Canadian Transportation Research Forum
Le Groupe de Recherches sur les Transports au Canada

PROCEEDINGS OF

SEVENTEENTH ANNUAL MEETING

CANADIAN TRANSPORTATION RESEARCH FORUM

Volume 1

MONTREAL, QUEBEC   MAY 26, 27 & 28, 1982

Compiled by: R. Lande
&
K. Tansey

PROTOTYPE IN CANADA: AN ENGINEERING DEFINITION STUDY OF AN ELECTRIC PUSHER LOCOMOTIVE OPERATION ON THE CARTIER RAILWAY COMPANY

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ABSTRACT

The Cartier Railway is a 447 km long railway originating at Mount Wright and Lac Jeannine in the north with the two branches joining and the main line carrying iron ore and concentrate south from Mount Wright and Lac Jeannine to Port Cartier on the St. Lawrence River.

The engineering definition study is the first phase of a project which foresees the operation of two prototype electric pusher locomotives on the Cartier Railway heavy grade section of line between TUP Siding and Lac Jeannine. The proposed project provides a demonstration of catenary construction in Canadian conditions based on the best choice of two alternative designs, a unique power supply from a small hydro-electric generating plant that is isolated from the Province-wide hydro grid, power conditioning including phase balancing techniques as might be required in areas of Canada where power supply is sparse and an opportunity to demonstrate techniques for the conversion of railway signal systems and telecommunications systems for compatibility with electrification. This study project will also provide cost background and an appraisal of the ability of Canadian pole line hardware companies to manufacture the components needed for the project.

FOREWORD

The Transportation Development Centre of Transport Canada has funded an engineering study for an Electrification Demonstration Project with the Cartier Railway Company. The study was conducted by Canadian Pacific Consulting Services Ltd. and covers train operations and motive power, traction power system, catenary system, signalling system, trackside communications and analysis of electromagnetic interference.

PURPOSE OF STUDY

The purpose of the study was to obtain a design and costs of electrifying a section of the Cartier Railway for a pusher operation between TUP Siding and the Lac Jeannine yard, a distance of approximately 13.2 km.

Including the sidings and back tracks the electrified distance involves some 19.2 km of trackage.

Upon implementation, this portion of the electrified railway will be used to:

- assess the reliability of the system in a harsh climate, under heavy tonnage operating conditions;
- examine alternatives in developing a least cost design which could have application in the rest of Canada;
- collect and analyse data on costs under actual operating conditions.

Subsidiary objectives will be to:

- expose Canadian industry to the hardware requirements of railway electrification to the end of establishing Canadian manufacture and supply;
- demonstrate the practicability and desirability of railway electrification as a viable alternative to the use of fossil fuels.

<u>GENERAL DESCRIPTION</u>

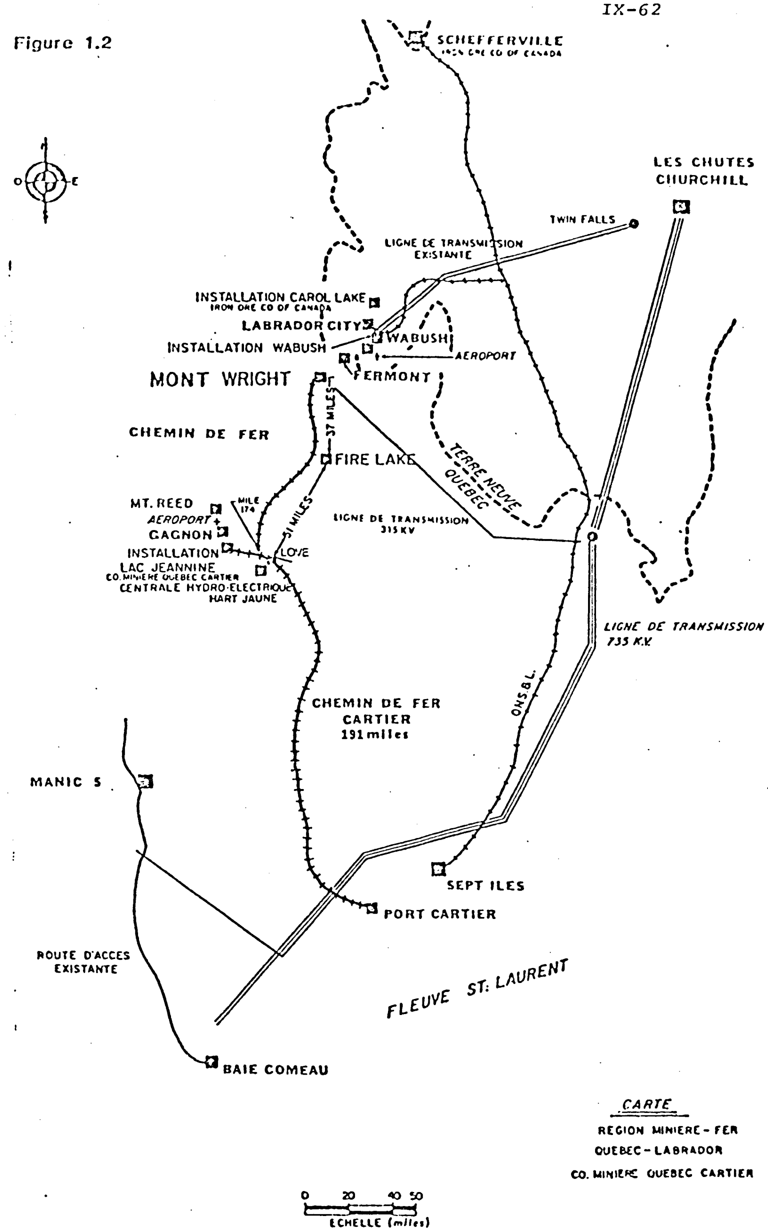
The Cartier Railway Company is an affiliate of La Compagnie Minière Quebec Cartier and both are subsidiaries of United States Steel Company.

It extends for some 447 km from Port Cartier in Northeastern Quebec northward to Mount Wright and Lac Jeannine.

Crude ore is hauled from the mining operations in the Fire Lake area to a crusher at Lac Jeannine and the resulting concentrate is hauled from Lac Jeannine to the port facilities at Port Cartier (see Figure 1.2).

The grade on the railway from Lac Jeannine to the south was designed to aid southbound loads with a grade from Lac Jeannine to TUP Siding being 1.35%. With the depletion of the ore body at Lac Jeannine it became necessary to go farther afield for crude ore, to Fire Lake and Mount Wright for example with a result that trains have to negotiate this 1.35% section between TUP and Lac Jeannine. This has necessitated the introduction of a pusher operation of three 3000-hp locomotives

Figure 1.2



at TUP Siding to aid the two 3000-hp header locomotives move the 75 to 100 car consist up the grade to Lac Jeannine.

For the demonstration project it is intended to replace the three 3000-hp diesel pusher locomotives with two electric locomotives.

La Compagne Miniére Quebec Cartier obtains its power from the 50 Foot Falls generating plant of the Hart Jaune Hydro Electric Power System which it owns and operates. This plant is in the proximity of the section proposed for electrification and will provide the power for the catenary from the Lac Jeannine substation.

ROUTE DESCRIPTION

Figure 2.1 shows the route from TUP Siding to Lac Jeannine. It comprises some 13.6 route kilometers and has a grade of 1.35% rising from TUP towards Lac Jeannine. Photographs 1 to 7 illustrate the terrain to be traversed.

As can be seen there is little indication of road access, however there is a crossing of a bush road at south TUP and access from the same road at Lac Jeannine.

Single track is involved throughout except at the sidings.

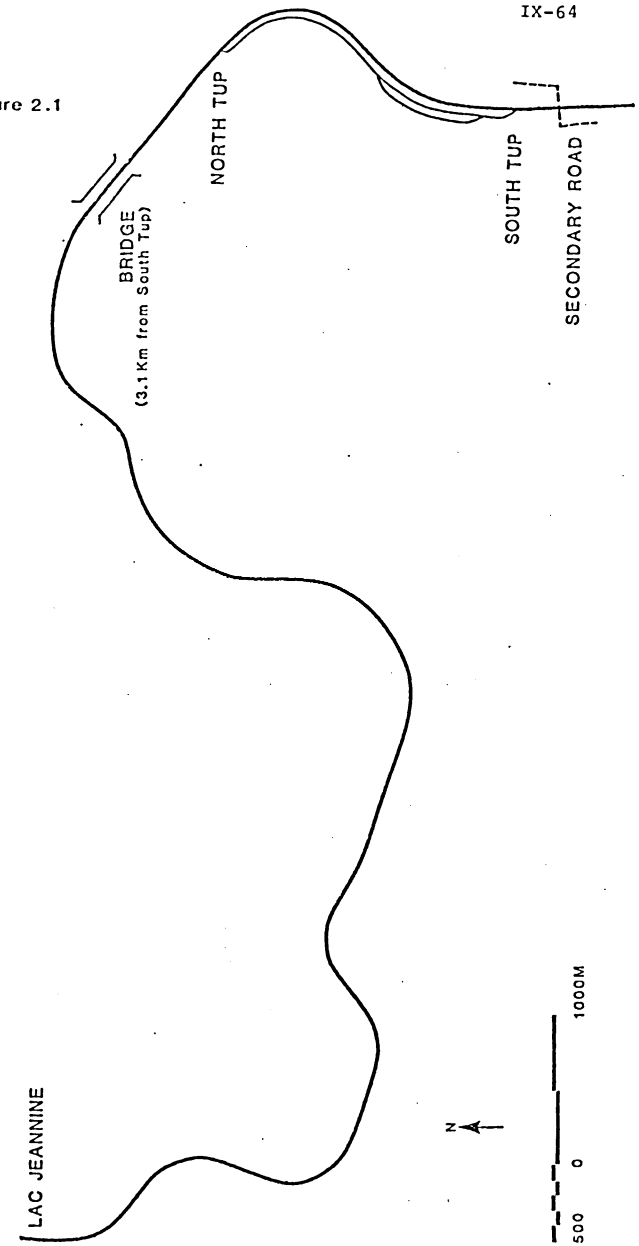
TRACKAGE TO BE ELECTRIFIED

Electrification will start some 80 metres south of the south switch at south TUP and continue northward to a point approximately 300 metres north of the south switch at Lac Jeannine, a distance of approximately 13.6 km. At south TUP all three tracks (mainline, siding and back track) will be electrified. The extension of 80 metres south is to permit the connection of the pusher electric locomotives. At the Lac Jeannine end, electrification is extended some 300 metres south of the south switch to permit decoupling of the pusher.

TRAIN PERFORMANCE SIMULATIONS

Train performance simulations were performed using a computerized train performance calculator to determine energy consumption, tractive effort and power requirements. From these catenary current profiles, annual energies and load factors were determined.

Figure 2.1



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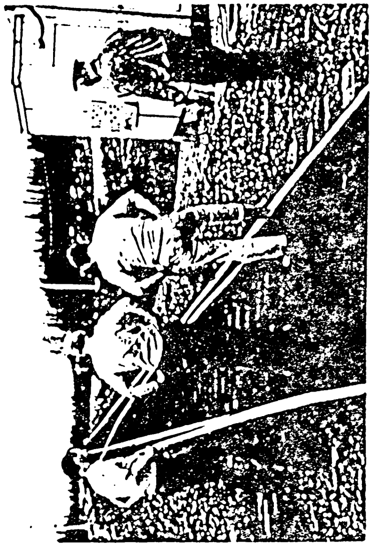

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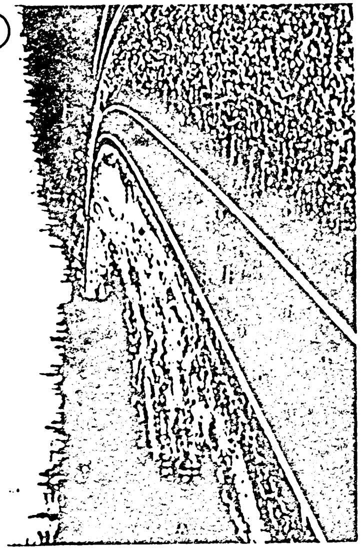

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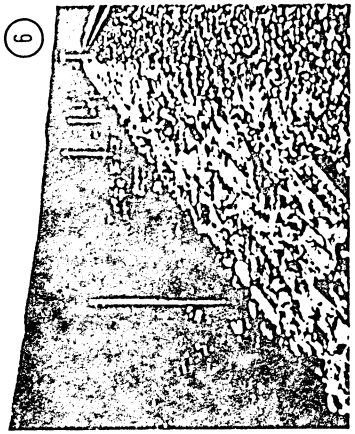

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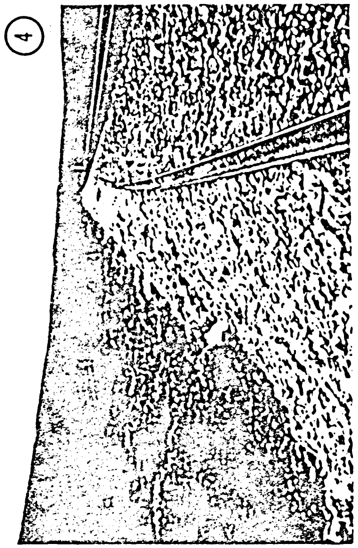

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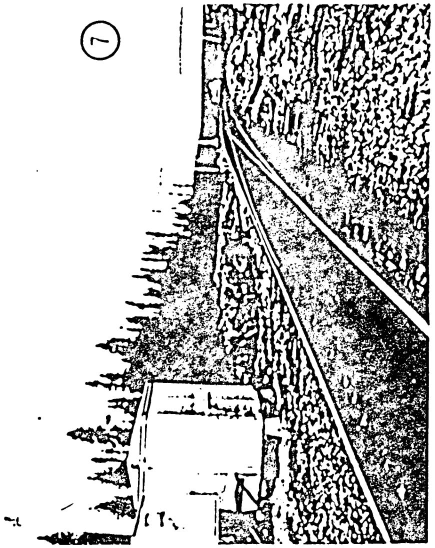

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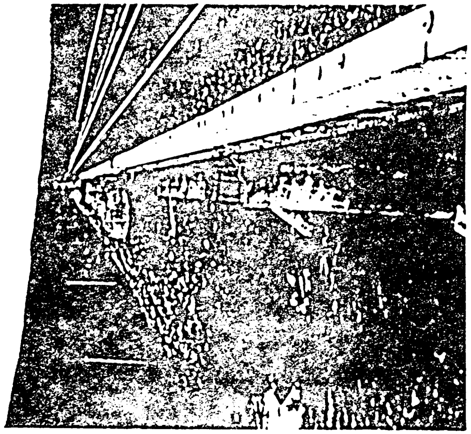

MOTIVE POWER

The electro-motive division of General Motors have agreed in principle to make available a GM6C and a GM10B electric locomotive for the pusher demonstration tests. These are nominal 6000-hp and 10,000-hp units respectively and will be used to replace the three pusher diesels.

Minor maintenance on the locomotives will be conducted at Lac Jeannine and should major maintenance be required the locomotives will be deadheaded to the shops at Port Cartier.

TRACTION POWER SYSTEM

A 13.8 to 25/50 KV step-up transformer rated 10MVA with phase balancing equipment and harmonic filters will be installed at the Lac Jeannine substation. The 25KV 60 hertz single phase feed for the railway will be extended on a 25KV line for approximately 1 km to a point near the south switch at Lac Jeannine at which point it will be connected to the overhead system. Current return will be through the rails.

The generators at the Hart Jaune generating plant will not withstand the large single-phase unbalanced traction load. Several methods of phase balancing were considered among which were rotating convertors, solid state convertors, scott transformers, and static phase balancer/compensator.

While the best technical solution might have been a solid state convertor its costs for these trials was considered prohibitive at some $700,000. The solution selected was a single stage phase balancer comprising one reactor and one capacitor. The principles of operation are shown on Figure 3. The reactor across phase AC and the capacitor across phase CB balance the load across AB.

CATENARY SYSTEM

The design of the catenary system has been prepared taking into account type and speed of trains, electrical loading requirements and environmental conditions.

Design will be for operation at 25KV capable of upgrading to 50KV by changing out the insulators. Subcontracts were let to SJ (Swedish State Railway) and Electrack for the purpose of obtaining designs which could be compared structurally and economically and also for completeness since more was asked of one contractor than of the other.

FIGURE 3

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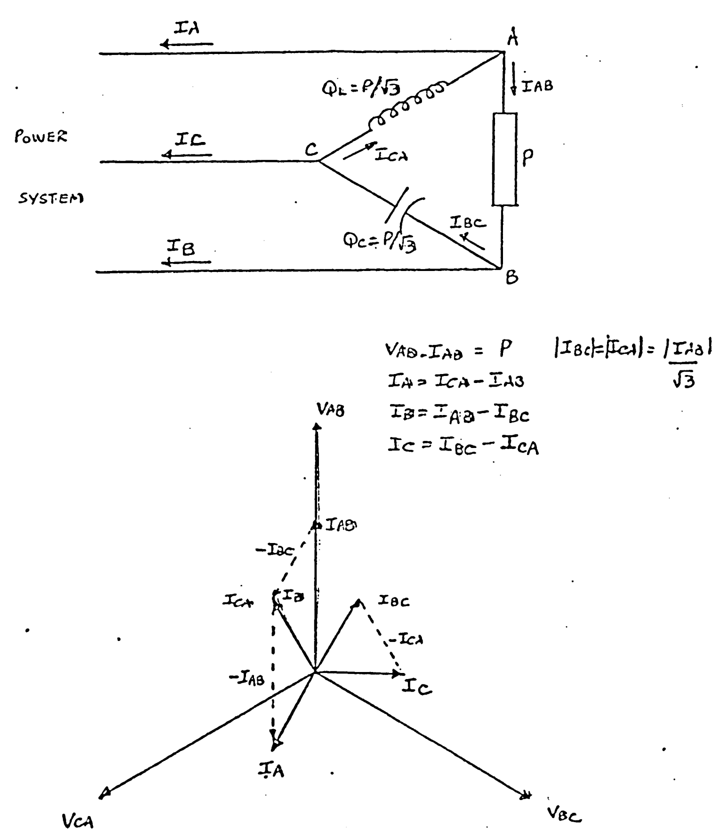
PRINCIPLES OF OPERATION OF PHASE BALANCER



A brief summary of the principal data for the SJ and Electrack proposals is shown in Tables 1 and 2.

Some of the differences between the designs are as follows:

1. The SJ construction proposes to exclude the steady arm which is part of the Electrack design.

2. SJ propose a 50 mm^2 bronze wire for the messenger while Electrack propose a 4/0 nineteen strand hard drawn copper wire.

3. SJ wire tensions are 9.8 kN for both the messenger and contact wires which are lower than Electrack's 20 kN for the messenger and 13 kN for the contact wire.

4. SJ use a rigid truss portal construction for multi-track spans while Electrack use headspans of cable to suspend the catenary insulator.

5. SJ layout requires 292 steel poles compared to Electrack's 350 steel poles.

6. "Stagger" or Zig-Zag of the contact wire for equalizing wear on the pantograph, for SJ is plus or minus 400 mm and for Electrack is plus or minus 225 mm maximum.

SIGNALLING SYSTEMS

The objective in respect to signalling in this project is to develop the modifications to the existing system which are required to make it fully compatible with the 25KV 60 Hertz electrified operation. No changes are necessary in the location of wayside signals or to the aspects displayed under different conditions of track occupancy.

The two main elements of the present signalling system to be addressed are the track circuits and the wayside control for cabling. Track circuits represent a particular problem since in electrified territory the electrical properties of the rails must be shared by both traction and signal currents.

All the existing track circuits are the direct current type.

TABLE 1

Principal Data - SJ Design

Catenary	-	simple, pre-sagged
Catenary tension	-	9.8 kN
Contact wire tension	-	9.8 kN
Maximum span	-	70 m
Catenary wire	-	50 mm^2 Bronze (CuMg)
Contact wire	-	100 mm^2 Copper
Drop Wire	-	20 mm^2 Copper
Earth Cable	-	99 mm^2 FeAl, (Pigeon)
Stagger	-	±400 mm
Tensioning	-	common counter weight for both catenary and contact wires
Insulator Type	-	rod insulator
Encumbrance	-	1300 mm
Contact wire pre-sag	-	60 mm
Tension Section Length (maximum)	-	1400 m
Contact wire height	-	7000 mm
Clearance (mast face to centreline of track)	-	3650 mm
Electrical Clearances	-	UIC 606
Temperature	-	-40°C to plus 35°C
Wind Loading	-	1 kN/m^2 plain surface
Pantograph upward force	-	70N ± 5N
Speed (maximum)	-	100 km/hr
Standards	-	UIC 606 UIC 870 DIN 48200 SEN 3601

TABLE 2

Principal Data - Electrack Design

Catenary	-	simple, pre-sagged
Messenger Tension	-	20,000 N
Contact Wire Tension	-	13,000 N
Maximum span	-	73 m
Messenger	-	4/0 19 STR HD Cu.
Contact Wire	-	4/0 Grooved HD Cu. (107 mm^2)
Ground Wire	-	3/0 ACSR Pigeon (99 mm^2)
Stagger	-	±150 mm tangent track, ±225 mm curved track
Tensioning	-	common counterweight for both messenger and contact wire
Tension Section Length	-	1600 m maximum
Contact Wire Height	-	7 m
Clearance	-	3.8 m (face of mast to centreline of track)
Electrical Clearances	-	to 50 kV requirements
Insultation levels	-	to 50 kV requirements
Temperature	-	$-50^{o}C$ to plus $32^{o}C$
Wind loading	-	56 mile per hour on projected area with 1/2 inch of radial ice
Contact Wire Deviation	-	Permitted deviation = Maximum Deviation - Fixed Allowances = 838.2 - 425.0 = 413.2 mm

One of the primary objectives of this electrification project is to examine alternatives in development of a least cost effective design that could have applications in the rest of Canada. Several alternatives with respect to track circuits which conform to these requirements were considered. The recommendation is to combine these alternatives in one system using each to its greatest advantage. The existing and proposed layout of track circuit is shown on Figure 5.6.2. The phase selective circuit is proposed for use in the single track section between TUP and Lac Jeannine (circuits DT, ET and FT).

The TRU-II type is proposed for use in the OS circuits, CG and GT.

Both the phase selective and TRU-II are both double rail track circuits with the result that broken rail protection is achieved.

A single rail DC circuit is proposed for use in electrified zone south of the following point at TUP north. The three track circuits involved are HT, JT and the OS circuit at TUP south.

A single phase 100 hertz power line is required to carry signal current for the track circuits between TUP and Lac Jeannine for the TRU-II and phase selective types. It is proposed that the existing open wire communications pair will be employed for this purpose.

TRACKSIDE COMMUNICATIONS

The trackside communications between Lac Jeannine and TUP siding consists of a paralleling pole line approximately 50 feet distant from the centreline of track. In addition to the voice circuits on the physical circuit three carrier systems in the frequency range of 7KHz to 220KHz, providing some 16 voice channels, are derived.

On an AC electrified railway, interference to the communications and signal circuits is caused by the heavy track current and traction contact wire and supporting catenary current, and its partial return through earth, as well as to harmonics generated by the thyristor control of the locomotive. This interference can be due to both electric and magnetic induction, but the latter dominates.

TRACK CIRCUIT TYPES:
CT. GT. - MODEL TRU II
DT. ET. FT. - PHASE SELECTIVE
HT. JT. KIT. - SINGLE RAIL DC

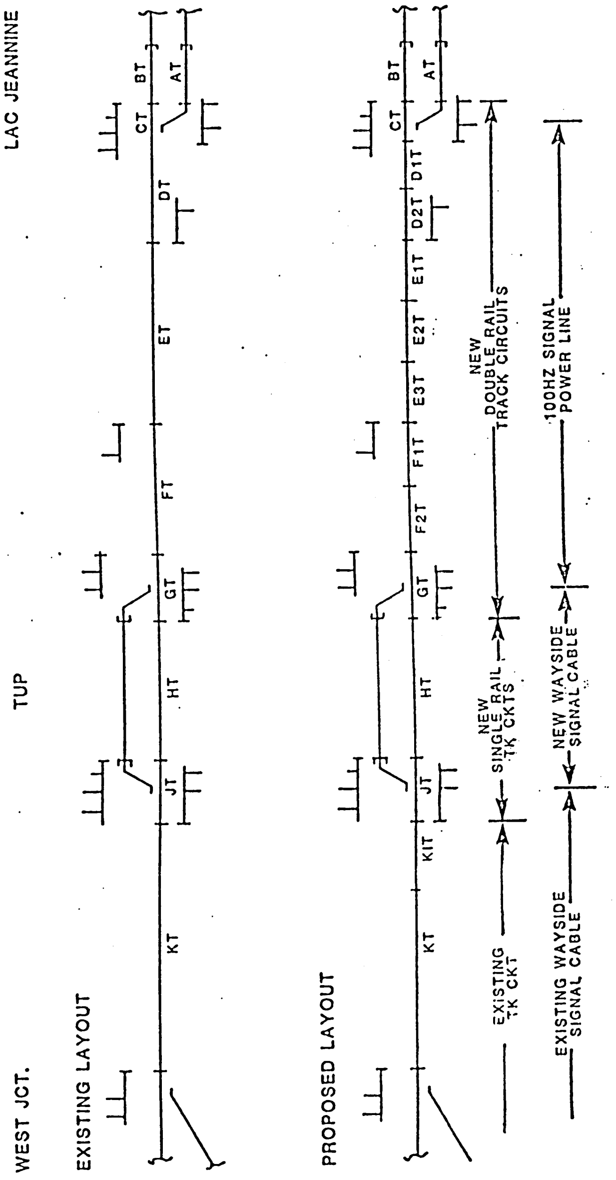


Figure 5.6.2
EXISTING AND PROPOSED LAYOUT OF TRACK CIRCUITS
West Junction to Lac Jeannine
Quebec Cartier Mining Co.
December 1981

Calculations indicate that the voice path of the paralleling open wire facilities will be seriously impaired in the presence of the generated EMI and considerable doubt exists as to the ability to operate carrier systems above the voice path. It is generally agreed, that open wire facilities in the presence of electrified railway interference must be replaced by shielded cable, radio systems or fibre optic systems.

In this particular instance the shielded cable option was discarded in view of the rocky terrain which would necessitate an aerial installation and maintaining the existing pole line and because costs in excess of $1 million can be expected. Further if cable was to be considered it would seem more appropriate to select an EMI immune system such as fibre optics. Booster transformers would also be required for the shielded cable installation, increasing the costs and catenary impedance.

The radio option is feasible but in this instance more costly in terms of the additional tower heights required.

The recommendation was to replace the communication facilities with a long wave length fibre optic system operating at 6.3 Mbs. A four fibre cable lashed to the ground wire is proposed. It will be equipped with a standard PCM channel bank of 48 channel capacity equipped with 24 channels. The fibre optic system will be provided on a one for one protective basis i.e. one operating and one hot standby.

Because this is a demonstration project it is proposed also to install a 3 km length of current carrying return wire and a booster transformer. This will then be evaluated as to effectiveness for mitigating induction into open wire and cable parallels.