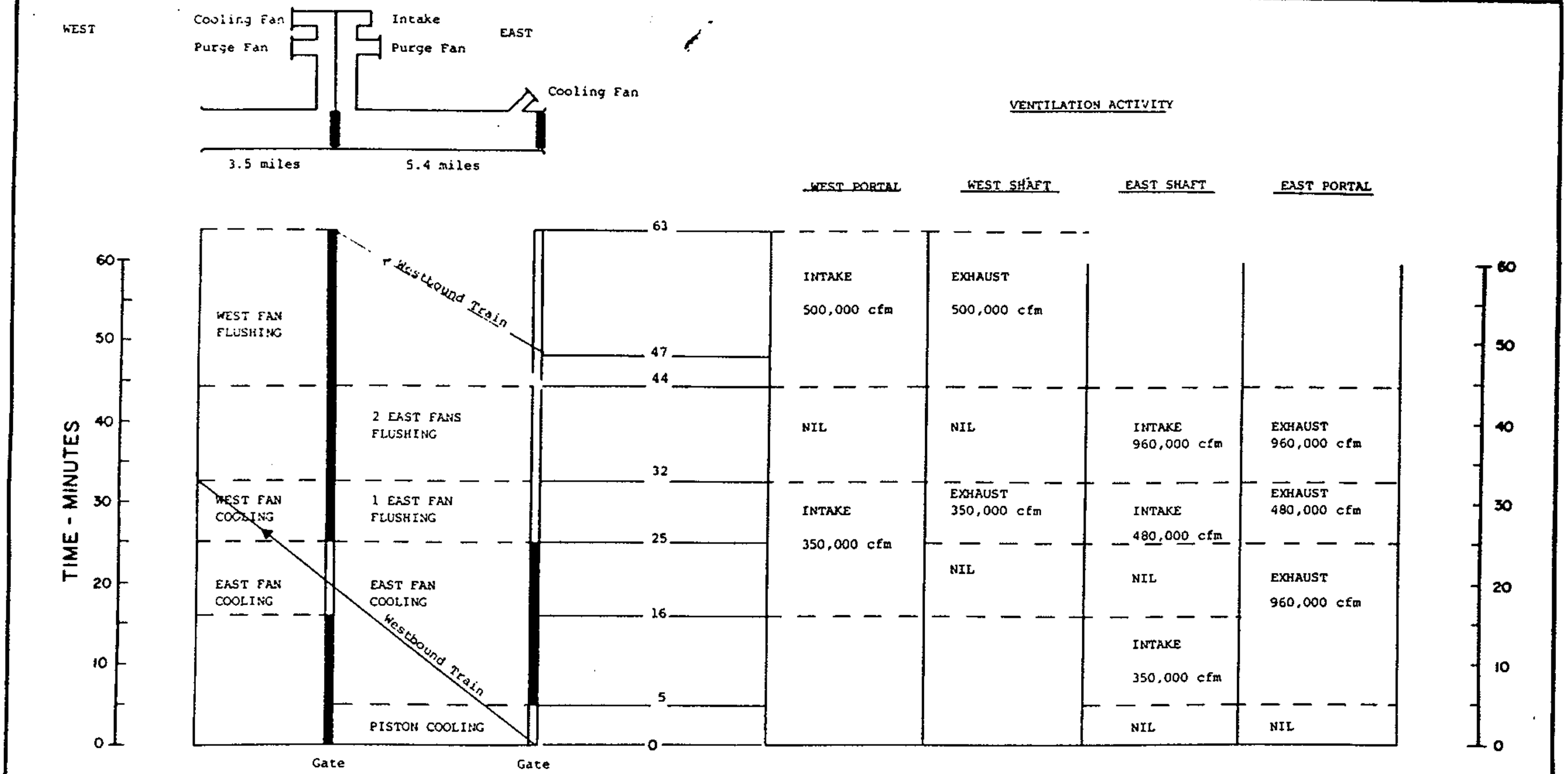
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 12
Concept 3 - Standby Power - Sequential Fans

DATE OF ISSUE: APRIL 12, 1982
APPROVED: [illegible]
PROJECT No. VA 2995
FIGURE 10.12



CYCLE TIME:	47 min.	
COOLING FANS:	1 x 350,000 (east)	Maximum of
	1 x 350,000 (west)	2 fans
PURGE FANS:	1 x 480,000 cfm (east)	running at
	1 x 500,000 cfm (west)	one time
TRAIN:	Coal Train - 15,000 T. Tons	
	Loco. Consist 3 + 2	
	Speed 16.4 mps	

TO BE READ WITH KLOHN LEONOFF REPORT DATED APRIL 12, 1982

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

PROJECT: CPR ROGERS PASS TUNNEL VENTILATION

TITLE: CYCLE DIAGRAM NO. 13
CONCEPT 3 - STANDBY POWER - CONCURRENT FANS

DATE OF ISSUE: APRIL 12, 1982 | PROJECT No. VA 2995 | FIGURE 10.13 | REV

APPROVED: [signature]

Cycle diagrams 3, 4 and 5 show the cycle times of 37 minutes and 30 minutes for 11,000 TT grain train with a 4 + 0 locomotive consist, a 6,000 TT merchandise train with a 2 + 0 locomotive consist and 6,000 TT merchandise train with a 3 + 0 locomotive consist for Concept 3.

Cycle diagram 6 shows the operation under Concept 4 in which the west section is exhausted through the west portal. This does not effect the cycle time but does reduce the total volume of emissions through the shaft. This also uses shaft Location 1.

Cycle diagram 7 shows the operation of Concept 5 in which "Tunnel modification" locomotives are used in addition to the purging of the west section of the tunnel through the west portal. In this case there are no emissions through the central shaft.

Cycle diagram 8 shows the operation of concept 3 with the new shaft Location 2 to the east of the Highway No. 1. In this case the cycle time is reduced to 37 minutes for the heavy coal train due to the location of the shaft somewhat closer to the tunnel centreline than in the basic Concept 3 layout. In this case the west section purging fan capacity has been increased to 2 x 360,000 cfm in order to compensate for the changes in length of the two tunnel sections.

If the shaft was moved to the centre of the tunnel the cycle time would be 34 minutes.

Cycle diagram 9 shows the operation of concept 1 in which the purging or cooling is operated from the ends of the tunnel only. This results in a cycle time of 60 minutes with exhaust from the east portal only. This operation has been stated by CP Rail to be unacceptable in terms of the results in delay to traffic. Cycle diagram 10 shows the cycle time for a 60,000 trailing ton merchandise train with a 3 locomotive consist. In this case the reduction in cycle time 47 minutes is achieved simply by the increase in speed of the train passage but with the same flushing time.

Cycle diagram 11 shows the operation if larger capacity purging fans are used in Concept 1. The resulting cycle time is 52 minutes.

Cycle diagrams 12 and 13 show the operations using two standby power capacities both of which result in longer cycle times.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Basis for Selection

The PBQD 1980 report (1) recommends Concept 3 in terms of reliability, cost effectiveness and impact on the park environment.

From the standpoint of reliability PBQD argues that concept 3 employs in each segment the same ventilation concept which is used successfully by the existing tunnels in the United States carrying heavy diesel traffic. We agree with this point of view although would point out that the early operation of the gate assemblies at the existing tunnels in the United States involved considerable maintenance and reliability problems. However, after 10 years of operation, at the Flathead installation in particular, it should now be possible to install a very much more reliable system. The proposed designs for the Rogers Pass Tunnel require two sets of gates, associated drive equipment and fans, on set of which would be operated underground in a chamber offset from the tunnel. While in principle this is a repeat of the existing systems there will no doubt be teething problems during the early days of operation underground.

The issue of cost effectiveness is also stated as a major criteria. This is manifest in the importance given in the reports to reducing cycle times and increasing train frequencies. We could judge the initial capital cost and operating cost of the various proposals. However, the benefits to CP Rail from the increase in train frequencies by a reduction of cycle time from 60 minutes to 40 minutes to 38 minutes or any other similar times can only really be judged by CP Rail themselves. In general terms, we do agree that every possible effort should be made to minimize the ventilation system cyle time in order to allow the most efficient use of the tunnel when serving normal forecast traffic or sudden increases in traffic flows due to unexpected opportunities for freight movement associated with export or other activities. A detailed quantification of these is, however, difficult.

PBQD state that the environmental impact of concept 3 is judged to be less adverse than concept 2. We agree since Concept 3 will reduce the amount of emissions from the shaft. We have suggested other opportunities for diverting flow from the shaft through other portals. A decision on the relative acceptability of these versus the shaft should be made by the Panel and others. We have restricted our efforts to identifying the options.

We cannot at this time identify the "best" concept since the costs, benefits and acceptability of the options presented need to be addressed by C.P.Rail, Parks Canada and other parties. However, given this data a recommendations could then be made to the Panel.

7.2 The CP Rail Proposal

It is understood that the current C.P.Rail proposal is based on PBQD's concept 3 with the intake shaft location 2 approximately 1,200 ft to the east of Highway No. 1 and approximately 900 ft above the highway in a group of trees and the West slope of Avalanche Mountain.

Our cycle diagram No. 1 summarizes the cooling fan and purging fan capacities, cycle times and ventilation exhaust and intakes from the various portals and shafts.

We endorse this concept as a technically viable scheme which will provide a close to optimum tunnel traffic capacity with a cycle time of 38-49 minutes for the heaviest coal trains.

Portal doors and mid-tunnels doors will be provided together with fans at the east portal and the foot of the shaft. Electric power is stated to be provided by a 13.8 KV feeder from a proposed master substation at the east portal. Distribution will be using a 4160 volt system. In addition there will be a motor control centre located at both fan installations together with control systems.

To accommodate the possibility of a loss of power supply to the tunnel a standby diesel generator system will be provided for a 4160 volt electric supply. PBQD (1) state that this unit will capable of operating 1 purge fan and 1 cooling fan sequentially. PBQD reports that in the event of on-site standby power only, the cycle time will be increased to 46 minutes. By our calculations it may be necessary to operate various combinations of two fans concurrently rather than sequentially as stated in the PBQD report to avoid very long cycle times. The standby power capacity to meet this demand needs to be clarified. In addition there will be an auxillary diesel driven generator. It is not stated, but we presume that the control system centre and standby power facilities will be located at the east portal.

The proposed ventilation shaft at location 2 on Avalanche Mountain will outcrop through approximately 120 ft of highly fractured and broken phyllite. This will no doubt require shaft liners for stability of the shaft. The possibility of progressive creep of the slope causing accummulation of load on the shaft from this layer will need to be addressed. In addition the requirements for avalanche protection will no doubt require a fairly substantial avalanche protection structure, possibly along the lines of the snow sheds currently in use. The construction of such a facility will require careful planning but our preliminary engineering assessment suggest that various technical options are possible to handle all of these factors.

The emmission quantities quoted by PBQD 1980 (1) appear to be generally conservative. Our recommended values are given in the cycle diagrams for each train type.

7.3 Alternative Concepts

We agree that Concept 1 presented by PBQD will not give a cycle time less than 52 to 60 minutes which would impose a significant constraint on CP Rail's Operations.

Concept 2 is an intermediate case without the advantages of Concept 3 but with more extensive shaft exhaust.

The initial version of Concept 3 with the shaft at Location 1 results in a cycle time of about 40 minutes. The soft ground conditions are much deeper (10) than at Location 2 and therefore shaft construction costs may be somewhat higher.

We suggest that Concept 4 involving purging from the west portal be given consideration. This will require examination of the trade offs between minimization of the exhaust from the shaft versus exhaust from the west portal over the mainline track adjacent to Highway No. 1. Cycle times would be the same as Concept 3.

The possibility of concept 5 using the tunnel modified locomotives is stated by CP Rail to be unacceptable due to problems with the use of these locomotives and other parts of their system. However, if upon re-examination these locomotives were acceptable then it would offer the possibility of eliminating exhaust from the shaft. Again, cycle times would be the same as Concept 3.

Concept 6 is basically an operational variant which would require CP Rail to exhaust from the east portal whenever possible and thus reduce the emissions from the shaft. However, this would be a best short term solution since as the traffic volumes build up it will become increasingly necessary to use the fans at the mid-tunnel shaft.

Concept 7 involving the possible delay in shaft construction awaiting a firm build up in traffic forecasts or possible electrification before the shaft is needed it does not appear to be a viable option in terms of the stated traffic forecast and the need for flexibility in load carrying capability earlier on in the use of the tunnel.

Concept 8 involving connections to the Connaught Tunnel or exhausting close to the existing Connaught west portal appears to be technically feasible and offer a range of potential benefits including a cycle time of 34 minutes but has considerable cost implications. We recommend that the costs and benefits of this option be examined more carefully.

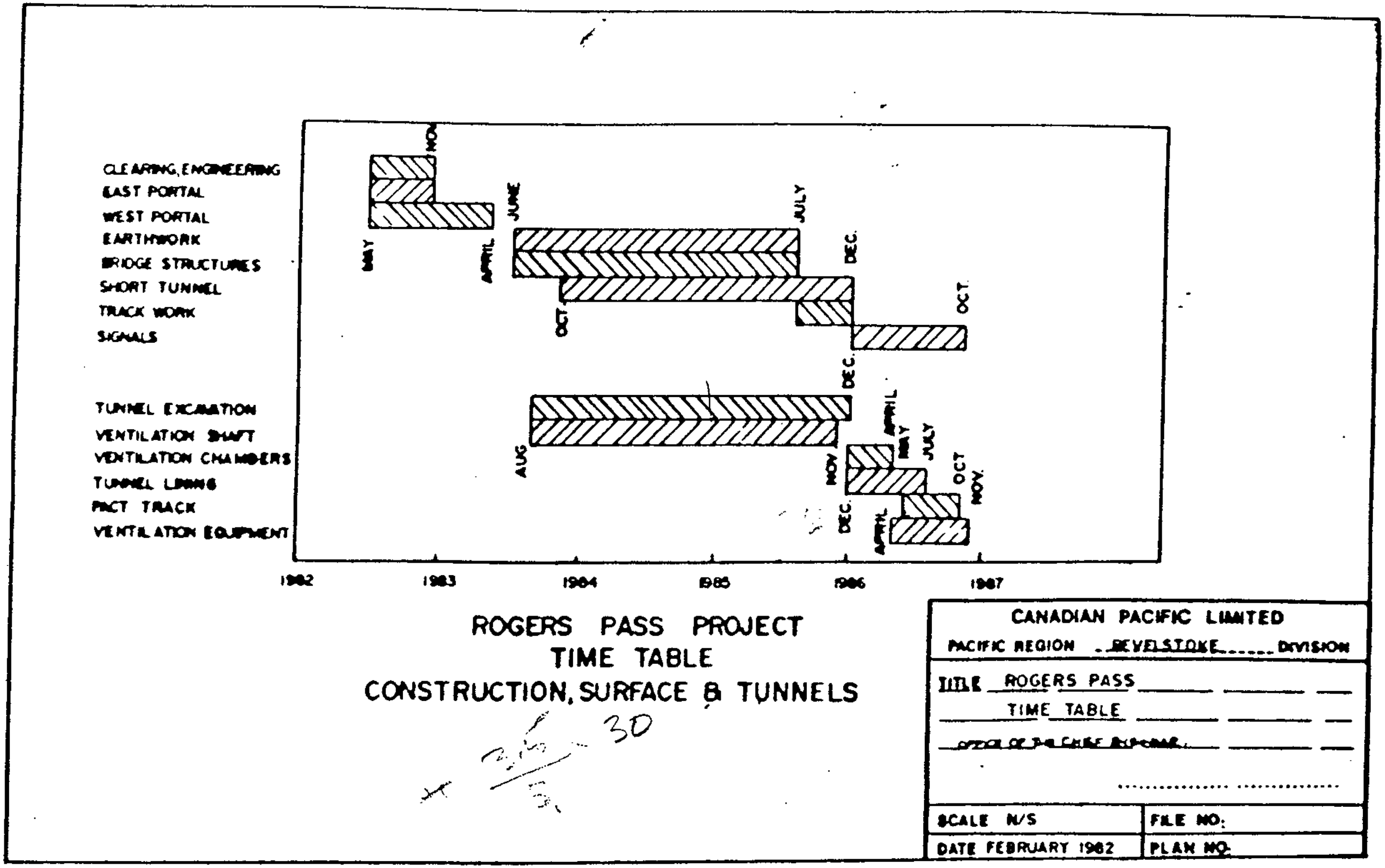


FIGURE 11: C.P. RAIL TIMETABLE

Concept 9 involving the use of scrubbers or precipitators does not appear to be appropriate.

7.4 Immediate Construction Requirements

CP Rail in their letter dated March 9, 1982 summarize their proposed 1982 construction season activities. We have reviewed these and the CP Rail Rogers Pass Time-table Figure 10, to determine the impact of further examination of any of the ventilation system alternatives.

Activity 1 - Surface Route

This is not affected by the ventilation system design

Activity 2 - East Portal Area

We have not identified possible changes to the ventilation system which would affect the east portal area layout. Finalization of the facilities layout will determine the extent of these works.

Activity 3 - West Portal Area

If concept 4, involving exhaust through the west portal is to be adopted, then there may be some modifications to the final concrete structures at the west portal. However, the initial construction of the Highway 1 detour and the preparation of access to the portal will likely not be affected.

Other Activities

The construction of the ventilation shaft, if required, and tunnel excavation is not scheduled until August 1983.

Engineering design to achieve this schedule is planned for the period May to November 1982. This is consistent with the proposed decision by the Minister of the Environment on the Panel's findings on May 1, 1982.

In summary, it is our opinion that the 1982 construction activities as detailed by C.P.Rail on March 4, 1982 (4) should be allowed to proceed since they will not be significantly affected by selection of any of the alternative ventilation systems discussed in their brief.

KLOHN LEONOFF LTD.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
R. G. CHARLWOOD

R.G. CHARLWOOD, Ph.D., P. Eng.
Manager, Special Services Division

REFERENCES

1. "Rogers Pass Tunnel Concpetual Ventilation Study", for Canadian Pacific Railway, Parsons Brinckerhoff Quade & Douglas, Inc. New York, April 1980.

2. "Rogers Pass Tunnel Ventilation Studies" For Canadian Pacific Railway, Parsons Brinckerhoff Quade & Douglas, Inc. New York, October 1981.

3. Press Releases: CP Rail's Rogers Pass Project, Minister Environment Canada, March 4, 10 and 17, 1982.

4. Letter Report: Rogers Pass Project, CP Rail, March 4, 1982.

5. Leeson, Bruce F., "Rail Grade Improvements - Rogers to Cougar Creek", For CP Rail, Parks Canada, Revelstoke, B.C. December 16, 1981.

6. "Initial Environmental Evaluation: CP Rail Improvements Rogers to Cougar", prepared by LGL Limited, for CP Rail, January 1981.

7. "Revised Air Quality Assessment - Rogers Pass Tunnel" For CP Rail Ltd. ESL Environmental Sciences Ltd., Vancouver, B.C., December 1981.

8. Decision Candian Transport Commission, March 9, 1982.

9. Gerath, R.F. and G.F. Buck. "Preliminary Geotechnical Evaluations: Surface Grade, Roger's Pass Revision", For CP Rail, Thurber Consultants Ltd. Victoria, B.C., November 30, 1978.

10. Maber, C.T., K.W. Savigny and G.F. Buck. "Rogers Pass Tunnel - 1980 Geotechnical Investigation" For CP Rail, Thurber Consultants Ltd., January 30, 1981.

REFERENCES
(Continued)

11. Charlwood, R.G., J.R. Huggett and P.E. Salt, "Tunnel Ventilation Systems for the British Columbia Railway", BHRA Fluid Engineering - 4th International Symposium, The Aerodynamics and Ventilation of Vehicle Tunnels, York, England, March 23-25, 1982.

12. Charlwood, R.G., J.R. Huggett and J.R. Pringle, "The Design of Ventilation Systems for Long Railway Tunnels - A Case Study for the Canadian National Railway", submitted in draft to Bulletin of America Railway Engineering Association, March 4, 1982.

13. Hobbs, J.R., R.A. Walter, T. Hard and D. Devoe, "Train Generated Air Contaminants in the Train Crew's Working Environment", U.S. Department of Transportation, Cambridge, HA, February 1977.

14. Berger, L.B. and L.H. McGuire, "Observations on the Use of A Diesel Freight Locomotive through A Railway Tunnel", U.S. Depart. of The Interior & Bureau of Mines, June 1946.

15. Heuer, R.E., "Anticipated Tunnelling Conditions - Rogers Pass Tunnel, British Columbia", for CP Rail, Special Projects, Report 8108, September 1981.

16. Fox, J., Chief Engineer, CP Rail, Telephone discussion with R.G. Charlwood, April 7, 1982.

17. Daugherty, R.L., "Piston Effect of Trains in Tunnels", Transactions of the ASME, February 1942, pp. 77-84.

18. Nelson, C.G., "Design Criteria for Railway Tunnel Ventilation Systems", ASHRAE Transactions HA-77-3, No. 2, New York, 1978, pp. 374-391.

19. Aisicks, E.G. and Danziger, N.H., "Ventilation Research Program at Cascade Tunnel, Great Northern Railway", American Railway Engineering Association, Vol. 71, Bulletin 622, September-October 1969.

REFERENCES
(Continued)

20. a) 1st International Symposium on the Aerodynamics and ventilation of Tunnels. BHRA Fluid Engineering, Cranfield, England, 1973.

b) 2nd International Symposium on the Aerodynamics and Ventilation of Tunnels. BHRA Fluid Engineering, Cranfield, England, 1976.

c) The Aerodynamics and Ventilation of Vehicle Tunnels, A State-of-the-Art Review and Bibliography, BHRA, 1976.

d) 3rd International Symposium on the Aerodynamics and Ventilation of Tunnels, BHRA Fluid Engineering, Cranfield, England, 1979.

e) 4th International Symposium on the Aerodynamics and Ventilation of Tunnels, BHRA Fluid Engineering, Cranfield, England, 1982.

KLOHN LEONOFF
CONSULTING ENGINEERS

Our File: VA 2995 April 12, 1982

Government of Canada
Environmental Assessment Review
Hull, Quebec
K1A 0H3

Attention: Mr. Guy Riverin,
Panel Secretary
Rogers Pass Environmental Assessment Panel

Rogers Pass Tunnel Ventilation System Review

Dear Sirs:

We have pleasure in submitting 12 copies of our brief on the above topic, together with one loose copy for further duplication and distribution by the Panel as required.

I will attend the Panel meetings in Vancouver and Calgary on April 13 and 16 to present a summary of this brief and advise the Panel.

I trust that our brief meets the Panel's requirements.

Respectfully submitted,
KLOHN LEONOFF LTD.

R.G. Charlwood, Ph.D., P.Eng.
Manager, Special Services Division

RGC/sdm

Klohn Leonoff Ltd. 10180 Shellbridge Way, Richmond, B.C. Canada V6X 2W7 • Telephone: (604) 273-0311 • Telex: 04-355520