# Edmonton Transit's Light Rail Transit Experience

JOHN F. NICOLL

The City of Edmonton in Alberta, Canada, operates an integrated transit network that uses 24 light rail cars in conjunction with 530 buses to meet peak hour demand. The light rail transit (LRT) system, which opened in 1978, is still being expanded. In the 10 years of the system's operation, the staff has solved a variety of problems that ranged from the tracks not built to standards that yield a comfortable ride for LRT passengers to excessive rail wear to confusing signals. Edmonton's severe weather presents the staff with other, continuing problems from ice in the switch points in winter to expansion ripples in the rails in summer. Also, a railroad tunnel used by light rail vehicles is subject to flooding and has given the transit staff experience dealing with track washouts. Procedures for dealing with these and other problems and equipment are outlined.

EDMONTON TRANSIT IS OWNED and operated by the City of Edmonton and operates 530 buses and 24 light rail cars in the peak hour in an integrated transit network. The transit system is supported 50 percent by the farebox revenue and 50 percent by the local property tax and a provincial operating grant of $8.00 per capita. Light rail transit (LRT) capital construction is funded 75 percent by the Province of Alberta and 25 percent by the City of Edmonton debentures.

Edmonton opened the LRT line in April 1978. The line opened with two underground and three surface stations. The track ran for 6.9 km, 2 km underground and 4.9 km on the surface, on a railroad right-of-way. The system began operating with 14 Duewag RTE 1 articulated cars. The surface right-of-way is leased from the Canadian National Railway; however LRT does not share the railroad's tracks. The Edmonton is unique to LRT in that it

*Edmonton Transit, Century Place, 13th Floor, 9803 102A Avenue, Edmonton, Alberta T5J 3A3, Canada.*

is one of the few systems in North America that goes underground in the city center.

Since its opening, the system has expanded 2.2 km northward into a residential district, Clareview, and further west into the downtown area. An additional 23 cars have been purchased. Construction is under way on an extension to the Government Centre and on to the university. The extension to the university will involve crossing the river and another section of tunneling.

## TRACKWORK

We started with a definite heavy rail bias in the design of the LRT system. We learned the subtleties of LRT operation and construction and the differences between heavy rail and LRT. Edmonton now boasts engineering companies that are at the forefront of the state of the art in LRT design and construction.

Edmonton's surface trackwork consists of conventional wood tie, cut spike, and ballast. Underground installations of direct fixation use the pandrol clip and the landis plate. The new trackwork will be direct fixation on concrete plinths, designed by a local engineering firm. One of the initial difficulties was that the track was not built to the standard that we have found is necessary for a comfortable ride for LRT patrons. Gauge varied greatly on the system, causing a large amount of car hunting from side to side as the car moved from one rail to the other. In some places the gauge of the track was out of tolerance by 12.5 mm to 15 mm (1/2 to 3/4 in.).

A difficulty we still have is with the quality of the ballast used on the line. The ballast has very few crushed faces and is often small rock, making it more like a bed of marbles at times than good stable ballast. As a result it is difficult to maintain track line and cross level, qualities that also affect the ride of the car. New ballast specifications include substantially larger rock with a greater percentage of crushed faces.

We were not satisfied with the original quality of the trackwork and in subsequent projects we carefully monitored the work and the tolerances used. We considered concrete ties for our Clareview extension. However, at the time the use of concrete ties was still in its infancy for LRT and there was a relatively high price difference. We decided to try the standard tie and ballast construction again, using better ballast and paying more attention to the quality of the construction. The quality of the track built was significantly better than what we had before, but obtaining the tight tolerances that LRT requires was still a problem with the wood tie. It was still not possible to achieve a gauge tolerance better than 6 mm using the standard wood tie and spike.

A major effort was put into scheduling the activities on the track area so that one contractor did not destroy or damage the work of another. This time we built the road bed and then brought in the ductline construction activities and catenary mast base construction contractors. When these contractors were finished, the track area was made available to the track contractor. Once the track was laid, no one was allowed on the track unless it was on track-mounted equipment. This paid dividends as there was no damage to work already done.

Rail wear was one of the first problems we had to contend with. We experienced rapid and aggressive wear on the outer rail of the 150 m radius curve. This curve was also wide in gauge by up to 3/4 in. The gauge widening helped accentuate tracking difficulties of the cars in the curves and aggravated rail wear.

The rail in this curve was regular carbon steel. In a matter of months a very course type of wear started at the gauge corner of the high rail. The metal was being stripped from the rail in shavings and was dropping to the floor. Eventually enough metal had been removed from the gauge corner of the upper rail to make the rail conform to the inverse shape of the wheel. At this time the wear on the upper rail slowed down somewhat, but was replaced by severe corrugation of the lower rail. This all took place within a period of 3 months. We tackled the corrugation problem by surface grinding the rail with a portable surface grinder used for grinding rail welds. Because the curves were not that long, it was possible to accomplish this task manually by operating several night shifts every so often.

We also improved our lubrication techniques. Initially we had an automatic rail lubricator installed. But getting it to work properly was impossible. Most of the grease was thrown to the track floor rather than being applied to the rail. We eventually discarded the automatic lubricator in favor of a system of manual greasing. As we improved the lubrication of the rail we observed an improvement in the condition of the upper rail. Instead of wearing very coarsely, it started to take on a polished appearance. The rail was starting to work harden.

In dealing with the initial wear problem we assumed that the problem was too excessive a side force on the rail, so we reduced the speed of the trains through the curves, a move that would ultimately prove retrogressive. We designed a restraint rail system for the lower rail that would contact the back of the wheel. The restraint rail, which had a replaceable wear bar, was to help guide the trucks of the car through the curves and to help steer them. Pulling the lead wheel down was intended to steer the truck into the curve and adopt a less cutting approach to the curve.

The restraint rail was a success to a degree. With it in place we could allow higher speeds in the curve. With the higher speeds there was a greater lateral force on the car pushing the car against the upper rail. This increased force helped the trucks to negotiate the curve. By reducing the angle of attack of the front wheels approaching the rail, the tendency of the wheel to cut the rail was reduced.

With the higher speeds and the improved lubrication the condition of the upper rail improved. The wear bar on the restraint rail was barely touched and has lasted quite well. However, by this time the upper rail had up to ½ in. wear on the gauge face, approaching the wear limits we had established. We replaced this rail in 1983 with chromium alloy rail and have had much better success with it.

We have learned that proper lubrication is essential in developing and maintaining a smooth work-hardened surface on the rail. Without lubrication rail wear quickly becomes very coarse, which is hard on the rail and hard on the wheel flanges. We had a derailment that was caused by a situation in which the rough flanges of a wheel negotiating a tight curve in the yard created enough friction to make the wheel climb out of the curve. This rough flange wear was due to a breakdown in the quality of the lubrication of the rail in the curves and the corresponding rough rail surface.

A similar situation occurred recently on one of our number 6 turnouts due to lack of lubrication. The manual lubrication rate fell behind on a long weekend. A car that recently had its wheels turned was being taken for a test run. The center bogie, which is much lighter than the powered bogies, derailed on the closure rail of a number 6 switch. The friction between the newly cut wheel without any lubricant and the dry closure rail was enough to cause the wheel to climb the rail as if it were a ramp. We have revised our procedures to make sure that the switch points are adequately lubricated and even more so if a car with a new set of wheels or recently turned wheels is to be released into service for the first time.

Edmonton's extreme weather conditions also presented problems. The highest temperature that we have recorded on the rail in the summer is 60°C. We can get temperatures as low as –40°C in the winter. We had a fair amount of difficulty due to freezing ice and snow in the switch point area when we used hot air switch point heaters. We have discontinued using heated forced air and rely instead on the air curtain type of switch blower. The energy requirements are less, the frost heave damage to the subgrade and alignment is less, and the blowers are more effective at keeping the switches clear of snow.

In the summer the solar heating of the rail and the high ambient temperature create expansion ripples in the rail. The continuous rail expands, and although it is held in place by the ballast, it still deviates from a true line and gauge. Our car ride deteriorates in the summer with rail expansion.

We have had two instances of rail pullaparts in 10 years of operation. The pullaparts occurred at weld locations when the temperature was below

−20°C. The remedy is to pull the rail back together with a 120-ton hydraulic puller and install a bolted joint. Then in the summer the welded joint can be replaced. We inspect the track visually in detail every quarter and have the rail inspected ultrasonically approximately every year to be sure we have done our utmost to protect public safety. The ultrasonic inspection has picked up rail defects that have since been repaired or the rail has been replaced. In light rail operation a reasonable testing frequency would normally be every 2 years.

We have noticed recently that cars tend to take on a shimmy in the idler bogie area in certain areas of the track, particularly where the gauge is less than 1435 mm. We are not sure why this did not happen before; it may be due to the revised part worn-wheel profile that we have started using, but it does not correlate directly to the time that we started running the new wheels. The shimmy occurs in areas of track that previously did not have problems. Some thought is being given to whether tie shrinking is causing the areas of narrow gauge. Wood can shrink up to 3 to 4 percent. With a gauge of 1435 mm that would be approximately 6 mm.

In our studies of this problem of center truck stability, we have found that the rate at which gauge varies is possibly one of the most significant forces on the stability and ride quality. This is perhaps because the gauge change occurs over a relatively short distance and could set up an oscillation in the truck if several sections close together have an excessive rate of gauge change. The one thing we do know at present is that the wheel profile we are using is extremely susceptible to narrow gauge. Wide gauge does not bother it as much, nor do errors in cross level, nor errors in line, provided that these errors are within a reasonable range.

There have been no major problems created by snow, but it is important that the flangeways in the crossing and frogs and the switch point area be kept clear of snow to avoid derailments. We have had one occurrence of a train derailing in the yard on wind-packed snow. We have a switch snow blower to keep the yard switches free of snow and the crew uses backpack-mounted portable blowers as well.

In 10 years we have had three once-in-50-years rain storms, one with a tornado. In one area of the system the line passes under the Canadian National tracks in a tunnel. Unfortunately this tunnel is lower than the storm sewer in this area of the city. As a result the tunnel has flooded three times. The force of the water coming from the sewer manholes has caused two track washouts. This is not the type of event that we would normally build a contingency plan around; however, we are getting pretty good at responding to it.

The washouts were the most extensive damage that the track has suffered and we were able to respond to the emergency because of planning and equipment on hand. Our planning is designed to let us respond to any kind of problem, with a particular emphasis on derailments and track damage. We have been able to respond well to these events because we have the right equipment or know where we can get the equipment readily. Personnel are available who know how to use the various equipment such as pumps, rerailing trucks, hy-rail equipment, etc.

One thing we have learned from the two washouts is the importance of having a well-organized repair site. It is essential that one person coordinate all repair activities. There is a tendency for people to attempt to do too much themselves or to work too long. It is important that the site coordinator schedule the work force so that all repair crews have enough rest to work safely. There is a tendency to work the entire force full out at the onset of a problem and then not to have any rested workers to continue the work.

In an emergency track repair situation it may be possible to restore limited service on another track. In emergency situations it is important that the normal operating rules and practices be followed. There is a tendency for the maintenance staff to rush the job and, in their preoccupation with the immediate repair, to neglect some of the operating procedures. We have found it advisable to designate an operating person to control traffic at the repair site to relieve the maintenance staff of this duty and also to ensure that proper and safe movements are made. This person serves as the liaison with the control center.

The following tools are used in our day-to-day rail maintenance and emergency repair work. Some of them may not be applicable to all rail systems.

Gauge-measuring tool, geismar or equivalent;
Rail puller, hydraulic, 100 tons or more;
Rail bender, manual;
Weld profile grinder, switch point grinder;
Rail saw, rail drill, and supply of bits;
Tamping tools, hand, automatic;
Shovels, lining bars;
Track wrenches;
Guard rail wrench;
Spike mauls;
Claw bars;
Level board;
Rail thermometer;
Track shovels;
Track jacks, 15 tons;
Adzes;

Rail tongs, tie tongs, or equivalent;
Large pipe wrench;
Lining jacks;
Snow brooms, snow shovels, ice picks;
Wrenches;
Push carts;
Track speeder, or pickup with hy-rail wheels equipped with brakes;
Spike puller;
Snow blower, powered;
Air compressor;
Multipurpose truck with hy-rail wheels and crane, and tilting box;
Lining machine;
Tamping machine;
Ballast regulator;
Extra low-boy rail trailer to accommodate nonrail vehicles;
Water tank;
Emergency light plant and lights;
Chain winches;
Gauge bars;
Tie plugs and spare parts as needed;
Hand tools;
Flashlights;
Gloves;
Protective equipment, i.e., glasses and clothing; and
Reflective vests.

## TRACTION POWER

Edmonton has enjoyed much success with its traction power system. The system is a combination of in-house design and outside consulting. We are still following the design guidelines laid out in 1976.

The overhead is a simple catenary system of 4/0 contact wire and a 4/0 messenger wire. The contact wire is alloy 80 cadmium copper and the messenger wire is hard drawn copper wire. Our original system is designed to operate three-car trains and does not have any parallel feeders in addition to the catenary. The newer sections of the system are being built to a design standard for operation of five-car trains and incorporate a 500 mcm feeder in parallel to the catenary. The catenary is auto-tensioned throughout with a small section in the tunnel that is fixed-tension. The contact wire is tensioned to 1300 kgm force and the messenger wire is tensioned to 1100 kgms force.

The typical tension length is 1100 m with a midspan anchor in the middle. The nominal spacing of the catenary masts is 55 m with a maximum design spacing of 60 m in the open route. One of the primary limiting factors in the design of the catenary system is the supporting strength of the masts under the worst-case loading of 12.5 mm of radial ice and 400 Pa of wind pressure at −20°C.

The dc feeders from the substation to the catenary are two 1000 mcm copper feeders from the dc breakers to the catenary system. The feeders are connected to the catenary at the midpoint of the acceleration zones downstream from the stations. The circuit section breaks are usually located upstream from the stations so that the trains are not drawing power as they cross the section isolator. The section isolators provide total circuit isolation—the skids of the isolator are not energized. The catenary is sectioned so that each track between stations is a separate circuit. This increases our flexibility of operation. To reduce the catenary voltage drop for trains starting between stations, the catenary circuits are fed from each end of the circuit.

The substations contain two transformer rectifier units of 1 megawatt each. To improve reliability we split the substation into two halves. The system can still operate with one transformer rectifier unit out of operation. The criteria that we established for available voltage to the car were nominal voltage of 600 volts plus 10 percent (720 volts) and minus 20 percent (420 volts minimum). The rail network or the negative circuit is not grounded to reduce the interference of our system on other underground metal installations. We established a criterion for a maximum voltage drop in the rail of 15 volts to limit the amount of stray current that might occur. For short periods of time we now allow a maximum of 50 volts rail voltage drop, although there are few circumstances that could occur on our system to create this large a rail voltage drop except for the loss of the power station at the end of the line.

We initially raised an alarm at the power control center if the system voltage exceeded 15 volts rail-to-ground and shut down the substation if the rail-to-ground voltage exceeded 45 volts to ground. After a few years of experience we modified this approach. At 45 volts a motorized disconnect switch connects the rails to ground. We were finding that there were too many nonsystem occurrences that could create a potential to ground that had nothing to do with our LRT system, yet our protective relaying saw it and locked out the entire system. The system was shut down once because of a lightning strike in the north end of town. The ground rose in potential with respect to the ground 7 km away. The measuring devices in the substations measured the potential and activated the lockout relays. At night when the system is shut down, the switches are opened and the relays reset. There are more sophisticated circuits available now that do the same thing now using thyristors.

The substations employ di/dt relays as well as time overcurrent relays for the circuit protection. The rate-of-rise relays have responded very well and take out any circuit fault immediately and are very good at discriminating between regular loads and faults.

Most of our catenary problems were discovered early and have occurred because of construction defects or minor design flaws that were not noticed. The biggest bug of a catenary system is ensuring a totally smooth underrun. Anytime it's not achieved, the pan gets snagged in the catenary and something has to give. Usually it's the pan.

## TRACTION POWER TROUBLES

The following list of problems is typical of those that can be expected with a catenary system. We report each incident that delays the LRT operation significantly on an incident report. The catenary failures and solutions below are drawn from those incident reports and represent the majority of the failures that we have had.

- Pantographs snagged:
  Midspan anchor too low, too slack, snagged pantograph—raise midspan anchors;
  Pantograph snagged section isolator—install properly;
  Pantograph snagged on crossover—repair loose fittings;
  Contact wire fasteners (clips) coming loose in threads—apply locktite;
  Contact wire terminations being jerked loose—repair; and
  Contact wire clip loose—tighten all.
- Broken equipment:
  Missing carbon from pan, snags wire and pulls wire out of clip—replace and repair any hard spots on the line that may be hitting the pans exceptionally hard;
  Broken tunnel arm hanger—repair;
  Broken contact wire hanger, hanger carrying current insufficient c jumpers—repair or add missing c jumpers; and
  Faulty tunnel arm hangers, design flaw—manufacturer replaced.
- Miscellaneous failures:
  Lightning arrestor blown, did not interrupt follow-through current—replace;
  Fallen overhead power line onto catenary—repair;
  Minor electrical short in car junction box—repair;
  Material dropped from an overpass while under construction;
  Track crew lifted crane into catenary—revise procedure and put limits stops on crane; and
  Arcing between pan and contact wire while lowering pan (at very low contact wire heights pan does not drop far enough or fast enough to

extinguish arc, wire burns through)—in new construction raise height of contact wire.

The catenary has been relatively trouble-free. We are now enjoying a mean time between failures of about 1½ years. We have replaced approximately 100 m of contact wire in areas where the contact wire changed height rapidly and the pantograph created a greater uplift pressure on the contact wires.

## SPECIAL EQUIPMENT

By and large catenary maintenance and substation maintenance can be done with the usual tools of the trade. However there are a few special items that are required:

- Bucket or lift truck equipped with rail wheels,
- Rail-mounted reel trailers to carry reels of contact wire and messenger wire ready to go at all times in case of major wire tear-downs, and
- Parallel clamps for contact wire pulling (normal line clamps are curved and will kink the contact wire).

## SIGNAL SYSTEM

Edmonton has a basic two-aspect signal system that is patterned after the European approach to light rail signaling. The Edmonton system relies on the motorman to operate the vehicle safely. Failsafe systems are used to prevent hazardous conditions from occurring during normal operations, and are designed to be activated in the event of system or human failure. They are not intended to hamper normal operations.

Automatic signaling equipment provides the level of efficiency that is required with the safety demanded of an LRT system. The systems prevent train-on-train and other types of collisions with fixed objects, and with conflicting automobile or pedestrian traffic. They also provide service efficiency through automation, performing routine and repetitive tasks, and enforce operating and safety rules, and equipment restrictions.

To prevent any mode of collision, the system is separated in a simple system of discrete signal blocks. The block cannot be longer than the distance between two stations but may be shorter if the distance between stations is relatively long. The governing factor on block length is the time it takes for the train to clear the block and allow another train to approach. Edmonton is operating on a basic 5-min schedule and will be for several years to come, so the blocks are designed to clear a train in a maximum of 2½ min. This difference in schedule and block time allows the system to remain on schedule even if one train is off schedule. In rush hour, where the travel time for blocks was very close to the design headway, the blocks can constrict the whole system, passing on delays to the following trains.

In addition to collision prevention the signal system also provides grade crossing protection and automatic route selection. All traffic conflicting traffic with an established route is prevented by the system.

The signal system also provides full grade crossing protection and preemption. At locations where the LRT system crosses a roadway the tracks are protected by gates. Traffic gates with barriers are the most effective for maintaining LRT's right to cross the roadway with the level of safety required and at the speed necessary to provide a competitive and efficient service.

In addition to the gate operation, there is an extended approach feature. If a train is within 15 sec of calling the gates down from the opposite direction, the gates will be held down waiting for the next train. The extended approach uses the next track circuit to the call-on circuit. This feature was more desirable than starting traffic moving across a crossing only to have another train immediately close it again.

A feature on Edmonton's system that is not common in North America is verification that the call-on circuit is operating. A call-on signal is located 222 m in advance of the crossing and changes from amber to green when the crossing protection is activated. The signal is protected by a train-stop magnet and will shut down a train that runs the amber light. The stopping distance for the crossing is not worst-case and allows for the use of the vehicle's dynamic brakes. The call-on signal concept came from a European supplier and we continue to use it. Although it is redundant with failsafe signaling, it is another check on the operation of the crossing call-on. Also, in possible future operations we might use something other than a track circuit to call on the gates. With the call-on signal we could use wheel detectors for gate activation knowing that, if they did not work, the train would not be allowed into the crossing. This is not something that we will be able to pursue for almost 10 years, as our next extensions will be in tunnels.

Our system has two main aspects, red and green. In addition to the main aspects we will also show a white lunar signal to the side of the signal if the line is in the divergent direction.

Originally our call-on signals were also red and green. This created some confusion. A call-on signal is not treated as seriously as a block signal, because it does not protect train movements. Its sole purpose is to provide protection to the crossing. We therefore allow a stop-and-proceed rule for the motorman at call-on signals if the signal is amber and control is not available. However there was confusion with block signals, which could not be passed except with special permission of control. The other area of confusion occurred at signals that were a combination block and call-on signal. The difficulty was that 99 percent of the time when a motorman approaches a call-on signal it changes to green. The same cannot be said of a combined call-on and block signal. About 10 percent of the time the train would approach the signal but, because the block ahead was occupied, the signal would not turn green. The time available to stop was now limited and required a relatively sharp stop.

The call-on signal lenses were replaced with amber lenses and at the combination signals another aspect was added, amber for the crossing only, with red reserved for the block. Now the motorman knows that an amber signal is for a crossing and should change as the vehicle approaches, but that he has to stop at a red signal. This system is a little different than that used in the rest of North America where the amber signal indicates the status of the next block. Given the expansion plans for the next 10 to 20 years there should be no major need to change the aspect system that we have now.

One failing of the system is that it lacks a communication system between the wayside and the vehicle aside from radio communication. A continuous cab signaling system was ruled out when we first installed the signal system because of the cost and a belief that LRT systems did not need signal systems. But it would be a useful feature if we could provide continuous information to the motorman about the route ahead. Our system is a point system; it clears a vehicle for the track ahead at a point on the line and at a point in time. If something happens to change the condition ahead of the vehicle, there is no way to communicate that information to the motorman via the signal system.

A continuous information system about permissive speeds and some form of on-board monitoring of actual speed would have been a preferable method of speed control to the speed check method that we use. If an operator is speeding in a given area, the train is automatically forced to a stop via a train-stop magnet and the motorman is required to report the shutdown to control. The speed checks are easily spotted and every operator knows exactly where they are. There is no means to prevent speeding once the train is past the speed check.

When LRT operations began, this speed check system was fraught with many difficulties and its reliability was questionable for a couple of months. The manufacturer redesigned a critical circuit board to solve the problems, but the damage had already been done in the minds of the people that the system is intended to serve.

## SIGNALING SYSTEM UPDATE/PROBLEMS

There have been very few problems with the signal system over the past 10 years. The system as supplied works as it was intended.

The signal system uses line frequency track circuits and two-phase motor relays for train detection. The motor relays have functioned well and we have not had any failures of the relays. Initially I had a concern about using the line frequency, but we have had no problems with line frequency interference or false picking of the relay. With the motor relay the track voltage must be present at the correct phase angle with respect to a reference voltage present in the signal room.

Some of the initial problems we have had with track circuits were a significant number of false occupancies during our first few months of operation due to iron fillings and cuttings left in the insulated joints. We remedied this in future work by insisting on glued insulated joints rather than the separate joints.

The European signaling technology uses a significantly different approach to vital relays than does the North American version. Rather than individual relays with multiple contacts, smaller relays and more checks on relay position are used. The relays are rack-mounted and are covered by common opaque covers. We initially experienced some difficulties with dust in the relays because the covers aren't sealed. Troubleshooting a circuit meant removing the covers to see the relay position. The unnecessary removing of covers disturbed dust and created more problems. We replaced the original covers with clear plastic ones of our own design from a local plastics manufacturer. Now all the relays are visible and it is not necessary to remove the dust covers for troubleshooting. We also air conditioned the relay rooms, not for the sake of the equipment but to stop the staff from leaving the doors open in the summer to cool down the room. We also installed built-in vacuum cleaners to take the dust to the outside in cleaning operations.

Our winter conditions create the most problems for our track circuits. The track circuits in the road crossings are the most difficult to set in the winter when Edmonton is exposed to many different types of weather. Another factor is the salt that is spread on roadways to melt snow. The cars carry salt from the roadway onto the crossing and drop salt and sand into the crossing.

When the weather is mild and dry the crossing is also dry. The resistivity of the crossing is high and signal losses are relatively low. But when the weather is wetter and snowing, the crossing is wet and laden with salt. A significant reduction of resistivity and larger signal losses occur as a result. If the temperature drops below the point at which salt water melts ice and freezing occurs, then the crossing resistivity goes up with a reduction of signal losses.

Because it warms up during the day and cools down significantly at night, ice and snow melt and refreeze, creating a large swing in conditions over a 12-hour period. To reduce the effects of this we try hard to keep the crossings as clean as possible, and to prevent moisture from entering the crossing and particularly from filling the spaces between the rails and concrete crossing blocks. We try to get good drainage and will be experimenting this year with a new high-density plastic crossing insert that should give us greater insulation value. A rubber crossing insert tried in the past helped, but the cost to retrofit our nine grade crossings was too high. This is an area in which an automatic gain control track circuit would be extremely helpful.

We found out early that sand and track-circuited tracks do not mix very well. We had one occurrence of a train ghosting on a track circuit at the end of the line. In attempting to get good adhesion for acceleration, one of the operators was using large quantities of sand. The sand was being crushed and forming a silica layer on the rail that was reducing the shunt. We removed the manual sanding feature from the cars and constantly keep an eye on the amount of sand build-up on the rails. A feature that helps to prevent ghosting is that the signal system needs to see a sequential dropping of track circuits if it is to allow the last track circuit to pick up when it is cleared.

In extremely cold weather sand from the braking, sand from the road crossings, and graphite from the lubrication all combine to form a very tough ice that can coat the rail and prevent a good shunt. When the ice reaches –30°C it is extremely hard and the weight of an a empty car is insufficient to break through it. When temperatures are that low, we use alcohol to clean the worst areas of build-up, which are usually just past a road crossing.

When we put the system in, the cost of providing a battery backup and inverters for the track circuits was prohibitive, so we installed diesel generators in the signal rooms. The generators provide enough power to operate the signal system fully should we lose commercial power, which we obtain from the traction substation next door. The generators, however, have a momentary power loss that is tolerable for most of the applications. The one application that we have found that cannot tolerate a power outage is the centralized traffic control system and the microprocessors that operate it. The centralized traffic control (CTC) system was installed as a retrofit. We have found out the hard way just how much of a nuisance and detriment to the system operation a minor glitch can be. The centralized traffic display is an essential item that must remain up and in full working order, all the more so when there are other system problems. If the CTC shuts down, radio communications must be relied on. We are now in the process of installing inverters and battery packs for the CTC system.

When the LRT system began operating we only had minimal event recorder capacity. Because we believed it desirable to record the events on line, we installed a series of 48 pen recorders in the signal rooms. Our experience with the pen recorders and the maintenance required has led us to purchase a solid-state data logger. We will record all system activities for upwards of 1 week on data loggers and then download the information to a microcomputer for analysis or printing if required.

One of our primary reasons for increasing our capacity to analyze events is to recreate the circumstances immediately before any event. The signal system does the job it is required to do, but it would be useful if it could communicate up-to-date information to the train operators and to the train-borne equipment itself. The decision not to have this feature was a dollar trade-off when the system was installed and is not the fault of the system that we are using.