TRIP REPORTS ON SITE VISITS TO FRANCE, SWEDEN AND ITALY

prepared for

Ontario-Quebec High-Speed Rail Project

by

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1: SITE VISIT TO FRANCE

The site visit to France was undertaken by Chris Boon and Gord English of CIGGT.

The trip began on 22 November with transfer from Kingston to Mirabel Airport and thence to Paris on CP 1052, which arrived at 0625 on 23 November. Transfer from Roissy-CDG to Etoile took over 90 minutes due to Metro strike and exceptionally heavy road traffic. Accommodation at L'Horset Washington hotel was arranged through the Canadian Embassy.

23 NOVEMBER

On the afternoon of 23 November, Boon and English met with Messrs. Jean-Claude Dufresnes and Henry Beekenkamp of Sofrerail.

M. Beekenkamp began by reviewing development and evolution of maintenance cycles for TGV-PSE wheelsets and bogies.

He noted that when the PSE services began, a visual 'safety check' of wheels, bogies and brakes was performed daily, or after 1600 km of running on the high-speed line or 2000 km of running on conventional lines, whichever was more restrictive. The visual check takes about 1 hour elapsed time to perform and requires 3 to 4 person-hours of labour for a 1-8-1 trainset. Initially these inspections were performed in stations, but this proved unsatisfactory, and the checks are now carried out at a shop facility with an inspection pit (Chatillon in Paris). The inspections are normally performed at night.

As experience with TGV operations was acquired, the 'daily' and '1600 km on new line' restrictions were dropped and the inspection interval raised to 3000 km.

In response to a question from Mr. English, M. Beekenkamp stated that the types of flaws or faults detected during this inspection typically did not require immediate attention, so that the action taken was to flag the specific problem in the computerized maintenance data file for that trainset, for action to be taken during the next level of maintenance.

M. Beekenkamp commented that originally this inspection identified small wheel flats, but that since anti-slip controls had been fitted to all TGV sets, this problem had virtually vanished. The PSE wheelsets, which are all equipped with tread brakes, started out requiring reprofiling every 50,000 km; the interval is now up to 350,000 km on average.

Each wheelset can be reprofiled four times. However, on the TGV-A trailer cars, which do not have tread brakes, the interval between reprofiling is much larger. Some wheelsets have run over 700,000 km without requiring a reprofiling. The powered axles, which still have tread brakes, have cycles similar to the PSE equipment. The expectation of SNCF and GEC-A is that with the TGV-R, which has no tread brakes, the longer wheelset life will become the norm.

Reprofiling can be carried out on a bogie-by-bogie basis (both wheelsets) or it can be performed for an entire consist. The PSE reprofilings have typically been the latter, while on the TGV-A the bogie-by-bogie approach is used, with the focus on the powered bogies. The NC underfloor wheel lathes can reprofile two wheelsets at a time. This requires approximately 1 hour of lathe time, and about 3-4 hours in total including trainset positioning and setup. All 8 powered axles on a TGV-A trainset can be reprofiled in approximately 6 hours elapsed time (about 16 person-hours labour).

At the commencement of TGV-PSE operations in 1981, the interval for the so-called 'VOR' visual inspection of bogies, brakes and other running gear was set at 7 to 9 days through negotiation between SNCF and the French MOT. Based on actual experience to date, this interval has been doubled to 14 days nominal/18 days maximum. The inspection includes rotation of wheels and measurement of profile and wheel diameter using hand tools. M. Beekenkamp stated that the maintenance and inspection facilities for the TGV-Nord will permit automated measurement of wheel profile and diameter.

In response to a question from Mr. English, M. Beekenkamp indicated that there are quantitative out-of-round and profile criteria that are used to trigger reprofiling and/or wheelset condemnation. The reasons for reprofiling include out-of-round wheels, diameter differentials, shelling and crushing. M. Beekenkamp stated he would obtain and forward the actual criteria to us. At time of writing these had not been received [93.01.04].

For the TGV-A, there is 'LV' scheduled maintenance every 90 days, with more in-depth activities every 180 days. The LV cycle for the PSE equipment is actually longer -- 130 days -- but the PSE trainsets receive an additional traction motor inspection every 60 days. The actual annual out-of-service time for each TGV-A trainset is three to four days less than for the PSE equipment, according to M. Beekenkamp.

During inspections of bogies and brakes, tread brake shoes are replaced as required [note that tread brakes will not be used on later generations of the TGV, so this aspect of maintenance is not relevant to our corridor]. However, brake discs (on trailer axles of the TGV-A) are not changed for wear but are changed whenever the wheelset is changed.

M. Beekenkamp stated that a trainset can have some brakes (and/or traction motors) disabled but still remain in service. The TORNAD on-board monitoring, diagnostic and control system monitors brake and traction status and capability (among other things) and provides the driver with real-time subsystem status, problem diagnostics and required action. Exhibit A summarizes the permitted speeds with different combinations of electro-pneumatic brakes and/or traction motors isolated or inactive in rheostatic braking.

The complete brake system of each trainset is checked at least once per day, in addition to review of the diagnostics generated by TORNAD. The TORNAD system runs regular automatic self-diagnostic checks in addition to daily function verification at trainset startup.

With respect to braking R&D to permit higher-speed operation (i.e., 350 km/h for TGV-NG), M. Beekenkamp confirmed that the carbon-carbon brake development had been deemphasized. He stated that SNCF and GEC-A were looking at magnetic eddy-current brakes and also at active aerodynamic braking.

TGV-A TRAINSETS

TABLE USED ON TGV-A LINE WITH THE
ELECTROPNEUMATIC BRAKE IN SERVICE

TRAIN WITH ONE TRAINSET
(15 Boggies; 8 Motors)

Quantity of boggies with the pneumatic brake isolated	Quantity of motors isolated or inactive in rheostatic braking				
	0	1	2	3	4
0	A	A	A	A	B
1	A	A	B	B	B
2	A	B	B	B	B
3	B	B	B	B	B
4	B	B	B	B	C
5	B	B	C	C	C
6	C	C	C	Z	Z
7 and more	Z	Z	Z	Z	Z

A	Maximum speed of 300 km/h
B	Maximum speed of 160 km/h
C	Maximum speed of 80 km/h
Z	Assistance

NOTE: In case of asking for assistance, the stopping train:

- must not move by itself;
- must be maintained in a standstill by mechanical wheel blocks.

The major emphasis is on improving understanding and control of the wheel/rail interface. He noted that tread brakes will be replaced by powered-axle disc brakes on the TGV-2N and later builds.

The conversation then turned to discussion of weather-related issues. M. Beekenkamp noted that a 220 km/h speed restriction can be imposed under 'heavy' snow and rain conditions. This action is initiated by the driver for reasons of reduced visibility during meets and/or release of blocks of snow and ice which may have accumulated on the train. The blocks can "splash" ballast into meeting trains and can also foul the ballast. He indicated that neither snow nor rain were monitored to automatically reduce speeds from central authority. The driver is in control and will reduce speeds on stops if he feels adhesion conditions are not good, and he will ask the dispatcher for a slow order of 220 km/h if he thinks conditions warrant it. (This point was addressed later in discussion with signal personnel, since the CTC system seems to have weather monitoring stations of its own. It was not clear whether the driver was the initiator in all circumstances or whether the dispatcher acted in some. We will try to get clarification on this.)

In response to a question from Mr. Boon regarding the effect of low temperature on the airspring suspension, M. Beekenkamp stated that SNCF has experienced no problems with the TGV suspension system in cold weather.

M. Beekenkamp confirmed that speed is restricted to 220 km/h or less when wind speed exceeds 70 km/h, due to poor power collection characteristics. The problem encountered early in the operation of the PSE line, where catenary sway allowed the pantograph to rise *above* the contact wire, which tore down several km of catenary, has also been addressed by modifying the contact shoe to a broad u-shaped lateral profile. In combination with the reduced speed, the problem appears to have been resolved.

The next topic of discussion was system reliability. Mr. English noted an apparent inconsistency between the on-time performance cited within different Sofrerail reports to VIA Rail Canada (97.5% of trains operated less than 14 minutes late) and that presented in the detailed results provided by SNCF and cited by M. Beekenkamp (over 99% less than 14 minutes late). Some discussion of the different standards applied by different departments within SNCF in defining 'on-time' and the differences in TGV regional statistics vs TGV high speed line statistics ensued, but this variation was not really resolved. It was suggested that this topic could best be discussed with the transportation planning group scheduled for later in the week, but the meeting was later cancelled. We are hoping to get comments from SofreRail on this point.

M. Beekenkamp stated that trainset availability is governed by an internal contract between the operating and maintenance departments, defining the minimum number of trainsets which must be available for weekdays (Monday midnight to Friday noon), normal weekends, and 'superpeaks'. Safety checks and inspections are performed at night or during daytime blocks when a particular trainset is inactive. Preventative maintenance activities are carried out during the weekday time period. On the PSE, trainset maintenance has expanded from 1 shift, 5 days a week; to 2 shifts, 7 days a week. The fleet availability targets are 83% weekday, 95% normal weekend and 99%+ on superpeaks, and according to M. Beekenkamp, are being consistently achieved.

NOTE: The ability of SNCF to serve their level of aggregate demand with the existing fleet, operating strategy and maintenance program and support facilities is dependent to a considerable degree on the existence on the temporal peaking. With equivalent aggregate demand but a much more uniform distribution by day of week, a higher number of in-service trainsets will be needed to meet weekday and normal weekend demand; meeting this requirement would necessitate a larger fleet, and/or additional maintenance assets, and/or a different maintenance strategy.

With respect to at-grade crossings, the LGVs are fully grade separated. On the lines of the conventional network which carry TGV traffic, the maximum train speed is 160 km/h. M. Beekenkamp stated that there are very few level crossings where even 160 km/h is permitted. Most are on lines where the maximum train speed is 140 km/h or less. SNCF level crossings are protected with either double or single automatic gates, lights and signs, depending on rail and road traffic levels and on whether the rail is single or double track. Single-gate crossings are restricted to low-density crossings (low rail *and* low road) with a low maximum train speed and long sight lines. However the SNCF grade crossings do not have constant warning time devices, and do not incorporate highway vehicle detection circuitry. SNCF conducted trials with vehicle detection devices in the mid-1970s, but the results were unsatisfactory. There are also some manned crossings where the road is normally *closed* and drivers must request permission to cross.

24 NOVEMBER

On 24 November, Messrs. Boon and English, accompanied by M. P. Chartier of Sofrerail and M. J-M Gayon of SNCF's International Affairs Department, travelled from Paris-Montparnasse to Le Mans on TGV-A 8205 (Photo I-1.1: Detail of SR-10 airspring suspension). Overpressure effects in the tunnel sections near Paris led to discussion of pressure-sealed coaches which SNCF has evaluated for higher speed lines with tunnels.

At LeMans, we were met by M. H. Sinon of the LGV-Atlantique Region de Paris Rive Gauche. He has responsibility for maintenance of signals, communications and electrification of this region. The visit began with inspection of the signal box at LeMans station. The equipment is conventional (i.e., not solid-state) as shown in Photos I-1.2 through I-2.3. Each signal box has a control board allowing maintenance teams to physically lock in speed limits of either 160 or 80 km/h on a block-by-block basis, once permission has been — and literally — received from the central control facility in Paris (Photo 2.1 - note locks).

Following the explanation of the signal box installation and function, we were taken by minibus to the Courtalain flyover where the LGV-A branches (Photos I-2.4 through I-6.4). This on-track inspection allowed us to take a close look at the track superstructure (rail, ties, fasteners, ballast), the #65 turnout (220 km/h), switch machine and switch heater, double and single-span catenary installations including tensioning devices, and the fragile-wire road vehicle intrusion detection installation on a nearby road overpass. The site was also equipped with a solar-powered rain gauge with automated reporting to the central control facility.

There were several interesting observations arising from this visit.

First, the contact strip on the head of the rail is very narrow on the fixed track (Photo I-4.1) showing the stability of the TGV truck, and relatively narrow even on the switch itself

(Photos I-5.2 and I-5.4). The rails and switch frog showed very little evidence of wear, a function of switch design and metallurgy, low track forces, and excellent wheelset maintenance.

In standard track, the ties were standard SNCF dual-block concrete/steel composites, with Nabla fasteners (Photos I-3.4, I-4.1). Note the thick (9mm) tie pad in Photo I-4.1. Retention of pad elasticity at low temperature is expected to be a problem (see notes for Friday November 27). Switches and turbouts are mounted on wooden ties.

The ballast (Photo I-4.1) was 50/25 graded crushed 'granite' and what appeared to be metaquartzite. These materials are generally suitable for this type of application, but there appear to be two deficiencies, based on visual inspection:

- the ballast material seems to have a large number of particles with a high shape factor (SF - defined as maximum dimension/minimum dimension), which results in poor interlocking, reduced section stability, and increased tendency to fracture; and

- some of the source material is composed of minerals with large grain sizes.

Ideally, ballast particles should be cuboid (SF between 1 and 2). SF values over 2 are not acceptable for this class of track, and there are numerous examples of such particles in the accompanying photos. Also, ballast materials should be fine-grained and free from planes of weakness (jointing, grain boundaries, gneissic or schistose texture). Coarse-grained materials tend to fracture readily on grain boundaries, and coarse-grained granites (and pegmatites) which contain a substantial proportion of feldspar, are also vulnerable to fracturing on the cleavage planes of these minerals. Once fractured, feldspars will weather to clay minerals, which foul the ballast and interfere with drainage.

The presence of the automated rain gauge (Photo I-6.4) linked into the central control facility seems inconsistent with the practice of slow orders being initiated by drivers based on visibility problems. We requested that Canarail make further inquiries to clarify the procedures in weather related slow orders. Apparently the rain gauges are used to identify locales where high rainfall rates and/or total rainfall over a short time period could lead to earth slips. If the rate/total rainfall exceed some threshold values, a field inspection is ordered. However, no slow order is imposed until *after* the inspection is completed. This strikes us as somewhat unusual — applying a slow order *until* the inspection would be more consistent with Canadian practice.

After lunch, we proceeded to M. Sinon's office at the Vendome yard (Photos I-7.1 through 8.2) to discuss maintenance organization and activities for the LGV-A.

There is a single organization responsible for maintenance of fixed facilities (track, electrification, signals and telecommunications) for each of the two LGVs (PSE, Atlantique). This differs from the way maintenance is organized on the conventional SNCF network, which is divided into 25 regions. Each LGV maintenance organization is responsible for about 300 km of track.

Fixed facility maintenance on the LGV-A requires about 170 persons, including clerical and support staff.

The track maintenance (TM) teams are headquartered at 3 locations: Massy, handling work between km 6-87; Chateaudun, handling from km 87 to km 181 on the northern arm; and Vendome, which is responsible for the track from Acquitaine Junction to the end of the Tours bypass on the southern arm. There are 2 TM teams based at each of Massy and Vendome, and 3 TM teams based at Chateaudun. Each team is comprised of a head, a deputy, a lead technician, and between 10 and 12 workers, and is equipped with on and off-track equipment.

Maintenance of signals and telecommunications (S&T) and catenary (CAT) is directed by a 5-person management group (head, 2 deputies, 2 inspectors). There are also 3 S&T teams of 7 to 8 technicians, based at Doudonne, Chateaudun and Vendome, and 3 separate CAT teams of 9 persons, based at Monges, Courtalain and Vendome.

M. Sinon commented that the Vendome base had a 3-person management plus 7 clerical/support staff.

In response to a question from Mr. Boon regarding staff training requirements for maintenance workers on the LGV, M. Sinon stated that workers transferring from the conventional network to an assignment on an LGV were given 5 months training. Track maintenance workers received additional specialized training on switches and crossovers. The catenary and track teams in general had at least 6 months experience prior to transferring to the LGV. At least 2 years experience is required for a team leader.

M. Sinon confirmed that a significant proportion of track maintenance is performed by outside contractors, including rail grinding, most lining, levelling and tamping, brush clearing, fence maintenance, and quarterly track geometry measurements using the Mauzin car. All inspection and maintenance planning functions are performed by in-house staff, as are all maintenance activities on safety-vital functions (signals, telecommunications, train control, weekly monitoring of track geometry using revenue trainsets with instrumented axles), maintenance of turnouts and crossovers, and related tamping.

The discussion then turned to actual levels of input to maintenance activities. As an example, M. Sinon stated that for each signals and telecommunications installation, there is a specified annual inspection and maintenance program, including scheduled changeout of contacting components and components subjected to vibration. He provided us with a crew inspection schedule for the signalling equipment.

In relation to unscheduled maintenance (reliability performance) M. Sinon went over some 1991 and 1992 "incident" report sheets with us. Each incident is reported in terms of time reported, time responded, time taken to repair and direct delays to train operations. For S&C maintenance, there were 165 'interventions' in 1991, and at the time of our visit in 1992 there had been 153 interventions. Not all of these led to train delays. The 1991 signals 'interventions' required 28000 person-hours of labour, and about 430,000 FF in materials. M. Sinon noted that the system is relatively new. Because of this, some of the materials replacements were under warranty. Thus, the level of materials expenditure would be higher under normal long term operation. On the other hand, many of the problems were "teething" problems of a new installation and the overall reliability is expected to rise as the signalling sub system aged.

The intervention report sheets are submitted to the regional headquarters for aggregation and monitoring of reliability performance. These data were not available to Mr. Sinon that day, but he indicated he would arrange for the headquarters's reports to be sent to us via SofreRail.

As for the other maintenance activities, there were 5000 maintenance hours required for telecommunications, and 21195 labour hours for catenary maintenance in 1991. About 100,000 hours of SNCF staff time went into track maintenance. Note that this is exclusive of any contracted work. M. Sinon did not have materials or other input levels available, but indicated this could be forwarded later.

WEDNESDAY, NOVEMBER 25

Accompanied by M. Chartier, Messrs Boon and English visited the central Atlantique-line control facility at Gare Montparnasse in the morning (photos 8.3 and 8.4). This visit was a substitute for the planned visit to the transportation planning section which was cancelled because of a strike. Most of the signalling related issues had been dealt with on the previous day so the visit was more of a site viewing than a discussion. A couple of points that were discussed are of interest. The question of the frequency of usage of crossovers in order to operate around a closed section of track was raised. The response was that such use may not be required for many months but that then there may be a number of incidents which lead to a crossover requirement for several days in a row. Crossovers are also used on a regular basis during driver training. The dispatchers will initiate a crossover without advance notice to the driver just so the driver is familiar with the operating requirements. The dispatch office has two control segments, one for the LGV operations and the other for the busy approaches to the Paris-Montparnasse complex, where commuter, conventional passenger and freight traffic as well as TGV services must be controlled. Crew calling and equipment lineups are not a major activity for the dispatchers because the schedule for both crew and equipment is set on a weekly basis.

The staffing level of the office was in the process of being reduced both at the supervisory level and the dispatch level. There was a union meeting on while we were there to discuss a strike action. We did not get final details of the current or planned level of staffing for the facility. However, the technology and function of the centre is very similar to Canadian dispatch centres.

The afternoon involved a visit with M. Martial Cherfils to the Chatillon maintenance facility (photos I-9.1 through I-14.4). Most of the equipment maintenance issues had been discussed on Monday so the visit was more of a visual followup. The high levels of inventory associated with cleaning/maintenance of interior upholstery was evident. The shop also had about 20 traction motors out of service. The indication was that they were there for scheduled maintenance rather than because of any problems.

The in-line wheel lathe was in operation during our visit. M. Cherfils indicated that the TGV wheels were not subjected to any tighter tolerances than other SNCF wheels. The conditions for removal were the same as those applied to SNCF freight car wheels. He also noted that the Atlantique train sets experienced different wheel lives than the PSE trainsets. The powered axles had a lower life (about 200,000 km) between turnings while unpowered axles had a higher life (some over 700,000 km.) compared with 350,000 km for all axles on the PSE equipment.

THURSDAY, NOVEMBER 26

In the morning, Messrs Boon and English met with Messrs Poulain, Cherfils, and an interpreter to review the ASTREE project (photos I-15.1 through 16.4). After a briefing on the project objectives and overview of the implementation strategy, we were taken for a short ride between the Gare de l'Est and Gargan in the Paris suburbs, on an old electric locomotive that has been converted to an experimental testbed for ASTREE. The ASTREE system is a computer based signalling system which uses data radio to transmit authorities from central to the mobile vehicle. ASTREE is at the demonstration stage of development. The short line to Gagnon and a couple of locomotives are now equipped. However, they plan to have the most of the Eastern region (650 km and 80 locomotives) implemented as a test bed by the end of 1993. M. Poulain indicated that the main impetus for ASTREE was reduced cost (about 30% of the cost of conventional signalling for a new line) but that flexibility and improved operations performance were also available.

The temporary test bed is using existing communications lines for data communications and the system lost contact with our test locomotive. The trip continued under verbal authority. At Gargan, we received a further briefing on the experimental control software and test program. The test facility is divided into two rooms and two banks of computers. One room houses the control system, while the other houses simulation systems to simulate the trains and line operations of the test line. The control computer can be linked to the actual system or to the simulated system.

The ASTREE system is at a similar level of development as CN's test bed for ATCS. Although a dedicated passenger system would have a much reduced complexity from the Canadian freight system, the ATCS specifications would offer significant economies in development and application for a Canadian corridor.

While at Gagnon, Mr. Boon took the opportunity to examine and photograph the protection devices at a very busy multi-track level crossing adjacent to the station. Beyond the full-width barriers, there is very little difference between the protection there and that used at most high-density crossings in Canada, although there may be some differences in the train detection and actuation circuits.

After lunch, Messrs. Boon and English, accompanied by our interpreter met with M. Alain Guidat, the Chief of Track Maintenance for New Lines for the LGV-PSE. M. Guidat made a very complete and detailed presentation of the maintenance organization, procedures and issues associated with the PSE line. He agreed to provide copies of most of his presentation overheads via SofreRail.

There are several interesting points which we noted during the presentation.

First, with respect to the organization of the track maintenance forces on the LGV-PSE, the line is split into two sections, 'LAROCHE' LGV, from km 0 to km 226, and MONTCHANIN LGV, from km 226 to km 389. Each section has a chief and a deputy. Each section is broken into three districts each covering approximately 85 km of route. Each district has two chiefs and one deputy, plus two crews of 10 to 12 persons. On the electrical side, the entire line is maintained by a force comprised of a chief, two deputies, a catenary inspector, 3 catenary crews and 3 signalling and communications crews.

M. Guidat stated that the PSE LGV is expected to handle double the number of trains by 1998. The two PSE tracks have 90 minute inspection blocks built into the daily train schedule. One block per day per track is available for daylight maintenance, which is limited to surveys and visual inspections. There are 26 switches and 58 other 'Appareils de Voie' which are also inspected in daylight. At night, there is a 6-hour maintenance window, 4 hours of which are available without interruption (the mail TGVs operated for the French Post Office are the only trains operating during the night window).

M. Guidat noted that the rails are ground each spring, then the track is tamped and levelled. Overall, the emphasis has been shifting toward grinding and away from tamping; the proportion of track maintenance effort devoted to tamping has declined from 31% to less than 25%. SNCF use a 2-5-1 grinding configuration prior to start of operations to ensure immediate compatibility between wheel and rail profiles. The frequency and amount of grinding is varied depending on subgrade quality.

FRIDAY, NOVEMBER 28

On Friday, Messrs Boon and English met with Messrs Roger Retiveau of Sofrerail and Pierre Porcin of SNCF Fixed-Plant Service to discuss signalling, train control and electrification.

M. Retiveau began the discussion with a brief overview of the TVM-300 train control system used on the PSE and Atlantique lines. He stated that this is a very simple system based on unidirection ground-to-train data transmission plus jointless parallel track circuits. Four frequencies (1700, 2000, 2300, 2600 Hz +/- 10 Hz) are used with FM modulation (10-30Hz). On the PSE line, the track circuit length on level ground is 2.5 km. The system is limited to 18 different messages, although only 14 are used. The minimum headway is 5 minutes. On the LGV-Atlantique, the nominal block length is 2 km, and the minimum allowable headway is 4 minutes, again on level ground. In both cases, the block length is increased on gradients.

Two of the four frequencies are alternated on a track and the circuits are staggered on adjacent tracks to avoid crosstalk. The layout is shown below:

^ F_1 ^ F_3 ^ F_1

--------------------<---- Track 1

^ F_2 ^ F_4 ^

-------------------->---- Track 2

Antennae in the nose of each power car ahead of outermost powered wheelset pick up the track circuit signal. M. Retiveau noted that there had been some initial problems with the welded connection between the rail and the signal boxes, but that these had been overcome,

The TVM-430, which is being installed on the TGV-Nord line, uses the same four frequencies for unidirectional ground-to-train communication but has 27 different FM possibilities. This allows transmission of 27-bit messages, with 4 control bits and 23 data bits. The TVM-430 sends block length, gradient, entering speed, exiting speed and maximum speed in block for each block, and can also send these data for the next block ahead. The nominal (level, tangent) block length is 1.5 km, versus 2 or 2.5 km for the TVM-300. This permits operation with as little as 3-minute headways.

The signal box design for the TVM-300 is entirely conventional with fail-safe relays, as illustrated in the photographs referenced above. The signal box design for the TVM-430 employs a hybrid with computerized solid-state interlockings linked by a vital circuit controlling relays linked to the track circuits and switch machines. This design was described as being 'a little more expensive' than the conventional design of its predecessor. Fibre-optic cables are used to link each signal box to the CTC; these cables also carry telecommunications circuits.

There are monthly inspections of the train control and signalling system using a rail-borne vehicle that measures the current in each track circuit and also the quality of the signal. The circuits have a capacitor every 100 m , and will continue to function with one capacitor out but not with three or four.

According to M. Retiveau, track-side signalling faults result in delays to about 4 trains in 1000 on the Atlantique lines; there were 33,000 trains operated on the LGV in 1991, so this incident rate would translate into 132 delays. (This is consistent with the 150 "interventions" mentioned by M. Sinon in Vendome). We have been promised copies of the overheads used in this presentation which will provide some additional detail on the distribution of magnitude of delay.

The TVM 430 also offers the advantage of variable slow order speeds, rather than the discrete 160 and 80 km/h hard-wired into the TVM-300. This feature will reduce time lost around maintenance sites and other features requiring temporary slow orders.

All versions of the TVM include a black-box recorder that monitors all events including overspeed events.

With respect to other devices linked to the train control system, the principle items of interest are hot-box detectors and vehicle intrusion detectors as fitted to highway overpasses. The hot-box detectors are set up so that a single failure does not restrict speed, but failure of two adjacent detectors triggers an automatic speed reduction. Similarly, if both wires on a detection mat are broken, the control system will automatically stop the trains, but if only one wire is broken, no stop is triggered.

At interconnections between an LGV and the conventional network, there are loops set between the rails to initialize or to change the frequency settings for the LGV or for the conventional network, as shown below:

```
 F1  F3   F1     etc
---+-------+-------+-------+-------+-------
            o
----+-----+---.---+------+------+
  F2  F4   F2   F4    F2
```

At 30 km/h on an open line, the system permits a train to proceed under visual control past a permissive stop point. At absolute stop points, there are track-mounted loops that provide a type of ATP that initiates immediate automatic braking and brings the train to a halt.

```
--------->---+---------------*---o---
     Permissive          Absolute Stop
     Stop               Coil
```

All slow orders are enforced with the signalling system. Station stops are designated as 160 km/h zones for stopping trains and the driver uses his own discretion in slowing to a stop. This practice permits delays in the order of 5 minutes for stops whereas they would be 10 minutes if fully enforced by the signal system.

Concerning the electrification system, connections to 127 kV lines are permitted if a 1% unbalance criterion for single phase loads is met. Double end feed configurations were once permitted but are not now.

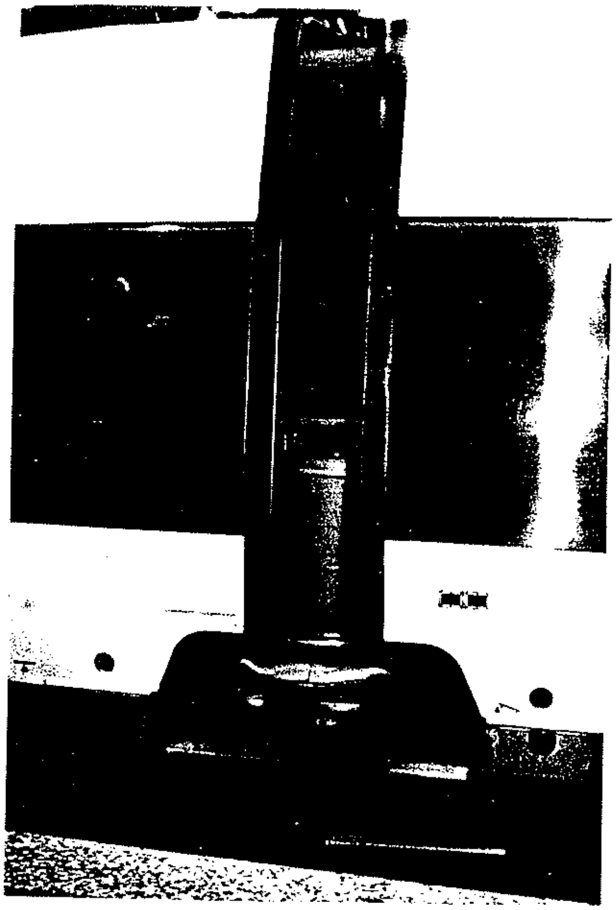
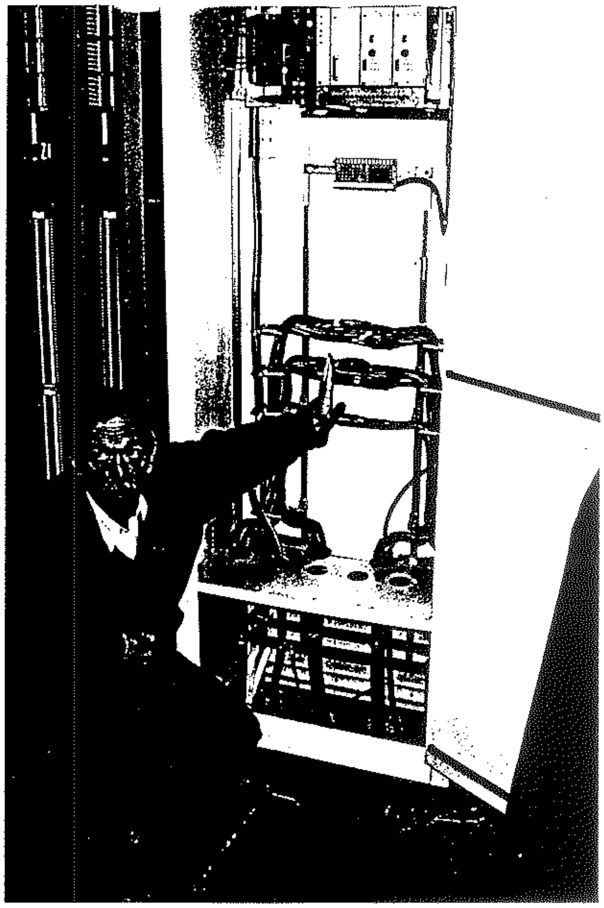
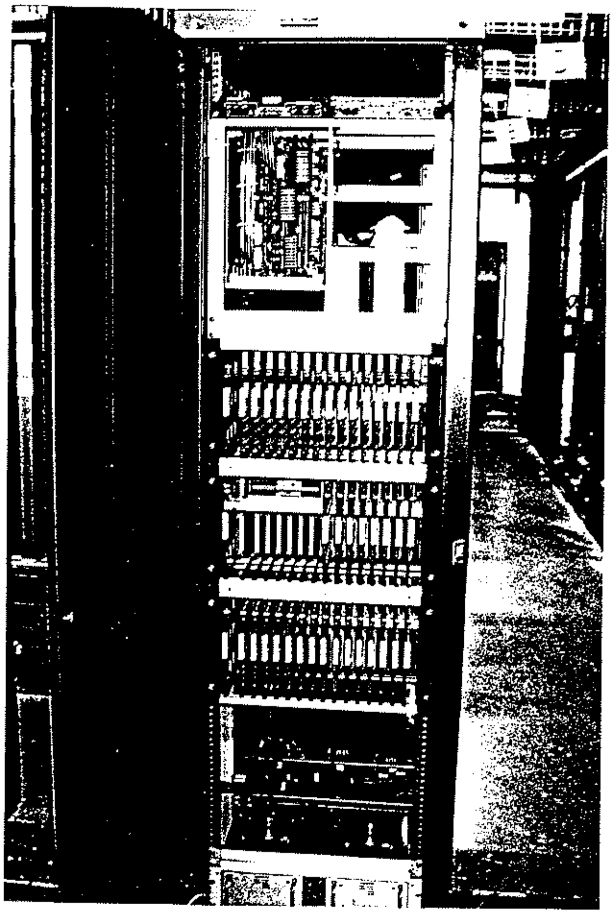
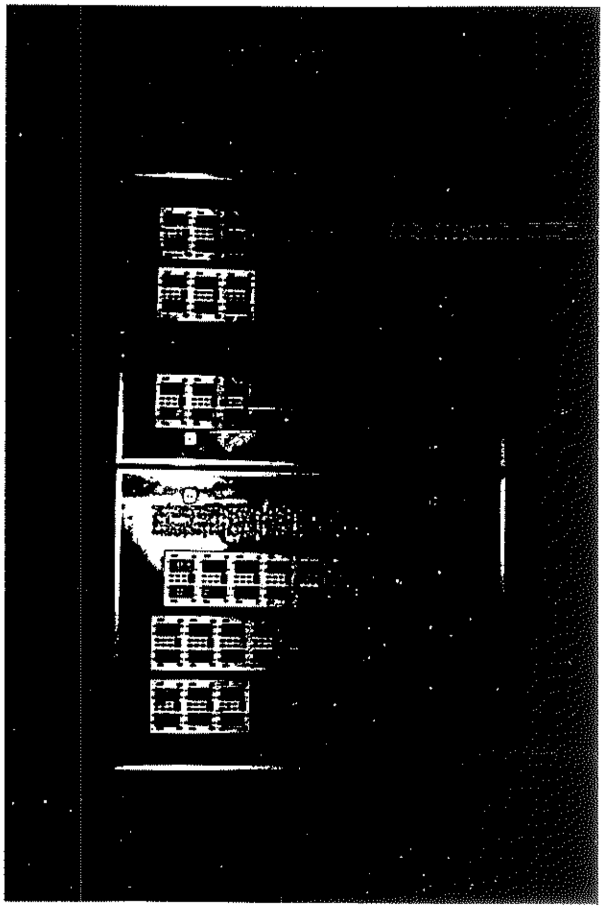
Deicing is achieved by switch connections to ground such that a 4 A/mm^2 current is achieved. Deicing is done in the morning before operations and takes about 15 minutes for 60 km.

Grounding of rails is done at 1500 m. intervals to masts and a continuous lead earth cable. Triple redundancy is used for glass insulators which shatter on impact; this provides reliability and prevents large chunks of broken insulator (as would be the case with ceramic insulators) falling on the track.

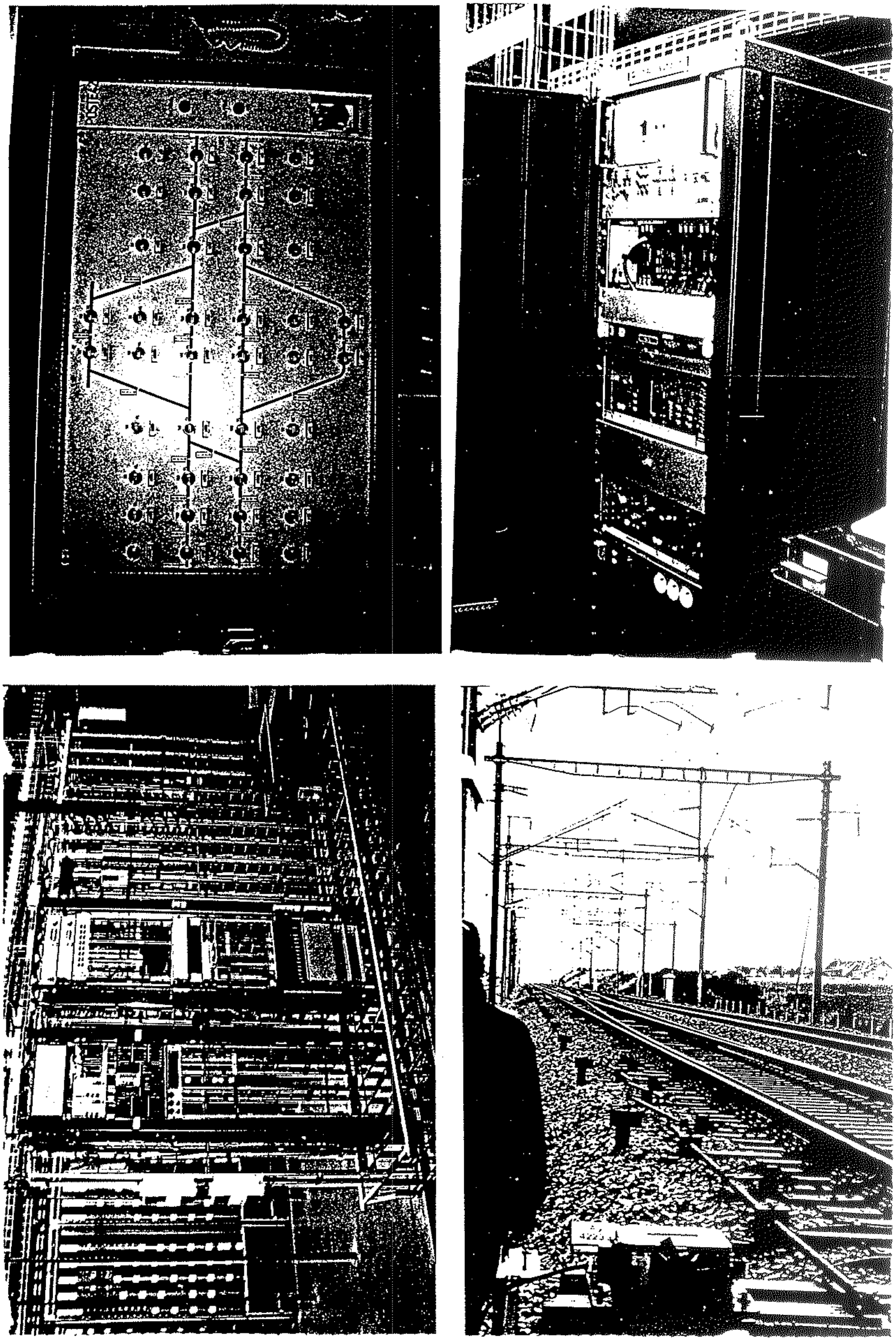
The question of payloads on the postal TGVs and on the TGV-Fret concept was raised with M. Dufresne in the afternoon. The postal TGVs have a nominal payload of about 60 tonnes (i.e., about 7.5 tonnes/trailer car in a 1-8-1 consist); typically the loads 'cube out' before they 'mass out'. The objective for the 'TGV-Fret' -- which is being taken seriously -- is a payload of 10 tonnes/trailer for a 1-8-1, or 80 tonnes total. The current postal operation is based on dedicated trainsets operating between specialized postal terminals. The plans for TGV-Fret are similar: dedicated consists serving existing and/or new freight handling facilities.

APPENDIX I

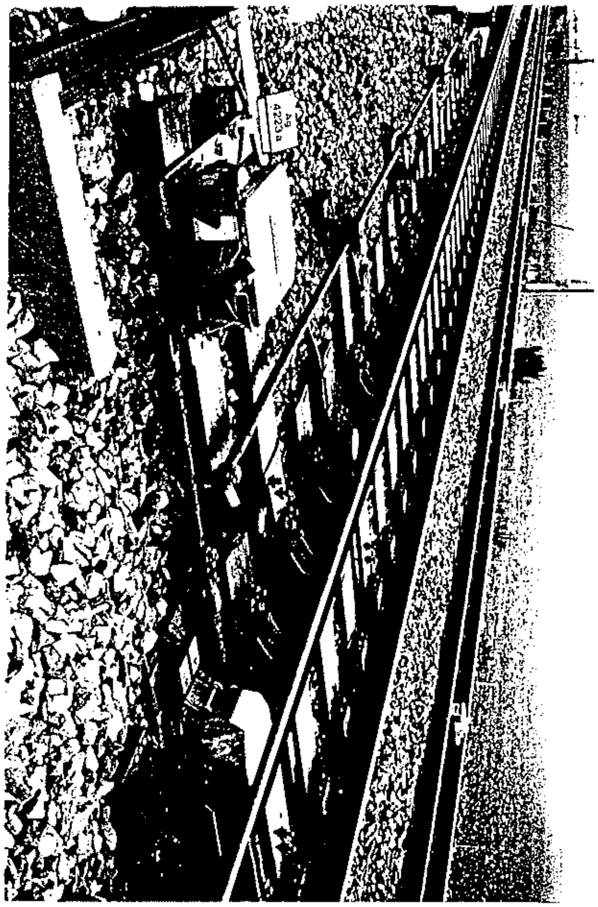
PHOTO REFERENCES FOR SNCF VISIT

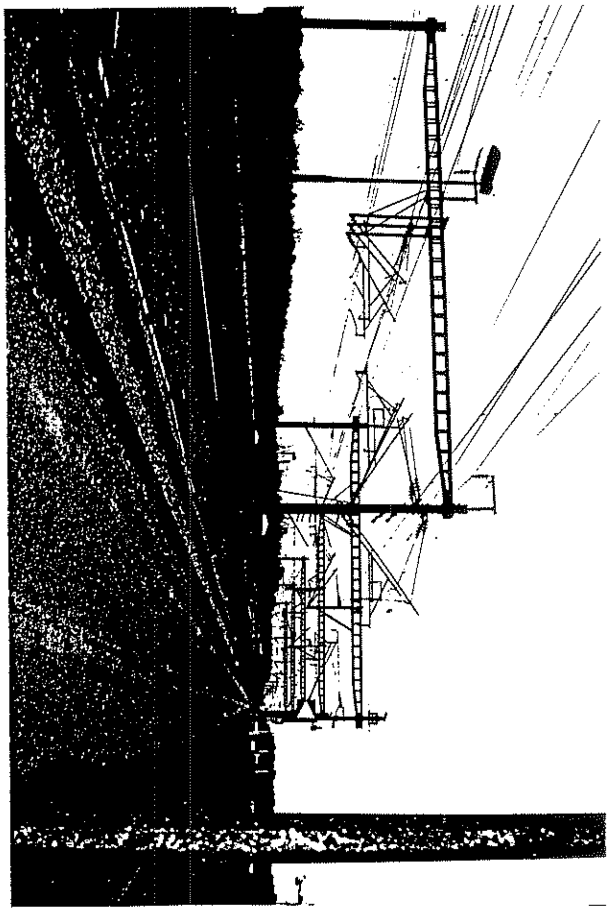





Photos I-1.1 — I-1.4

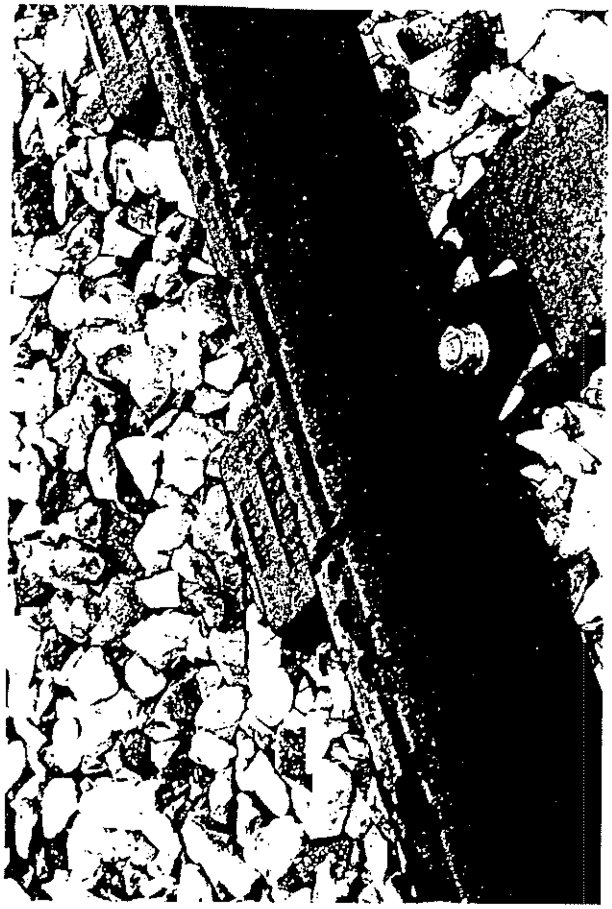


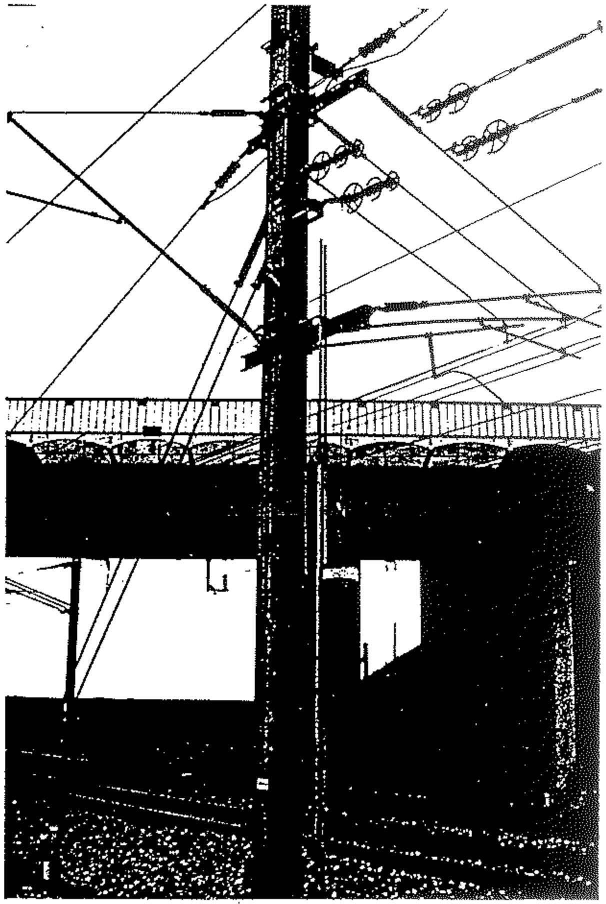
Photos I-2.1 — I-2.4

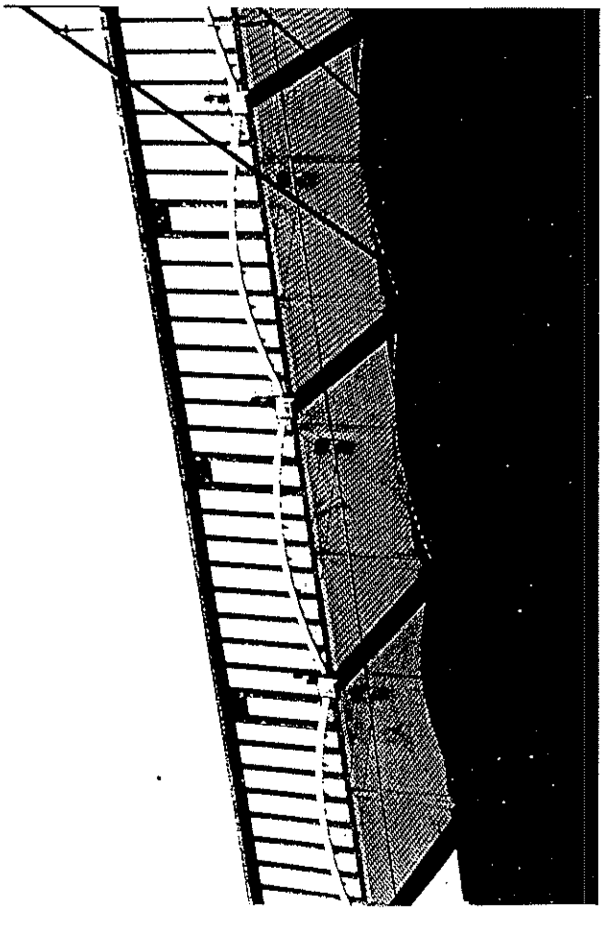


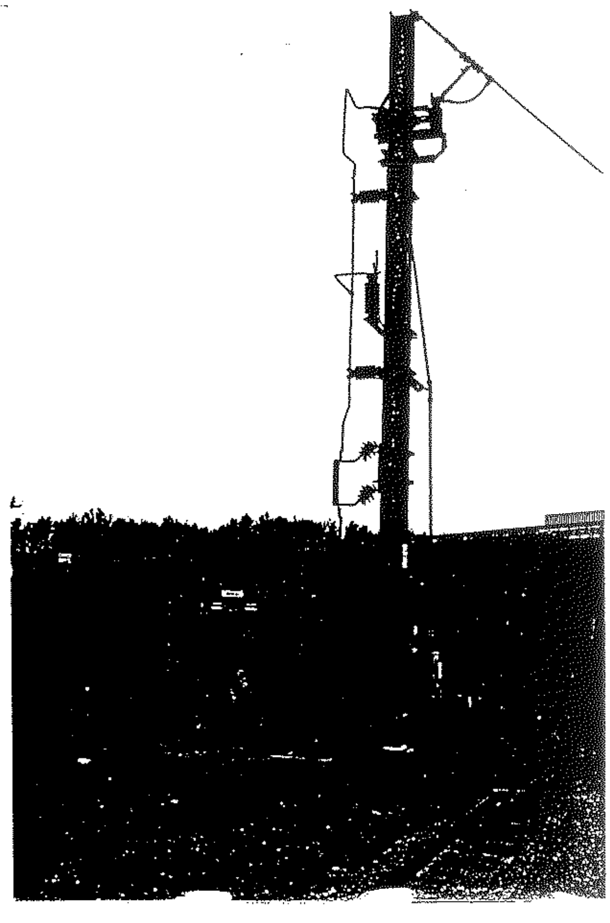


Photos I-3.1 — I-3.4

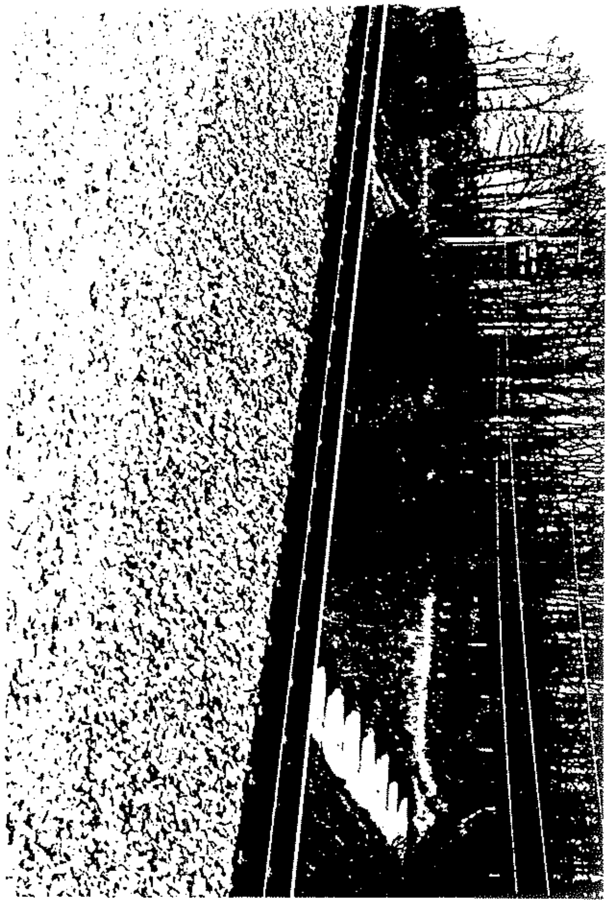


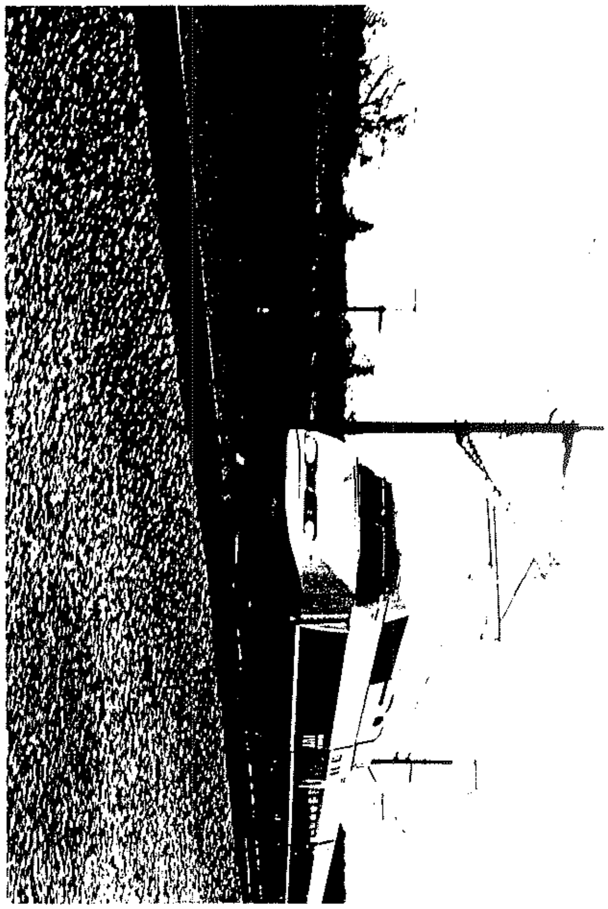




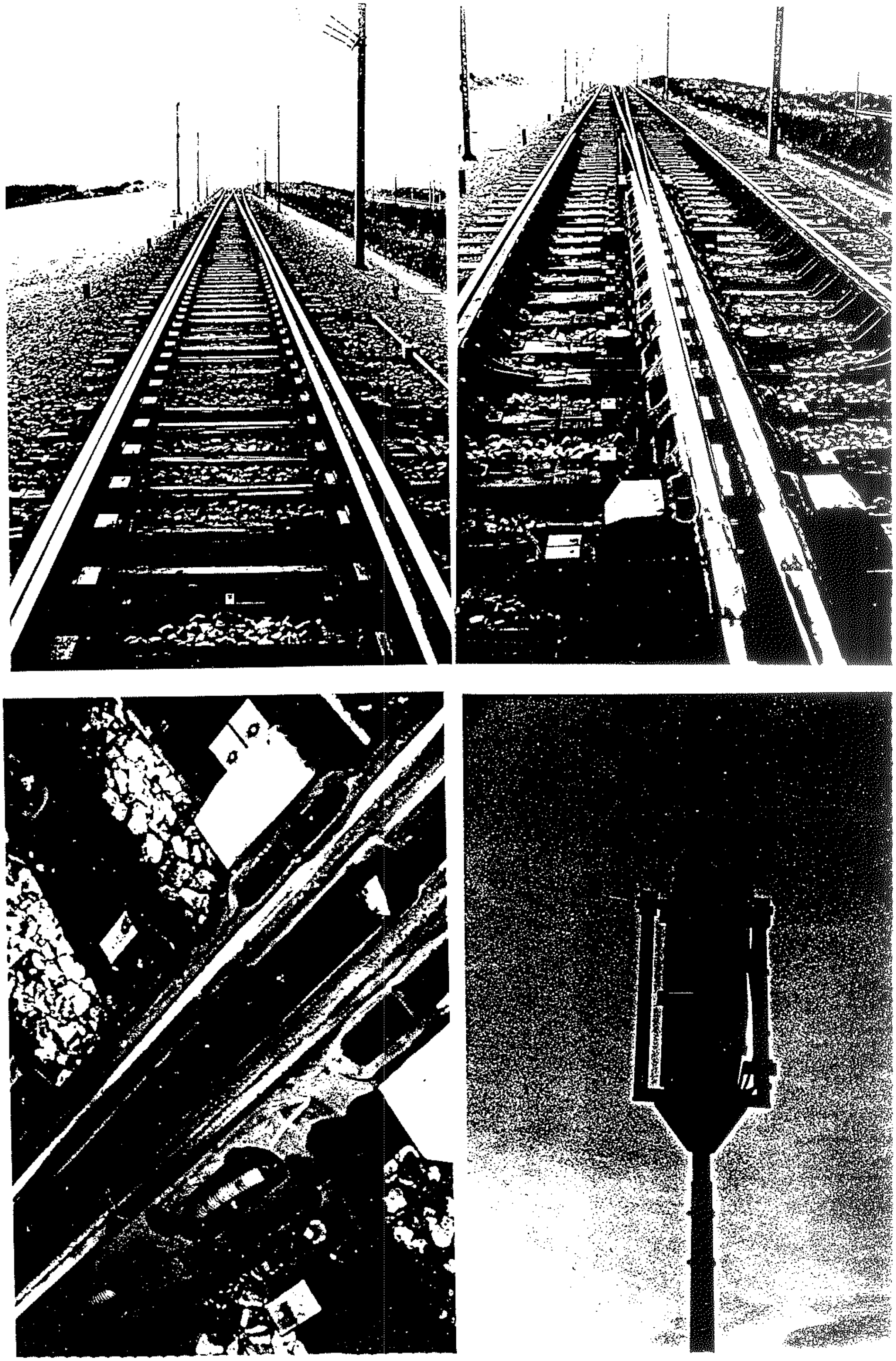


Photos I-4.1 — I-4.4

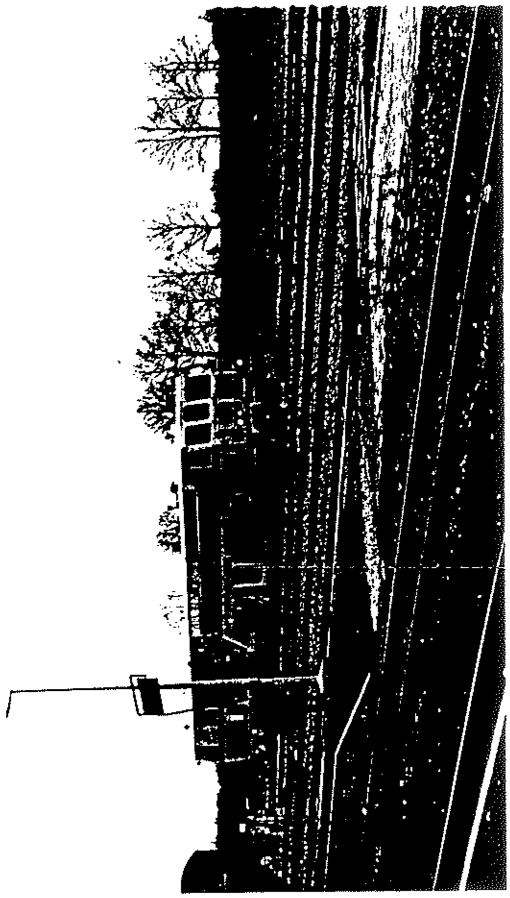
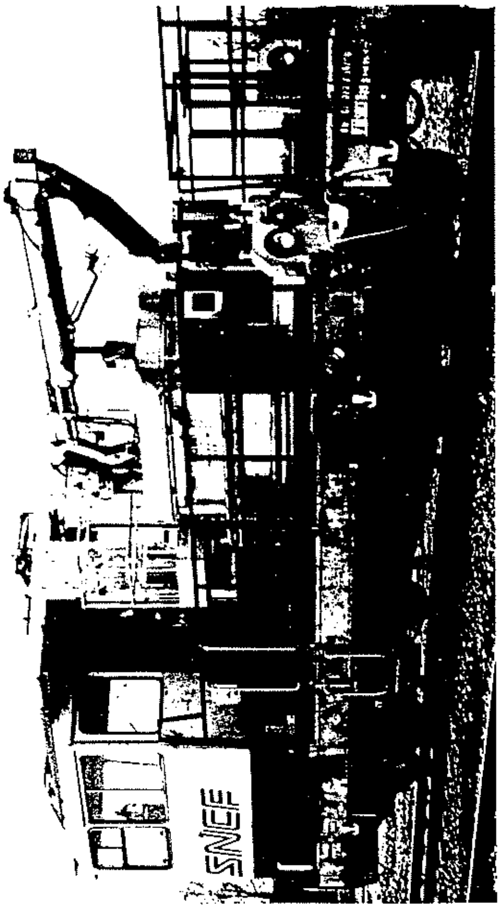



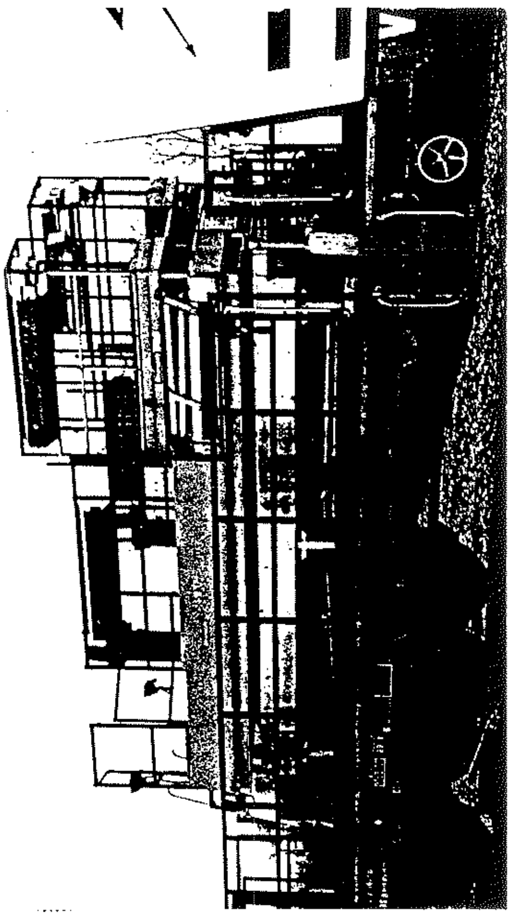


Photos I-5.1 — I-5.4

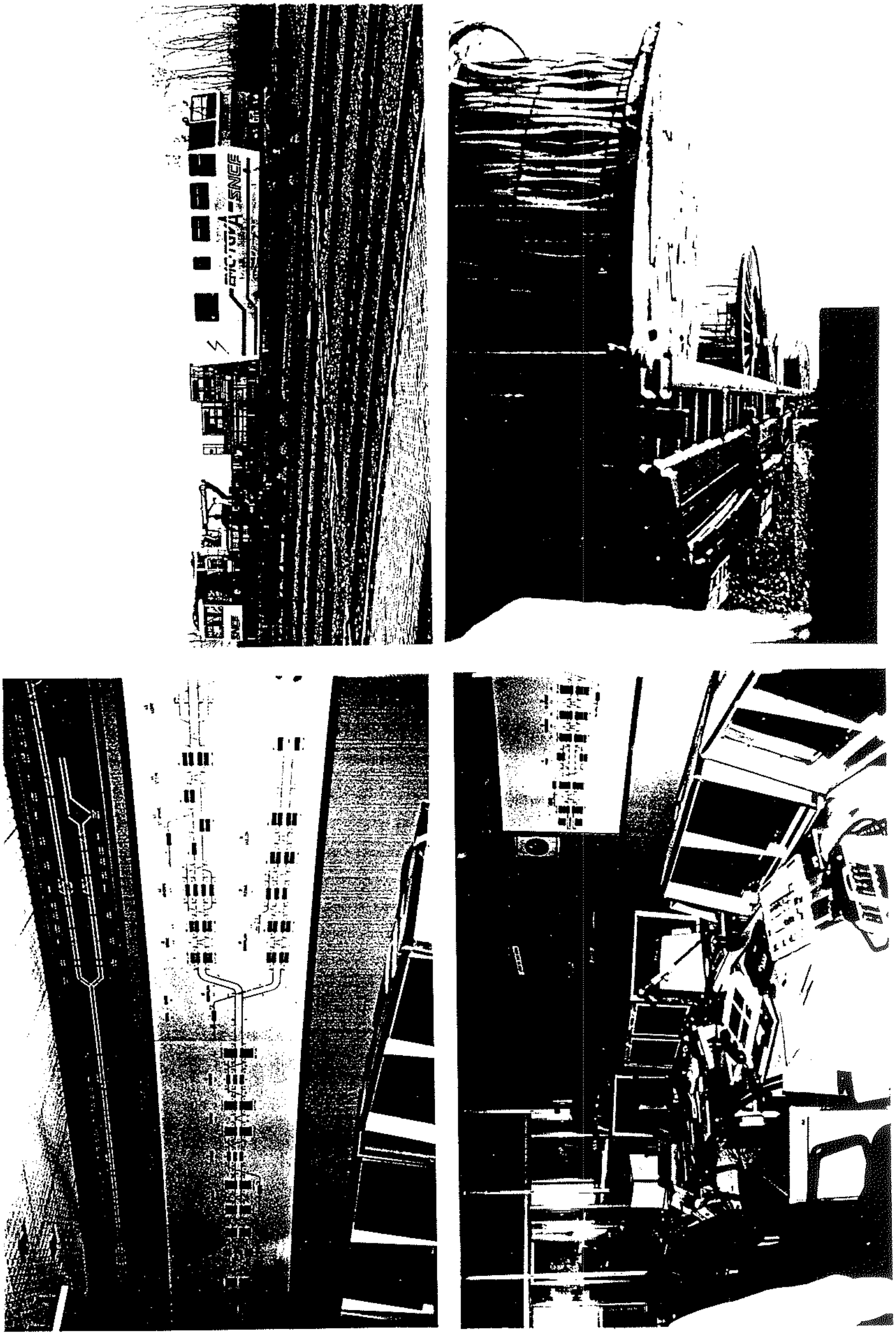


Photos I-6.1 — I-6.4

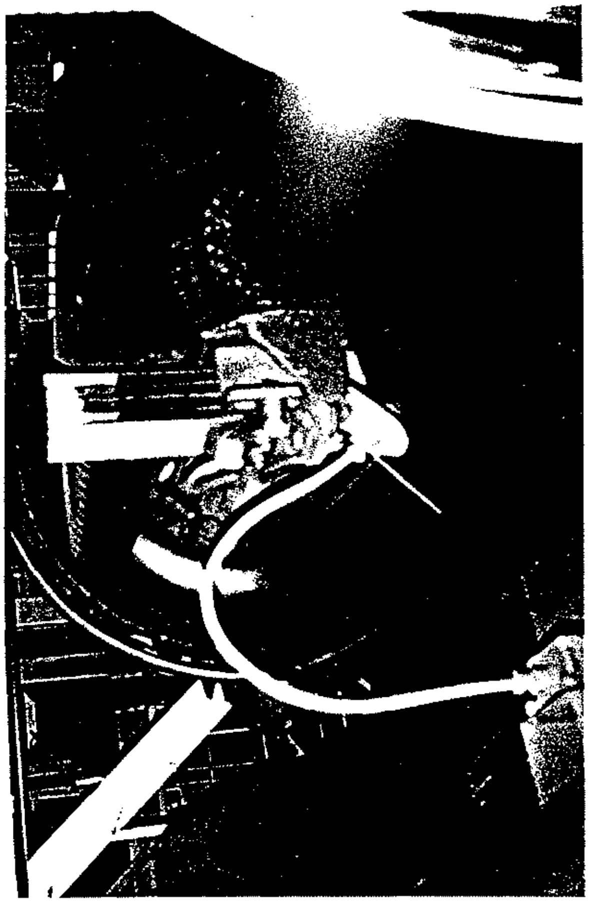
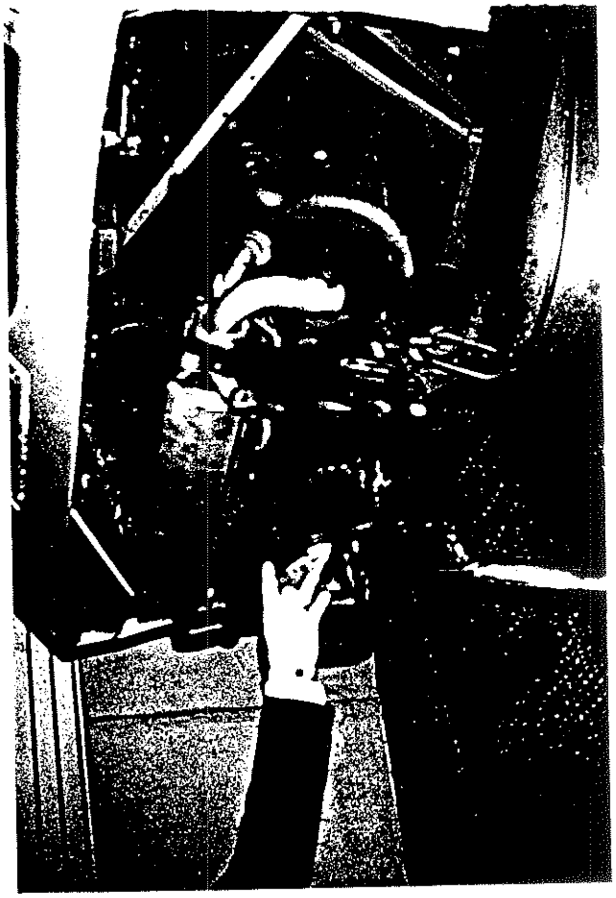



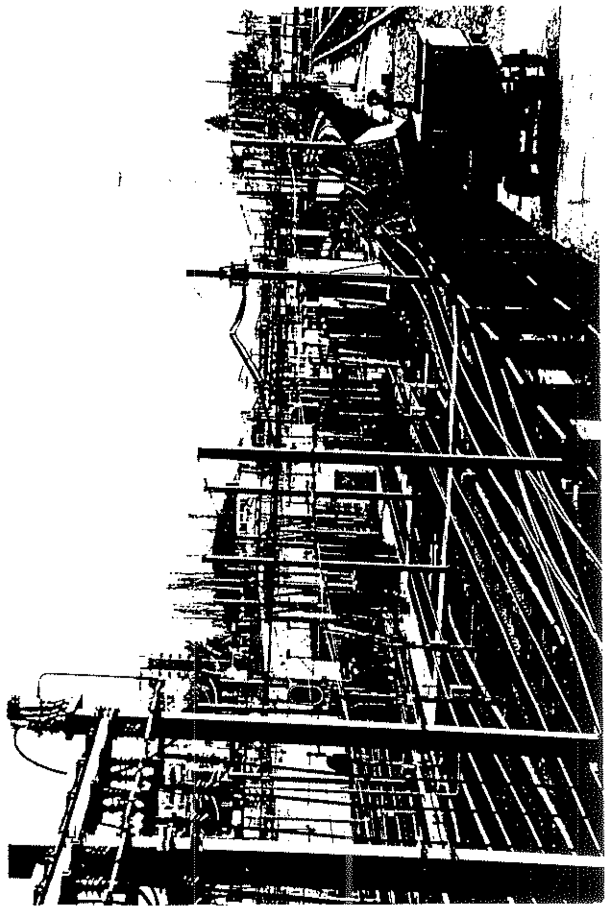


Photos I-7.1 — I-7.4

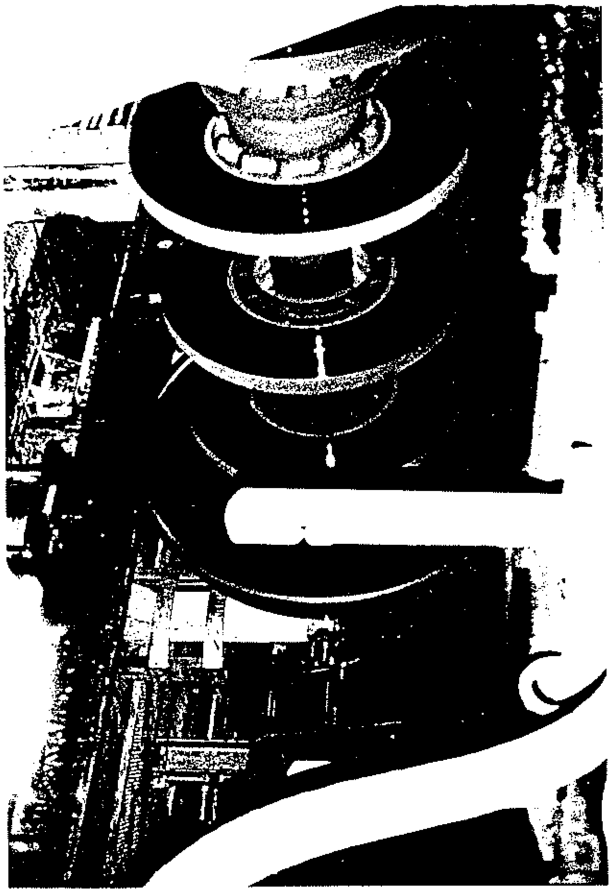


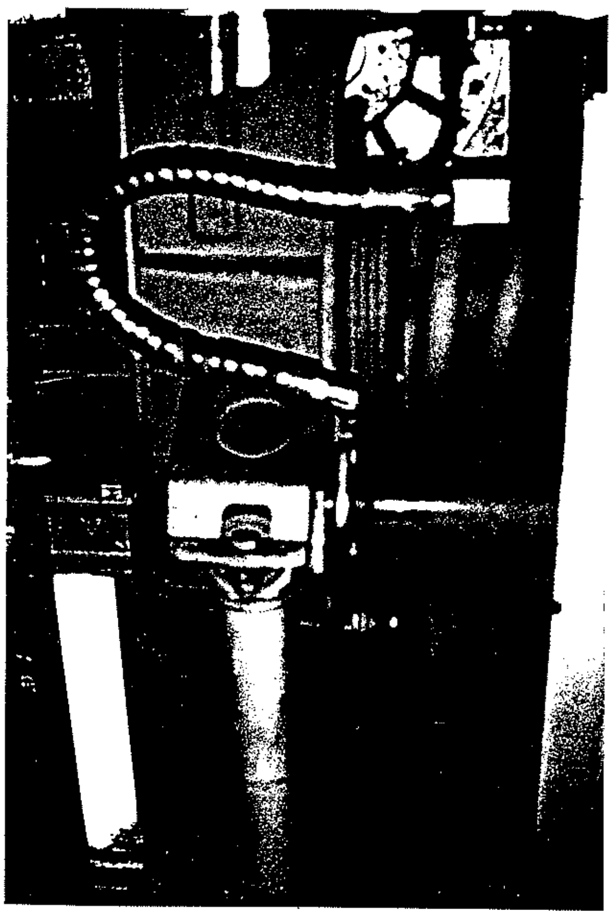
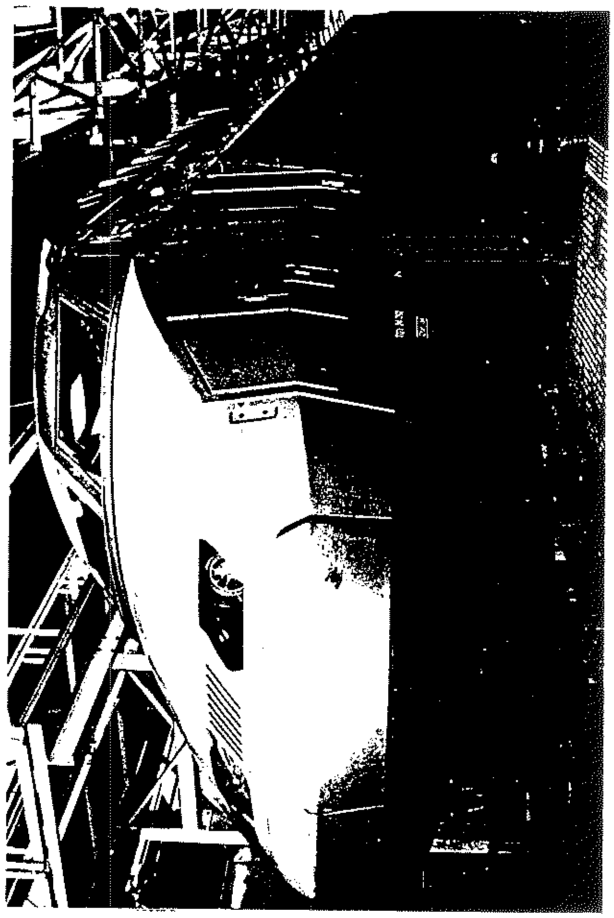
Photos I-8.-1 — I-8.4

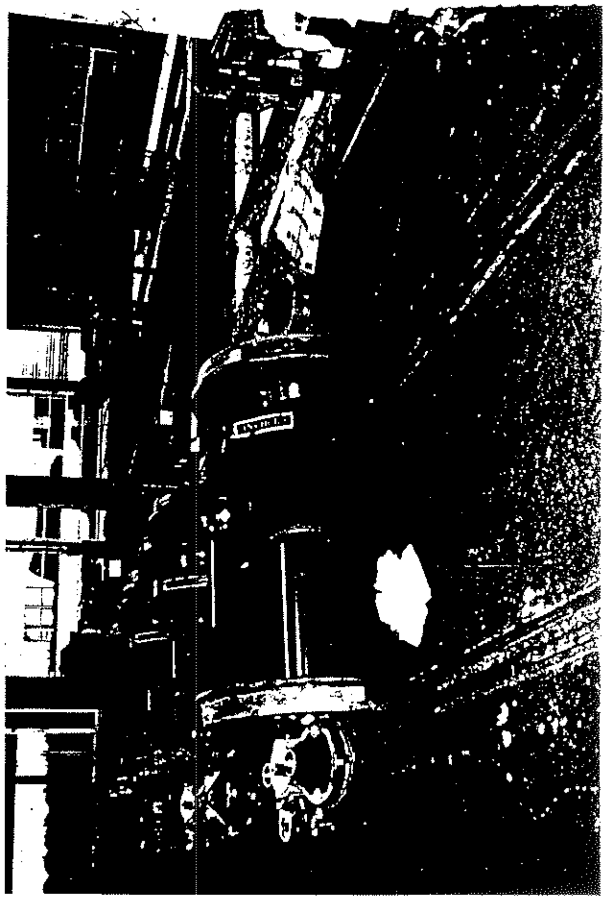


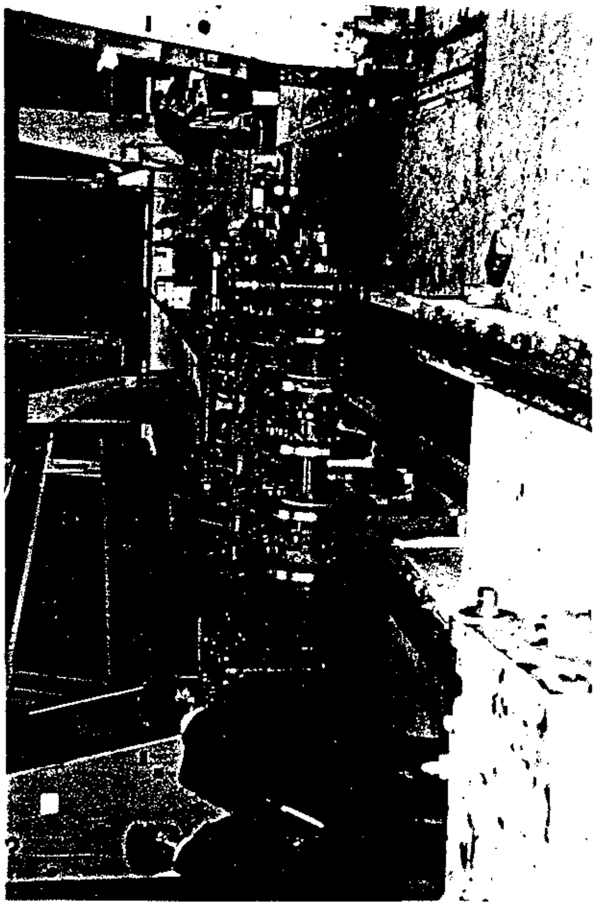
Photos I-9.1 — I-9.4

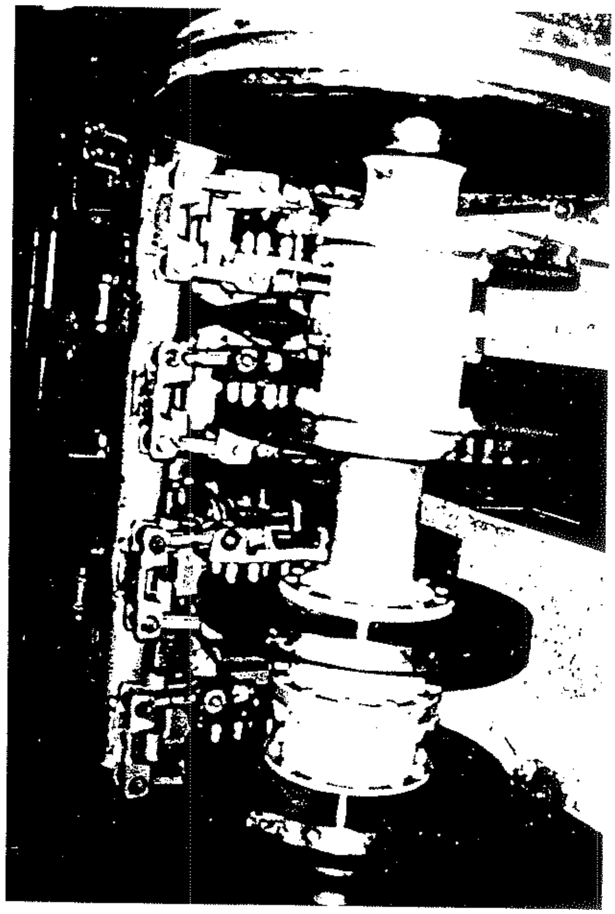


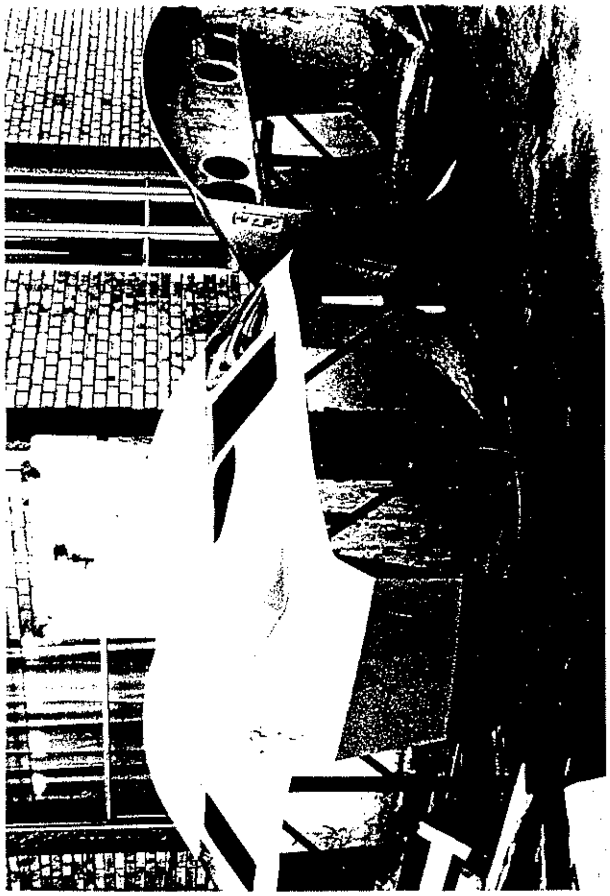
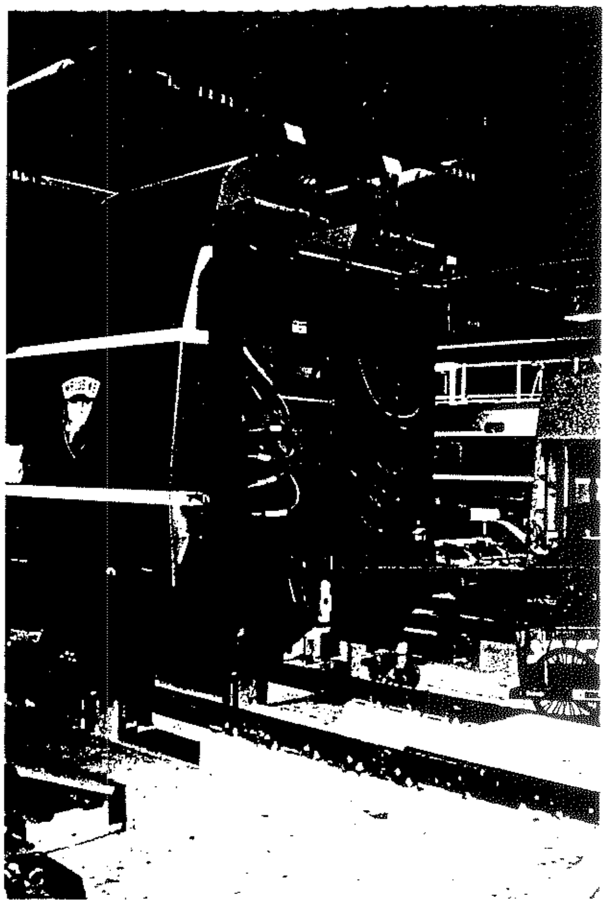
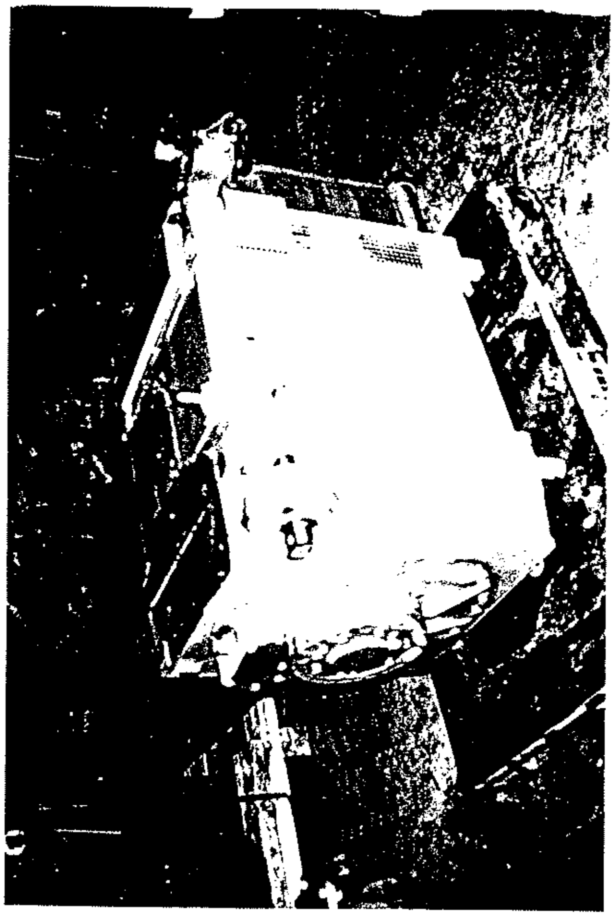
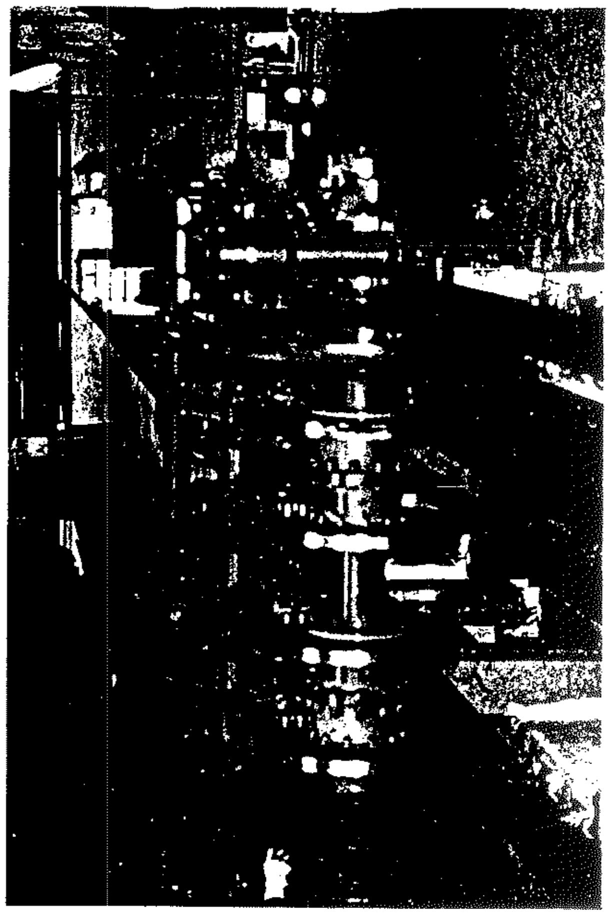
Photos I-10.1 — I-10.4



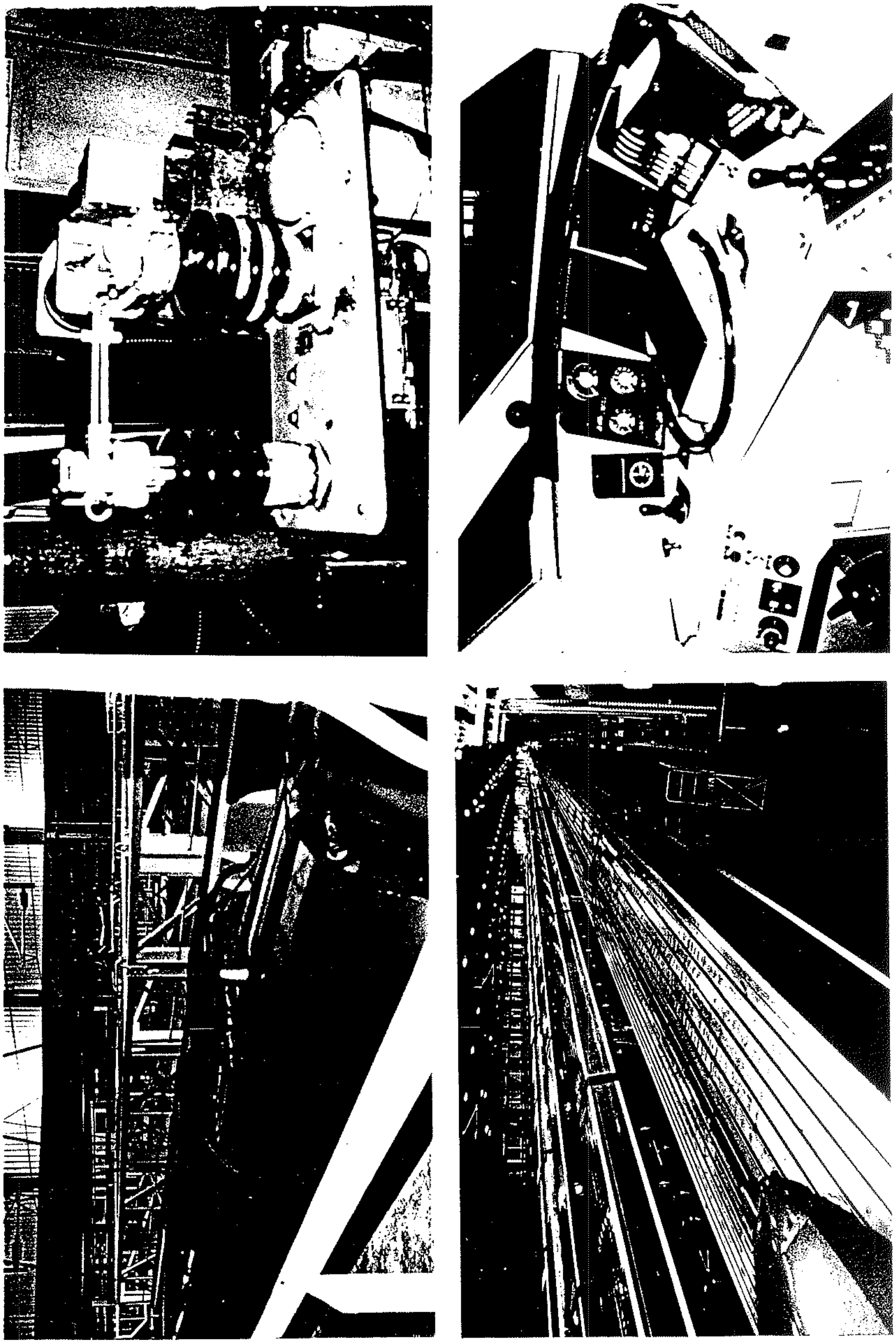




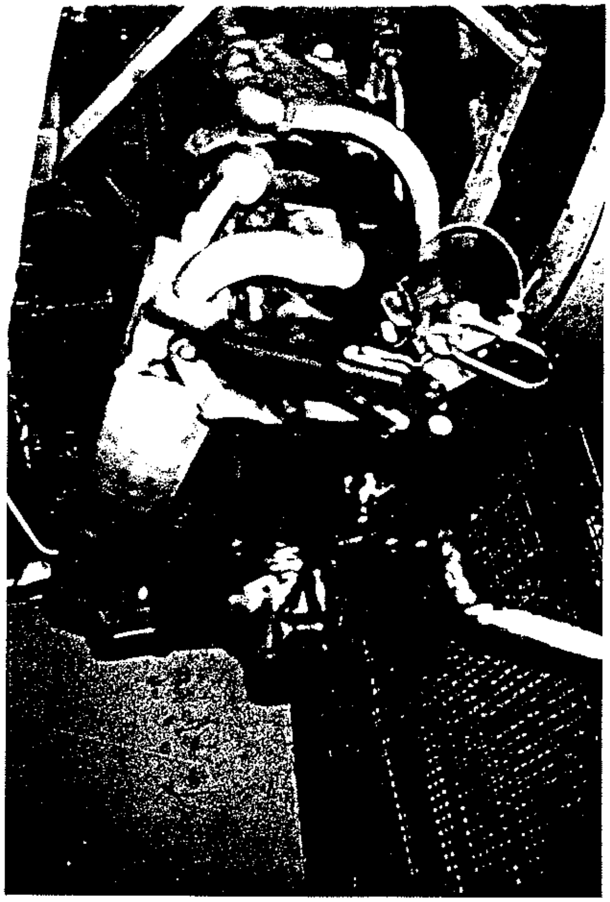
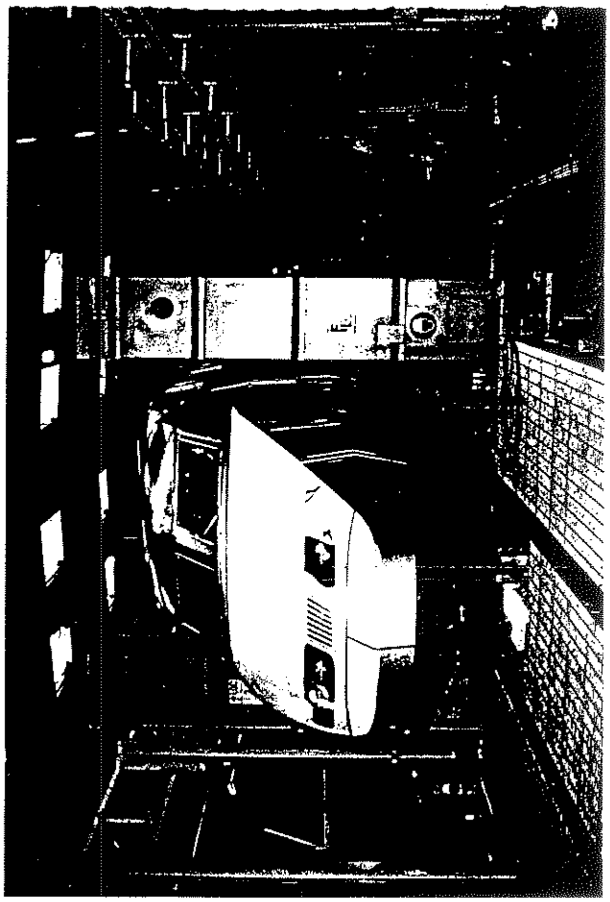
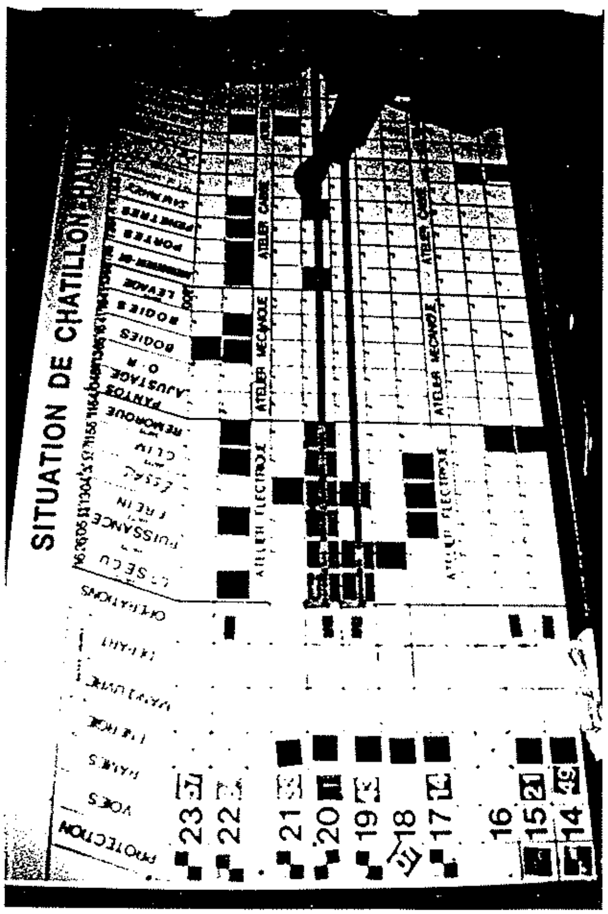
Photos I-11.1 — I-11.4

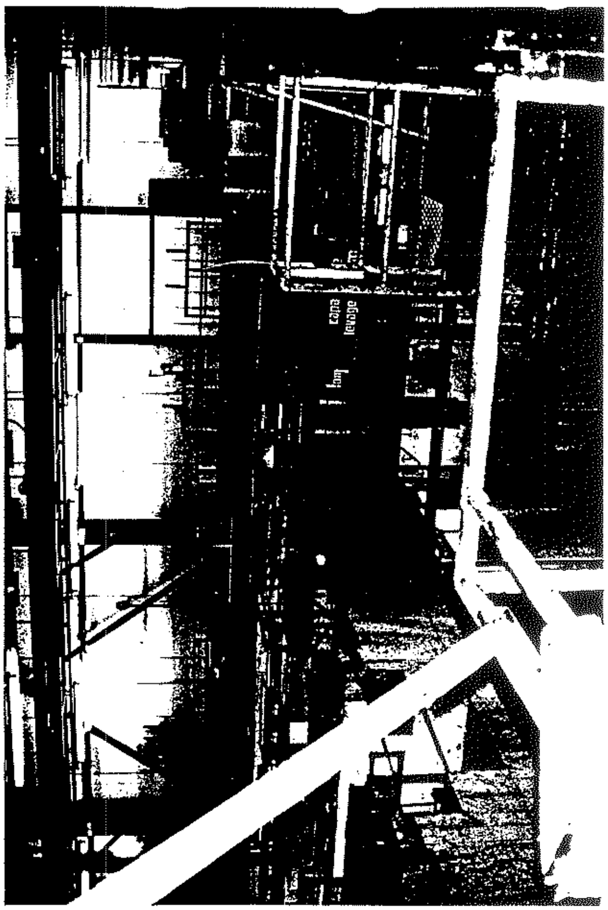





Photos I-12.1 — I-12.4

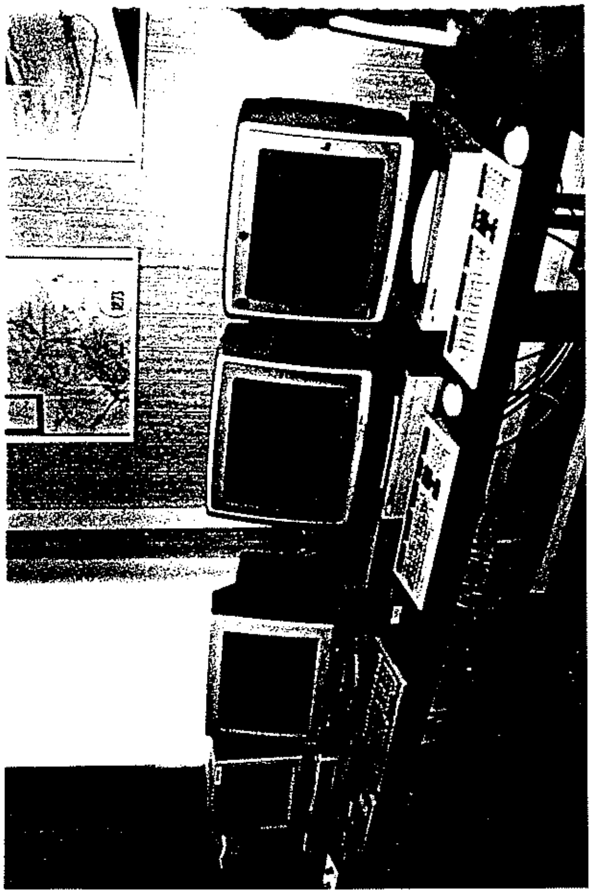


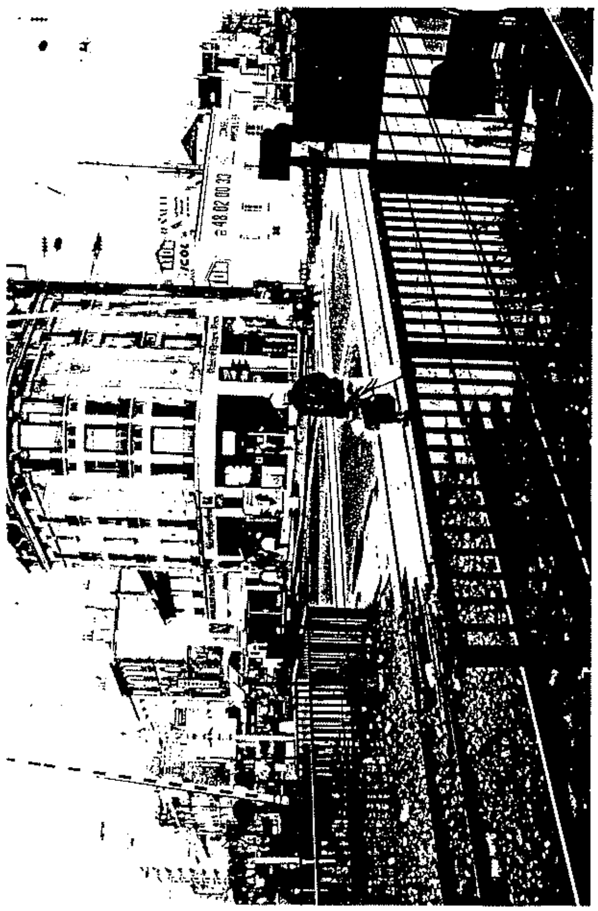
Photos I-13.1 — I-13.4

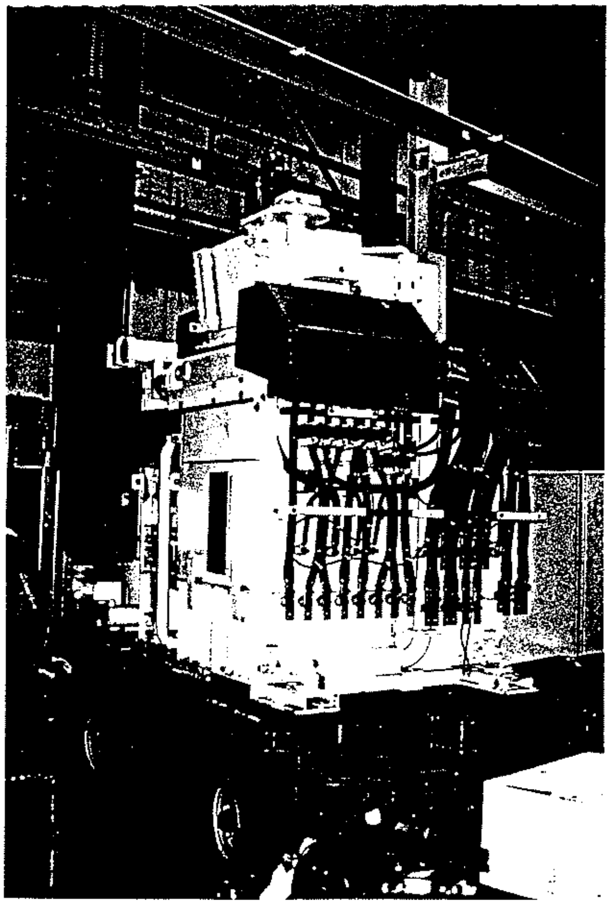


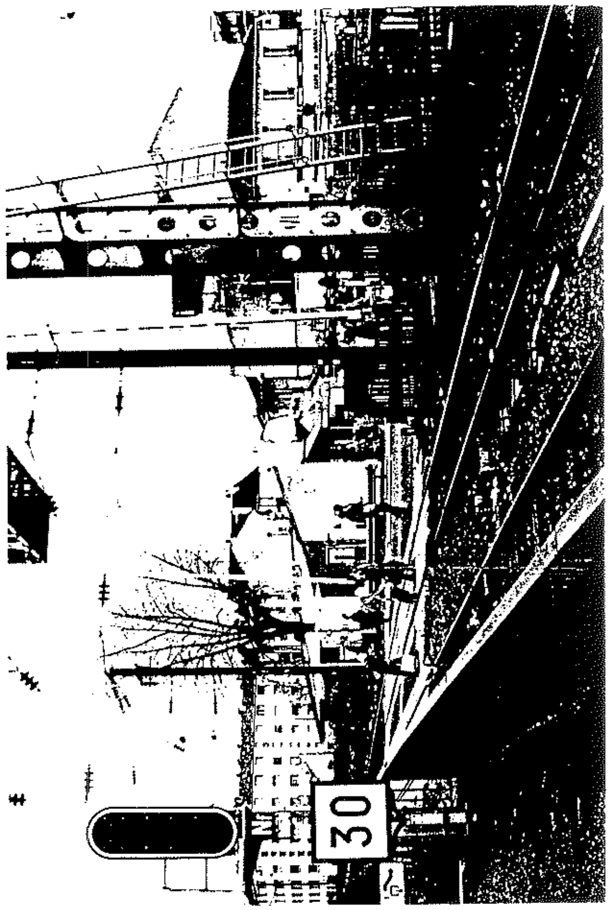
Photos I-14.1 — I-14.4

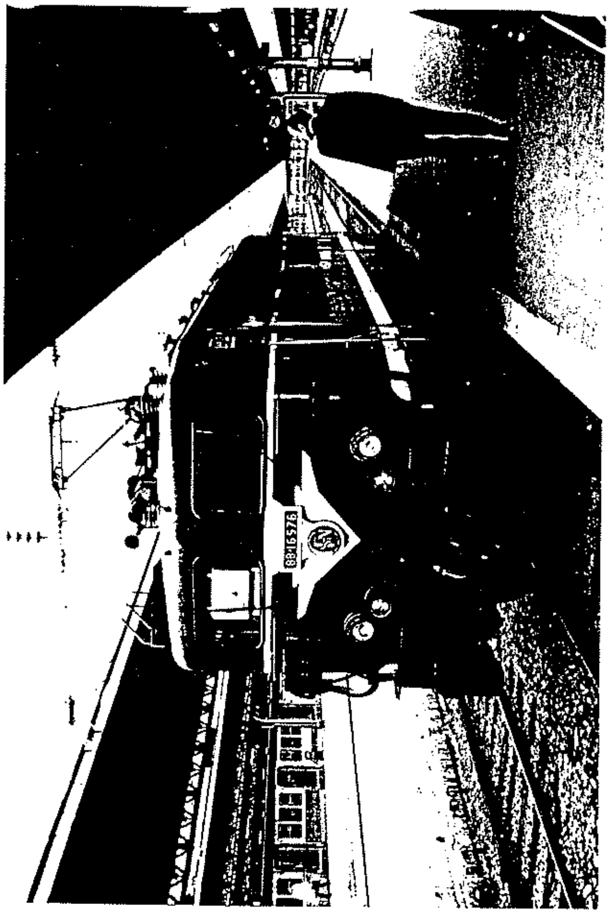


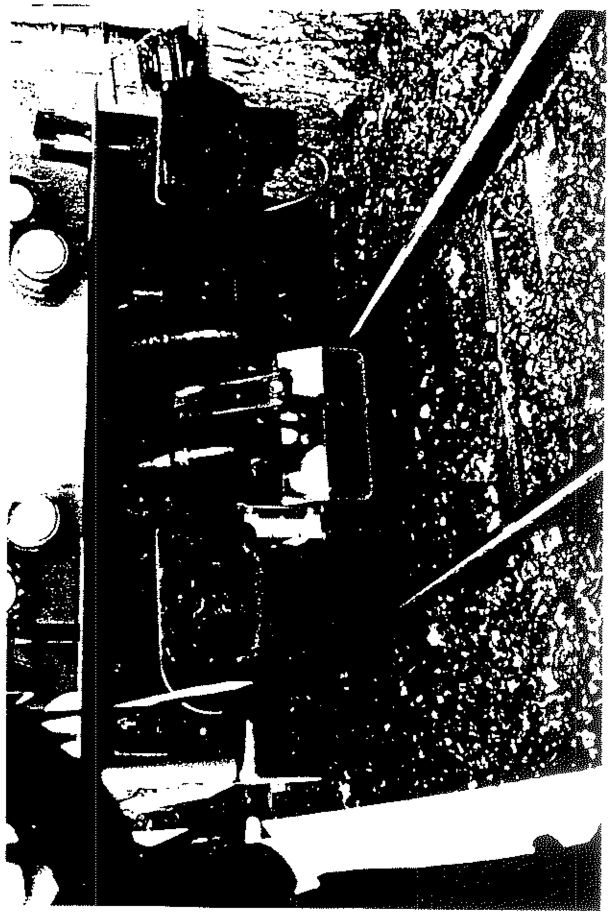


Photos I-15.1 — I-15.4









Photos I-16.1 — I-16.4

The site visit to Sweden was undertaken by Messrs Chris Boon and Gordon English of CIGGT. We arrived in Stockholm from Paris late on the afternoon of Sunday 29 November.

MONDAY, 30 NOVEMBER

Beginning at 0900, Messrs Boon and English met with Messrs. Hans Carlsson (Swederail), Bo Marklund (Swederail and SJ) and Bengt Furustam (Swederail and Banverket). Mr. Carlsson welcomed us to Sweden, and gave a snapshot summary of the country and its railroad system.

Sweden has about 8.5 million people, extends for more than 2000 km north to south, and has about 11000 km of railroad track, comprised of about 6200 km of mainline, 3500 km of regional lines, 450 km of heavy-haul track for iron ore movements, and about 1000 km of little-used 'inland' line that exists primarily for strategic security reasons. Of the total system, only 1200 km are double-track, but 5600 km have automatic train control (ATC), and 4150 are equipped with CTC. 5300 km of the network is laid with CWR, and 7000 km are electrified. The latter segments carry over 90% of the traffic.

At present there are 7 X-2000 services per day each way between Stockholm (1.5 million) and Gothenburg (.8 million). In August 1992 service was started between Stocholm and Karlstad (120,000), a distance of about 400km, with three departures in each direction.

Mr. Marklund then gave us a short presentation on the X-2000 from the standpoint of SJ. Mr. Maklund said that the X2000 was the first purchase made by the SJ under a life cycle cost approach. The interval between scheduled maintenance and the reliability specifications were included in the contract and negotiated with the supplier in terms of the tradeoffs on capital costs and maintenance cost. He noted that, because southern Sweden has had very mild winters the past few years, the winter performance of the production X-2000 trainsets has not yet been certified as acceptable by SJ.

Mr. Furustam was the final speaker of the morning. He began with a short explanation of how the Banverket (BV) came to be formed, what its responsibilities and mandate are, and how it is funded.

In summary, BV was formed in 1988 by separating the ownership and responsibility for construction and maintenance of railroad infrastructure from ownership, operation and maintenance of rolling stock. In principle, BV can grant any qualified operator access to its track, although so far only SJ has requested such access, either for its own operations or on behalf of subordinate governments to operate regional services.

As a distinct administrative entity, BV is now equivalent to the road authority in Sweden, and has similar access to federal funding. The criteria against which the performance of BV is judged have a socioeconomic focus; financial or commercial performance is important but not predominant. Just as the road authority can build new highways, so can BV construct new track: the Grodinge line south of Stockholm is an example of direct relevance to the X-2000 program and also to the assessment of the Quebec-Ontario corridor. The funding formula under which BV operates calls for 20% of the life-cycle (capital and O&M) costs of infrastructure to be paid for by operators (SJ to date) with the balance paid for through a government appropriation. Mr. Furustam noted that if SJ decided it required improvement in quality of the infrastructure provided, beyond that which BV had judged to be necessary, then SJ could negotiate the improvement, but with acceptance that it (SJ) might be required to pay the full cost.

After lunch, Mr. Marklund escorted Messrs Boon and English to the SJ depot and workshops at Hagalund, a suburb of Stockholm, to inspect the X-2000 equipment undergoing inspections and maintenance there [Reference Photos II-1.1 through II-3.4 plus II-4.2]. This facility has undergone some internal modifications to facilitate efficient X-2000 maintenance, but is basically a pre-existing SJ rolling stock maintenance and storage facility.

We had the opportunity to examine several X-2000 sets that were in the shop, including getting down in the inspection pit to look at the powered and unpowered trucks and drive train, walking through a complete trainset, and watching a driver power up a set and work through the pre-trip checklist prior to moving the trainset to the Stockholm station for an afternoon departure. Mr. Marklund noted that SJ has a chronic problem with the intrusion of moose on its tracks, and there has been at least one moose/X-2000 collision, although he was not certain of the speed at which it occurred. The damaged nose cone (shown in Photo II-4.2) was one consequence of the accident. This could be a problem for Canadian operations, at least for portions of any alignment between Quebec City and Ottawa, unless fencing is provided and maintained.

While on site we noted a pair of X-2000 sets coupled together. Mr. Marklund stated that although the intention had not been to do so, SJ had decided to use this configuration in response to particularly high peaks in demand. Coupling the sets requires manual removal of the streamlined cowlings on the driving trailer of the lead set and the power car of the trailing set. Each set must have its pantograph up. This arrangement also causes some problems with pantograph/catenary interface due to incomplete damping of the dynamic effects following passage of the lead pantograph. SJ always operates its X-2000 sets with the power car in the direction of Gothenburg and the DT in the direction of Stockholm. Their feeling was that with one direction only, they will always know that the pantograph separation is 6 cars. If they had some trainsets reversed, they may get a 10 car separation or they may get only a one car separation. This indicates that turning a consist, or switching from tail end to head end presents a significant time or cost penalty in their operation.

We then visited the maintenance supervisor so we could see the computerized fault tracking and maintenance activity planning and monitoring system. This allows tracking of each vehicle in terms of faults diagnosed, faults corrected and required maintenance inputs, and also non-critical faults in fault-tolerant subsystems, correction of which has been deferred to the next scheduled maintenance period.

We then returned to the Swederail headquarters to meet with Mr. Anders Ekman to discuss transportation planning and other operational issues. Mr. Eckman provided an overview of the X2000 introduction to service. He noted many of our questions and arranged to have them addressed in a later meeting scheduled for Wednesday with Mr. Fora.

TUESDAY, DECEMBER 1

At 0645, Messrs. Boon and English met Messrs. Marklund and Furustam in the Stockholm Central Station, then boarded train 405, the 7:05 AM X-2000 departure to Gothenburg (Photos II-4.1 and 4.3). We rode in the first-class compartment, and were served an excellent breakfast by the very efficient and pleasant attendant, who was also responsible for checking at wayside that passengers were boarding the correct car and for collecting tickets. As with virtually every Swede we had occasion to speak to, her English was excellent.

During the first third of the journey south from Stockholm, the ride quality was remarkably poor. Even our hosts seemed rather surprised at just how bad it was. Although the speed was 160 km/h or less, severe lateral jerks were frequent and vertical acceleration and vibration were quite noticeable. Overall, the ride quality was inferior to that of the LRC on the CN Kingston subdivision after correction of spring thaw alignment defects. Mr. Furustam noted that the track in that section of the line was of inferior design (dual-block ties with an inadequate cross-piece, fasteners with low and variable hold-down capabilities) and that significant work was planned for the next couple of seasons to overcome the problems. The last 300 km of the trip, on track built to better standards (concrete monoblock ties with pandrol fasteners, among other things) was much better in terms of ride quality; the X-2000 ride was markedly superior to the above mentioned LRC ride quality.

We arrived at Gothenburg (Photo II-4.4) on time (10:04) and proceeded by cab to the X-2000 workshop in Gothenburg. This is the principal X-2000 facility, where most of the major maintenance activities will be performed as they are due. We met with the maintenance manager, and discussed maintenance cycles and practices as applied to the X-2000. (Photos II-5.1 through II-5.4)

The 13 trainsets in service at the time of our visit are still under warranty to greater or lesser extent. The complete trainset is covered for one year, with extended coverage of varying length on specific subsystems and components (e.g., computers - 2 years, axles - 5 years).

Each trip, the trainsets receive an interior cleaning, and the brakes are tested by the driver. If a defect is discovered, the guard train held at each terminal can be substituted with little or no loss of schedule. During winter, there may be some arcing problems due to frost on the catenary, but this can generally be resolved in 10 to 15 minutes in the station. The cleaning requires about 30 minutes with 6 to 8 people per trainset per trip, or about 10 hours per day per trainset, including vacuuming. As well each car receives a 'deep cleaning' including wet vacuuming once a week. Each trainset receives an exterior washing daily.

On a daily basis, there is a more extensive brake check, a check of the pantograph, and check and monitoring of the on-board fault detection and diagnosis system.

The most frequent workshop-based maintenance activity is the so-called 'T' inspection. This is performed every 6250 km or weekly, at either workshop, and involves an under-car walk-through inspection, brake test and change of brake shoes as required, and inspection of hydraulics. Toilets and side doors are also checked. The T inspection requires 5 hours of labour, and is normally performed at night, and in conjunction with some portion of an Overhaul-1 (OH-1) under the 'split system' used by SJ to level out hours out of service and make best use of both rolling stock and maintenance assets. To date, the defect detected most frequently in T inspections is leakage in the hydraulic system. [A gasket design has been modified and is being retrofitted so this should be resolved.]

The OH-1 involves all 'T' activities, plus inspection of underfloor equipment and hydraulic pumps. Side door and toilet functions are tested using the on-board computer diagnostics. ABB specifies changing all HVAC filters, but SJ is of the opinion that these filters will last longer than the 25000 km/4 weeks to an OH-1. The OH-1 requires 25 labour hours (including the 5 for the embedded T inspection). The OH-1 inspections and tests are split up and performed as add-ons to the weekly T inspections as noted above:

```
          W1    W2    W3    W4    W5

Conventional:  --              --  25 p-hr


          OH1              OH1

             --  --  --    5 p-hr
              T   T   T
          --  --  --  --  --  0


Split System:

          --  --  --  --  --  10 p-hr
          OH1   OH1   OH1   OH1   OH1
          --  --  --  --  --   5 p-hr
          T   T   T   T   T
          --  --  --  --  --   0
```

The practice of staggering the activity associated with a scheduled maintenance over a two-three week interval rather than taking the equipment out of service for a 2 - 3 day block is a good idea for light density corridors like ours. When a small number of trainsets is involved it helps to smooth out work activity and also provides better availability.

OH-2 maintenance is carried out every 100,000 miles or 4 months, but to stagger the timing the process starts for the first trainset at 85,000 km and is completed for all trainsets by 115,000 km. This activity subsumes all T and OH-1 inspections and tests, plus tests on the moving parts of all doors, a major brake test, scheduled renewal of filters, and check and replacement as required of lubricants and brake pads.

OH-3 occurs at 300,000 km and again is staggered to start at 255,000 km and end by 345,000 km for all sets in the fleet. OH-3 subsumes all T, OH-1 and OH-2 activities. As well, all safety-critical subsystems/components are inspected, tested and if necessary replaced, as a priority. Other activities include wheel reprofiling, detailed inspection of all mechanical elements in interior and exterior doors, and hydrostatic cleaning of hydraulic oils (oils are changed every 1,200,000 km). This work requires 10 days of trainset time with 400 to 500 person-hours of labour.

OH-4 takes place every 600,000 km, and requires 800 to 900 person-hours of labour. Bogies and suspension components are inspected and wheels turned as required. All underfloor components are removed for inspection, testing and repair as required and replaced with new/refurbished modules.

Note that at this stage the traction motors and drive train still have not been touched, beyond filter changes for the roof-mounted air inlets and lubricant changes in OH-3 for the motor/cardan shaft coupling and the cardan shaft/axle gearbox. There are no scheduled changes for the bearings, although these are changed automatically whenever axles are changed out.

One maintenance requirement that struck us as a potential source of extra maintenance is the small differential wheel diameter permitted on powered bogies. Because both traction motors are linked to a single controller, SJ considers that it is essential for all four wheels be maintained to within 2mm of the same nominal diameter. (This tight wheel diameter tolerance was later discussed with ABB. They indicated that 5 mm was the acceptable limit.) Wheel diameter tolerances are a common concern with ac traction. One alternative is to provide separate controllers for each axle (which would also allow isolation of each motor separately rather than of an entire bogie as is now done). However, SJ's life cycle cost approach in developing the equipment specification arrived at a common supply bus specification.

Falling chunks of snow/ice splashing ballast is a concern for SJ. The maintenance manager cited as an example of the problems caused by this phenomenon the piercing of brake hoses by ballast particles. Following discussions with DB, which has also experienced this problem, SJ/BV are looking into the efficacy of brushing ballast at least 2 cm below the top of the tie.

After a brief tour of the maintenance shops, we returned to Gothenburg station and caught the 1:00 pm X-2000 back to Stockholm. On this trip we were able to visit the driving trailer and observe first-hand the effects of operation of the tilt mechanism [Photos II-6.1, 6.2 and 6.3]; note angle of tilt relative to the horizon and also the wayside signalling and in-cab ATC. With one interesting exception, everything went smoothly, and the ride quality was very good, with no sense of lag between spiral entry and tilt onset.

The exception occurred as we approached a level crossing. The ATC system indicated that the crossing protection mechanism was not in the proper 'down' position, and imposed a mandatory stop-and-proceed (at 30 km/h) as the crossing was approached. Under this order, the driver can proceed at that speed past the last signal provided s/he can verify visually that there is no road vehicle on the crossing. In the event, it turned out that one of the full-width dates had jammed part way down.

WEDNESDAY, 2 DECEMBER

Messrs. Boon and English met with Messrs. Furustam, Marklund and Curt Fallman of the Swedish Railway Inspectorate, at the Swederail offices.

The Swedish Railway Inspectorate has an oversight safety responsibility, and was created in parallel with the SJ/BV split, to ensure that no critical safety functions were 'lost' in the division. (Both SJ and BV also have internal safety groups.) SRI is analogous to the FRA or the TC Safety Group, but it also has responsibility for metros, tramways and other fixed-guideway transit systems.

The first topic of discussion was signalling, train control and safety.

The interlockings used on the SJ system now are almost all solid state. Safety of vital logic is achieved through the use of what is termed 'software diversity', rather than through the use of redundant hardware. Essentially, there is a single processor running two distinct programs -- A and B -- that have been created by different programmers using different architectures to achieve a common objective. The input to and output from the programs differ slightly, all the way through to the actuator commands. The interlocking has one processor, two programs, two communications channels, and a comparator function that allows tracking of agreement of the sense of the command and system status at each stage. If there is disagreement, all trains are stopped. This provides fail-safe logic for all vital functions.

The SJ approach to automatic train protection has been to totally tie the system into the existing wayside system. The transponders are powered and transmit a signal to the locomotive giving the indication of the wayside signal. This is tied in to the point that a burnt out light at wayside will be transmitted as a stop-and-proceed to the locomotive. The onboard computer enforces the signal aspects received. The ATC can and does provide much more information to drivers than can wayside signals. There are still some low-density freight lines which are not equipped with ATC. So far there has been no decision taken on eliminating wayside signals.

Drivers can be given special authorization by radio to pass a red signal, but are then required to perform certain procedures to override the ATC, and are limited to 40 km/h.

The SJ/BV chose to implement their intermittent transponder-based ATC after extensive investigation. It is their opinion that continuous systems such as the LZB used in Germany are too expensive and also too vulnerable to disruption (LZB requires a continuous cable down the centre of the track on top of the ties, where it is exposed to derailments, dragging equipment, errant maintenance activities, vandalism, and similar hazards.) The Swedish system costs about half as much as the LZB, according to Furustam. He asserted that the investment in the ATC has been 'profitable', in the sense that the reduction in costs due to accidents and avoidable delays has been greater than the initial cost of the system.

The transponder beacons are installed between the rails on the track centreline and are paired to permit detection of train direction; the paired beacons are *not* redundant. Each transponder can transmit three 8-bit 'words': X, which defines the type of beacon; Y, at the signal, which contains the main signal information, such as top speed, for the current block; and Z, which provides 'distant' or 'look-ahead' information for the next signal.

For the X-2000, all speed information is provided by the ATC, and the level-crossing interlockings are also tied to the ATC. The length of the signal sections varies from 1km to 2.5 km, with the longer sections on the central high-speed section and the shorter sections on either end where there are numerous commuter and regional trains.

At 200 km/h, crossing barriers begin to lower 6 km ahead of the train. Each crossing requires at least 12 transponders, some have as many as 50.

In total, there are about 10,000 transponders between Stockholm and Gothenburg. The transponder loops are located above the ties.

All long-distance vital logic circuits are based on fibre-optic cables laid in a concrete trench. Up to 400 'signal objects' can be controlled from a single control centre. The central computers are paired to provide fault tolerance and thus increase reliability. In addition to wayside signal displays, switch machines and crossing protection, devices such as fragile-wire earth/snowslide detectors are also linked into the ATC system.

To provide a context for level crossing safety and the related issue of requirements for grade separations, Mr. Fallman noted that in 1950, there were about 500,000 cars in Sweden; in 1992, there were 3.5 million. Despite this increase, crossing accidents had dropped from 150 in 1954 to 60 in 1990. This was in part to due to elimination of many crossings, in part to better driver education, and in part to better signage and protection at crossings.
Mr. Furustam noted that BV spends about 180 million SKr ($36 million Cdn) a year on improved crossing protection and grade separations, and stated that probably the greatest effect on accident came with the addition of half-barriers and lights at crossings that previously been unprotected (signs only).

In response to a question regarding the reliability of the road vehicle detection coils, it was stated that the detection coils are sensitive to vibration, and also that the electrification return current in the nearest rail may have transients that can induce false positive signals in the detection coils. On the other hand, it was also noted that if a road vehicle enters a crossing and then stops, the positive signal will eventually disappear. Mr. Boon and Mr. English have different recollections of the time lapse in losing a stationary vehicle: one thought it was 2 to 3 minutes, the other 20 to 30 minutes. We have not yet received clarification of this important point. It is also possible for a road vehicle to be undetected if it is short enough that it does not overlap two adjacent looped cables in the track. A motorcycle or a larger vehicle deliberately parked on the tracks by vandals could meet this condition.

The overall reliability of the ATC appears to be quite good. Mr. Furustam stated that only about 2.5% of all signal failures are related to the ATC. The majority are mundane problems like defective track circuits and burned-out signal lamps. This does not include failures of ATC components mounted on board the power car. He noted that an accurate speedometer is essential if the ATC is to function effectively.

The X-2000 was originally designed to have 3 on-board computers in the power car, with agreement of 2/3 required for vital functions. This has now been reduced to 2 machines. The reliability of the on-board equipment overall has been lower than was expected, but virtually all the faults have been in the low-tech components (lamps, etc) not in the solid-state electronics.

After lunch, we were joined by Bjorn Fora, an expert on X-2000 operations. He provided a summary of the evolution of the X-2000 fleet and services:

Date	Trips/Week	Trips/Day	Trainsets		Total
			Trip Time	In Operation	
Stockholm-Gothenburg					
90.09	6	1	3:35	1	1
91.03	24	4	3:32	2	2
91.08	48	8	3:18	3	3
92.01	58	10	3:15	4	5
92.03	78	14	3:15	5	5
92.08	78	14	2:59	6	8
Stockholm-Karlstad					
92.08	12	2	2:38	1	9
92.10	34	6	2.38	2	10

Note that there are now 3 spare or guade trainsets, plus the one that is currently being tested on AMTRAK.

Detailed delay data were sent later by mail. The data reflect a situation somewhat different from that expected for our evaluation case. During much of their data collection period they had no spare trains at either end of the corridor. They also are in the process of upgrading track and handle significant levels of conventional trains on the X2000 lines. Nonetheless, with some interpretation the data are useful for our corridor. As with the SNCF system, one of the biggest trip reliability problems is the conventional signalling system. The trainsets themselves are quite reliable with redundancy built into all of the critical electronics and hydraulics.

Braking distances on the ATC are based on operations without regenerative braking. Note that the X-2000 as currently built does not have any resistor banks on board, and so cannot employ non-regenerative dynamic braking. The magnetic track brake is required on 2/3 of the trucks in the train if the speed is to exceed 160 km/h. The magnetic track brake is a friction brake, not an eddy-current brake. It provides a 36-tonne per coach normal force, and is rough on the rails. The brake can also produce problems of shorting out insulated joints associated with conventional track circuits.

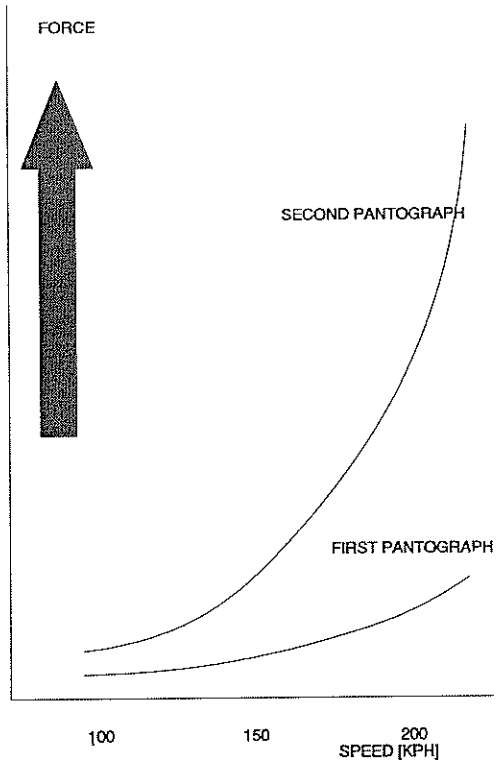
The cab car has 6 tonnes of ballast to provide better braking (and also to discourage overriding in event of a collision. 'Leaf season' in the fall is a major problem in those areas with deciduous forest.

On the X-2000, which has 880 mm wheels, up to 3 flat spots are permitted even on leading truck of driving trailer. No spot can be more than 40mm long, and weather conditions must be normal (i.e., dry). If a flat is over 40mm on a low-tonnage axle, certain speeds must be avoided.

The average utilization for X-2000 trainsets works out to over 900 km per day. Some sets make as many as three one-way trips Stockholm-Gothenburg. Station stops are based on a nominal 1-minute dwell time, but Mr. Fora admitted that this would be exceeded if wheelchair access was required. The 2:59 run time cited above is for non-stop service and includes a 7 minute allowance over the minimum run time simulations. With one intermediate stop, the trip time rises to 3:06.

At this point Mr. Fora left and Mr, Leif Lundin, the Chief Electrical Engineer for BV, joined the meeting to discuss the catenary and modification for 200 km/h operation.

The 1966 catenary design is a stitchwire system using a 50mm^2 copper messenger wire and a 100mm^2 grooved copper contact wire at 7.1 kN tension. In preparation for the X-2000, the contact wire tension was increased to 10 kN, to reduce pantograph/catenary contact forces and force variability. This has worked reasonably well with one pantograph active. However, there is still a problem with two pantographs, as shown in the diagram below.



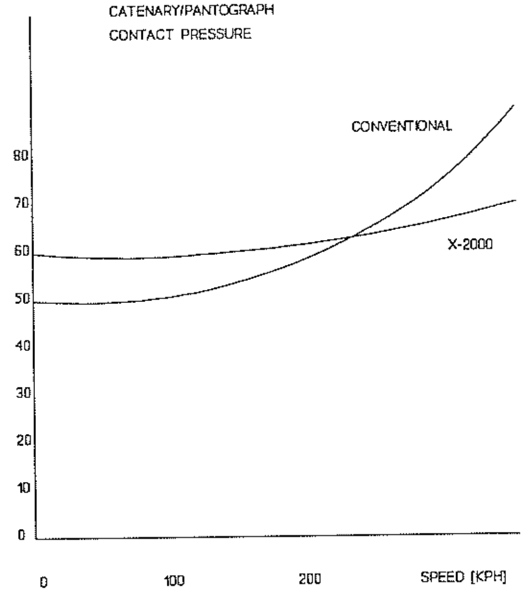
Relationship between Speed and Contact Force With One and Two Pantographs

For new construction such as on the Grodinge line, the Swedes are using a design bought from the Germans using a 70mm^2 Bronze messenger with a 42 kN breaking load, and a 120 mm^2 silver-copper contact wire with a yield strength of 165N/mm^2, tensioned at 15 kN. This allows a higher critical speed with two pantographs raised. However, since the pantograph provides an effective contact zone of +/- 200mm around the nominal centreline, this arrangement allows a maximum lateral force of 2250N, which corresponds to a minimum radius of curvature of 2000 m.

While this arrangement and the X-2000 air suspension pantograph yields a higher static contact pressure at low speed than does the older design (60 vs 50 kN), the pressure is much less speed sensitive, as shown below. It is not clear if the pantograph design will be affected by very low temperatures.

The BV practice is to undertake complete maintenance of its catenary every 6 years. Essentially each line segment is divided into 6 parts, and one part is done each year. On Stockholm-Gotenburg, the catenary will see 60 to 75 pantograph passes per track per day (more in the urban zones). Of this, only about 10% is attributable to the X-2000. The maintenance approach is not systematic or even uniform across the BV system. A test coach is used to measure the dynamic performance of the catenary. Two runs per year are made on the main lines, 1 per year on the secondary lines, and as infrequently as 1 every 2 to 3 years on some branch lines.

The session provided information on the steps which SJ is taking to improve capacity on its electrified lines. However, the system they have was built early this century with rotating (now mostly electronic) converters to provide 16 2/3 Hz. Substation spacing is at 80 to 120 km, with typically 2x15 mVA installed. This system and its evolution is not relevant to our corridor and has not been reported on.



Static contact pressure as a function of speed for old and new catenary

THURSDAY, DECEMBER 3

Accompanied by Mr. Furustam, Messrs Boon and English took a regional train to Flemingsburg, where we were met by Mr. Hans Astrand, the project manager for BV for the Grodinge new line (Photos II-6.4 through II-8.1). We drove from the station to his site office. He gave a short overview of the Grodinge project, notably the very large bridge across the navigable Igelsta Bay and the westward extension of that structure across the Nyloping road. He noted that there was great emphasis on quality control throughout the work and that all contractors had been prequalified before being permitted to bid on work elements. The project office has 55 persons devoted to overseeing adherence to design and quality standards, and to meeting schedule and budgetary objectives.

The project is slightly behind schedule (due to a modification to the alignment) but is apparently within a fraction of a percent of being on budget. The alignment change was a major modification to include a local community which wanted a stop. [The new structure of transportation policy in Sweden, does not seem to have eliminated effective local interest groups from influencing major projects; but under the new system, the community itself had to pay for the incremental costs of changing the alignment to pass through their community.]

The discussion then turned to the details of construction of the new line from Flemingsburg to Jarna.

The line has been designed for a nominal top speed of 250 kph, with a 2000 m minimum horizontal curve radius but with 3000 to 4000 m radii curves wherever possible. The minimum vertical curve radius is 20,000 m, and the maximum gradient is 1%. There are 12 tunnels, totalling 7.95 km in length. Of that, 5.5 km are double-track, with a cross-sectional area of $96m^2$, and the balance for single track with a $55m^2$ cross-section. The longest individual tunnel is 1.8 km. All were cut using 'conventional' blasting techniques. The spoil was used as fill for construction of the new line.

The line is being constructed with UIC 60 rail on concrete monoblock ties with pandrol fasteners. Tie spacing is 0.65m. The ballast is 25/50 graded crushed rock with a minimum of 30 cm under the ties and a total depth of 50 cm from the top of the tie. 90 cm of subballast is used except in tunnels.

The line is being built through typical 'knob and swamp' terrain similar to that found in the Frontenac Axis between Ottawa and Kingston/Toronto. Where there is solid ground, soil cover is minimal and the rock subgrade has excellent bearing strength. However, the swampy sections between the knobs are another story. Over $70000m^3$ of peats, silts and clays have been removed to spoil, and have been replaced with blasted rock from the tunnel excavations. In some instances, lime injection stabilization has been used in an attempt to stabilize remaining incompetent materials where the total depth made removal impractical. In one location, where the new line crosses an old municipal landfill site, it was necessary to use driven friction piles up to 35m in length, as removal of the material in the site was not an option. Mr. Astrand stated that the sections of the line on poor subgrade had been preloaded with a minimum of 2m of blasted rock for 1 to 2 years before actual construction was started, to ensure that any settlement that was likely to occur had already taken place. The earthworks involved in construction of the new line are up to 20m in height.

A portion of the new line south of Sodertalie is located in an existing railway right-of-way (Photos II.12.1- -12.4). In response to questions from Mr. Boon, Mr. Astrand stated that in this section, all the tracks have been rebuilt to ensure a uniform standard of construction and adequate drainage, and also that construction in the active right-of-way, with consequent limitations on workspace and site access, resulted in a 20% to 50% premium on the cost of new construction in a new ROW. In some instances (as in the accompanying photos) the existing line was removed once the new line was commissioned. However, that has not occurred at all locations, according to Mr. Astrand.

We were then taken to visit the Igelsta Bridge construction site (Photos II-6.4 to II 8.1). This is an extremely impressive structure, with a maximum clear span of 158m over the navigable waterway and 40.5m vertical clearance under the same span (to the water surface). The bridge is 2.014 km long. Details of construction are given in Annex A.

After lunch, we walked over to the local BV Eastern District offices and met with Mr. Kurt Andresson, who is responsible for maintenance planning for BV's Eastern District. This district is responsible for 184 track-km, which makes it a very small district by Swedish standards, but these lines carry a great deal of traffic.

Mr. Andresson stated that most of their maintenance work was done at night, but that he could obtain daytime occupancy of up to 6 hours through negotiation with the Region. However, only two such occupancies were available on any day for the region as a whole. Normally if one track is being worked on, the adjacent track is subject to a slow order to protect the maintenance personnel. His district has 5 working units, which may be specialized or mixed depending on the requirements of specific jobs. Most of the track maintenance effort goes on tamping and lining; rail grinding is not used extensively, although limited grinding is used to control corrugation in curves and to reduce noise. Most of the track maintenance equipment is supplied and maintained by contractors, not by SJ or BV.

The track maintenance force consist of 195 persons. Signal maintenance is carried out by a team of 31 persons: a district leader, a chief technician, 3 team leaders, 9 signal technicians, and 17 repair staff.

In response to questions, Mr. Andresson stated that the lines carrying the X-2000 received about 20% more lining and tamping effort than did tracks carrying only 'conventional' traffic, but that this work was carried out in the context of the negotiated contract between BV and SJ, so that it was less a question of what was required in absolute terms than what was agreed to. Signal inspection and maintenance cycles have not been altered, but there are more signal components to deal with on the lines carrying the X-2000 traffic.

This district contains most of the track responsible for the very rough and uncomfortable ride on out Tuesday trip to Gothenburg. When this issue was raised, Mr. Andresson agreed that there were indeed problems with track quality. The ties and fasteners in this district are almost all the old-style dual-block with the early type of fastener, and many are no longer functioning properly. Apparently the metal connector between the concrete blocks is basically a pipe that often fails, so that the blocks move independently. Cracking under the rail seat is a major problem. Also, the fasteners do not provide adequate hold-down force.

The intent is to renew about 70% of the track-miles in the district in 1993. This will entail ballast cleaning, replacement of the old ties with new monoblock ties with pandrol fasteners, and lining and tamping. The rail is already UIC 60 CWR.

After our conversation with Mr. Andreasson, we visited a level crossing equipped with the vehicle detection circuitry (Photos II-8.2 to II-10.4, plus II-11.3). During our time on site, a regional train passed through the crossing and we were able to observe its functioning.

The level crossing site was quite interesting, insofar as BV appear to have gone to considerable lengths to make sure that the crossing can be seen by approaching motorists. The double-width barriers are equipped with fragile-wire intrusion detection circuits, so that a vehicle crashing through a barrier will trigger a 'stop' signal. Of course, this is does not eliminate the risk of a last-minute skid onto the crossing, but it does reduce the level of risk exposure.

However, this crossing is not on a very high-traffic-density road (or rail line, for that matter). We were on site for about forty minutes and saw one train and no automobiles.

We were next taken to a location near Jarna where the new line passes under a road (Photos II-11.1, 11.2 and 11.4). The quality of the construction appeared excellent, although the geological structure in one wall of the rock cut could lead to spalling from freeze-thaw action.

Our final field visit was to the point where the new line joins the existing rail ROW just south of Jarna (Photos II-12.1 to II-12.4). At this last site we were able to inspect the signal box controlling the that portion of the new and existing lines. The old line had already been taken up at that point, but was still in place further south.

FRIDAY, DECEMBER 4

On Friday 4 December, Messrs Boon and English, accompanied by Mr. Marklund, journeyed by train to Vasteras to meet with representatives of ABB Traction to discuss issues related to the X-2000 design and to on-going and planned R&D activities.

We met initially with Messrs Ollie Ewers, the General Manager Stationary Equipment Division. We were shown a short AV presentation on ABB and on the X-2000, then opened a general discussion. Mr. Ewers informed us that we would be joined by specialist staff to respond to the specific questions we had raised.

One issue that arose from the initial general discussion related to the fact that the X-2000 power car as designed and built is not equipped to provide rheostatic braking, but only regenerative braking. While all braking distances are based on pneumatic braking only, this arrangement means that if the overhead electrical system is down, no dynamic braking is available. This was confirmed by Mr. Wennberg. Also, north american utilities are notoriously resistant to regenerative braking due to problems with harmonic content.

We were then joined by Ms. Karin Hakansson, Manager-Mechanical Systems; Mr. Sven Lundholm, Manager Advanced Engineering, Rolling Stock Division; Mr. Odd Sylwan, Drive Systems and Acoustics; and Mr. Ake Wenneberg, ABB's Director of Tilt Train Marketing.

The first topic discussed was the structural strength of the vehicle and the design philosophy of ABB with respect to passenger safety. Essentially, the driver's cab on the vehicles built for SJ is a crush zone, but the passenger compartments are not. Exhibit 2 illustrates the result of finite element analysis for collision of the power car or driving trailer with a 4-tonne cylinder 2 m in length and 1m in diameter at 200 kph. The cylinder is stopped by the time it reaches the back wall of the driver's cab. Similar results are claimed for an 8-tonne, 4-m long cylinder. However, this does not really deal with the question of collision with a moving vehicle at a combined speed of perhaps 300 kph.

The coaches are built to resist 200 tonnes at the couplers, in accordance with UIC 566. The coaches are designed to deform in a well-defined pattern in the areas occupied by vestibules and toilets when loads exceed 200 tonnes. The resistance to compression at the roof is 45 tonnes. Ms. Hakansson stated that ABB did not have values for resistance to vertical and shear forces.

With respect to redesign to conform to FRA/AAR standards, as will be required if AMTRAK decides to order the X-2000, Mr. Wenneberg stated that meeting the AAR interchange load standards would add at most 1 metric tonne per axle. He had more concern about the possibility that regenerative braking would not be acceptable to U.S. and Canadian utilities, as on-board resistance banks for dynamic braking would both add mass and cause problems with physical location and load balance. He stated that the couplers would have to modified to conform to North American practice (as has been done for the AMTRAK demonstration) and the mechanism for attaching the trucks to the carbody in the event of a collision would also require some modification to meet U.S. requirements.

He also noted that ABB plans to eliminate disc brakes from the powered axles on the next generation of the X-2000. The discs are set into the wheels and add unsprung mass. If they are removed, then that would help compensate for added structural mass and would also facilitate operation at higher speed. ABB are also looking at an eddy-current emergency brake either in place of or as a supplement to the magnetic friction brake now fitted to the X-2000.

NOTE: SINCE OUR RETURN FROM SWEDEN, WE HAVE SPOKEN WITH MR. ZELKO LENDICH OF ABB CANADA (JAN 21/92). HE HAS STATED CATEGORICALLY THAT ANY X-2000 IMPORTED INTO NORTH AMERICA WILL BE REDESIGNED TO FULLY COMPLY WITH ALL EXISTING FRA REGULATIONS AND WITH THE AAR STANDARDS, ON AN ITEM-BY-ITEM BASIS. BASED ON THE INFORMATION PROVIDED TO US IN SWEDEN, IT APPEARS THAT THIS SHOULD BE POSSIBLE WITH LITTLE OR NO IMPACT ON PERFORMANCE, AND MARGINAL IMPACT ON LIFE-CYCLE COSTS. THIS WOULD ALSO ELIMINATE REGULATORY COMPLIANCE CONCERNS WITH RESPECT TO OPERATIONAL COMPATIBILITY, BUT DOES NOT AFFECT ISSUES RELATED TO INFRASTRUCTURE STABILITY UNDER FREEZE-THAW CONDITIONS. ALSO, THE REAL SAFETY RISK ARISING FROM DIFFERENT LOCOMOTIVE FRAME HEIGHTS WILL NOT BE ELIMINATED.

Mr. Odd Sylwan next addressed our questions with respect to noise and vibration. Mr. Sylwan stated that work on noise-related issues had started more than ten years ago, with parallel investigation by the corporate research group and by ABB traction. The interior noise targets were 65 dB(A) in coaches and 68 dB(A) in the driver's cab. The Internal noise spectrum is a broadband centred around 250 Hz.

Exterior noise is principally in the 1 to 2 kHz range, measured at 25 m from the track centreline. The X-2000 at 200 kph is less noisy (91 dB(A)) than Rc locomotive-hauled trains at 140 to 160 kph (92 dB(A)). These noise levels are for 'ideal' conditions in open country, as specified under ISO 3095. At 160 kph, the X-2000 produces about 85 to 86 dB(A). He stated that over the common operating speed range, the relationship of noise in dB(A) to overall speed is roughly as 30ln(V). In tunnels, the measured interior noise level was about 6 dB(A) higher at 220 to 230 kph (as measured on the DB system).

Mr. Sylwan stated that the principal sources of noise and their relationship with speed were:

	Bogies	30 ln(V)
	Drive train	20 ln(V)
and	Aerodynamic	75 ln(V)

The average drag coefficient for the power car and driving trailer is C_d=0.19. One of the accompanying diagrams shows noise levels measured at rest in a station with all auxiliaries running, at a distance of 7.5 m from the track. Normally few auxiliaries would be in operation if the vehicle was at rest.

Mr. Sylwan provided copies of noise data obtained during the test runs on DB. He noted that at equivalent speed, the measured noise was about 2 dB(A) lower than on Swedish track, due to the superior quality of the DB high speed track.

Mr. Lundholm then discussed wayside vibration and supplied such limited data as were available. Basically he was of the opinion that this should not be an issue except in very unusual circumstances

Mr. Wennberg and Mr. Lundholm spoke at some length about planned changes to the next generation of X-2000. The new design will feature a higher-rated water-cooled inverter that will boost available power by about 25 to 30 % and also be more environmentally benign. Changes will be made to the gearbox, the voltage in the dc link will be increased from 2400 to 2800, and higher current will be fed to the traction motors. the motors themselves will be equipped with improved insulation and their rating increased to 1100 kw continuous, up from the 800 kw on the existing version. The short-term rating will rise to 1375 kw. This will provide each power car with 4.4 mW installed continuous power (the same as each TGV-A power car). The roof-mounted air conditioning heat exchangers will be relocated below the cars, to reduce aerodynamic drag. Overall, the objective is cut trainset resistance by 25 to 30%.

We again discussed the 6 tonnes of ballast in the driving trailer and the dummy powered truck at the nose end of the DT. One element in this SJ specification was concern for aerodynamic uplift in meeting another train while going full speed at maximum tilt-angle in a curve. SJ has also introduced a speed limit on maximum tilt curves when lateral wind speeds exceed 25 m/s (90 km/h). Mr. Wennberg commented that the lateral wind load requirements imposed substantial cost. NOTE: lateral wind load will also be an issue with AMTRAK, as much of the NEC alignment north of New Haven is right on the Atlantic and is subject to, at times, very severe lateral wind loads, especially gust loads. It was not clear whether operating experience would allow SJ to relax this specification in the future.

Mr. Wennberg stated that next summer (i.e., summer 1993) ABB will carry out test running at speeds up to 280 kph on new track. The test program will look at bogie performance and also pantograph design and performance. ABB stated that they have not done any high-speed roller-rig tests on the bogies, and the target 300 km/h capability will be evaluated in field tests.

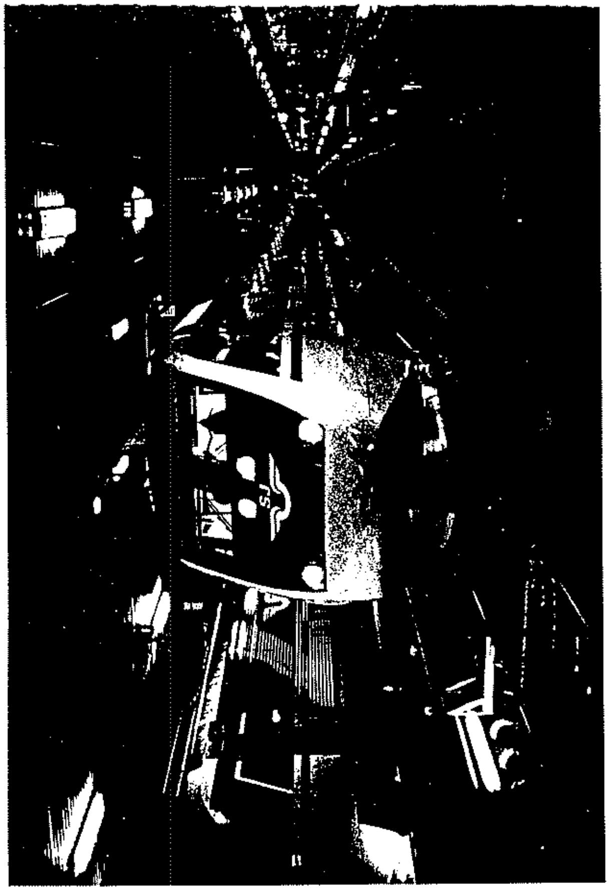
In response to a question from Mr. English, Mr. Wennberg stated that the maintenance experience with the X-2000 to date was very close to what ABB had expected overall, and that some aspects were doing much better than predicted. He cited as an example flange wear, which has been about on quarter what was estimated for operation on curvy lines. Design reliability has been better than ABB expected and much better than the contractual requirements imposed by SJ.

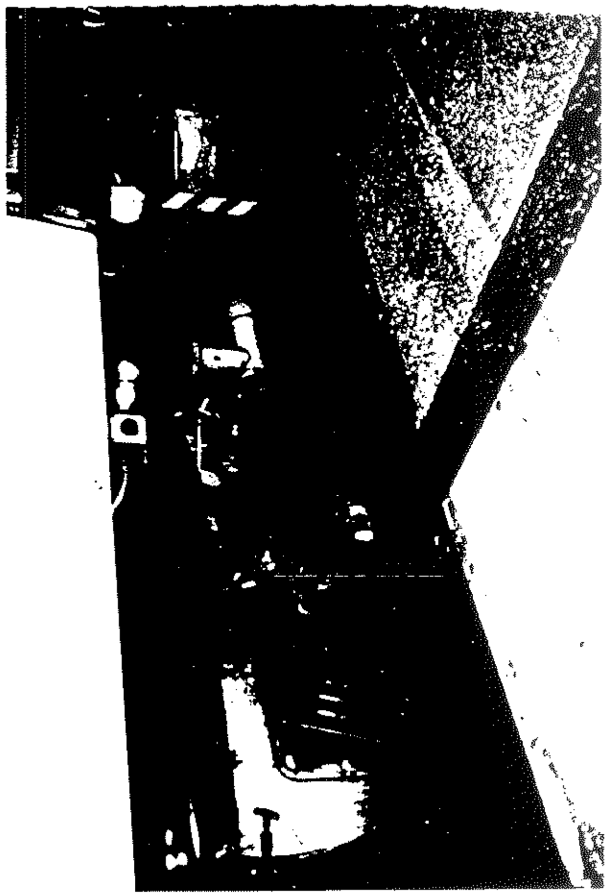
ABB emphasized that the tilt system cannot fail tilted, and that there have been only 4 tilt failures (resulting in the redundant system to be activated) in two years of operation. No schedule delays resulted.

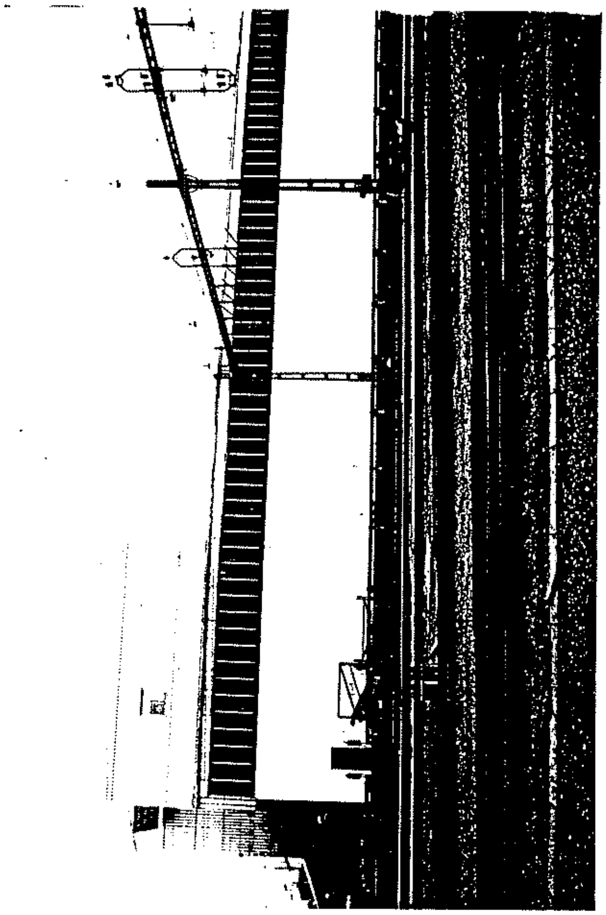
With respect to electrical and magnetic fields, there was a consensus that these are a growing issue in Sweden, as elsewhere in the world and especially the U.S. ABB has begun to study the issue, but has as yet made no field strength measurements in the X-2000. It is unlikely that they will do so unless someone imposes the requirement, since any results offer the opportunity for distortion and media hype.

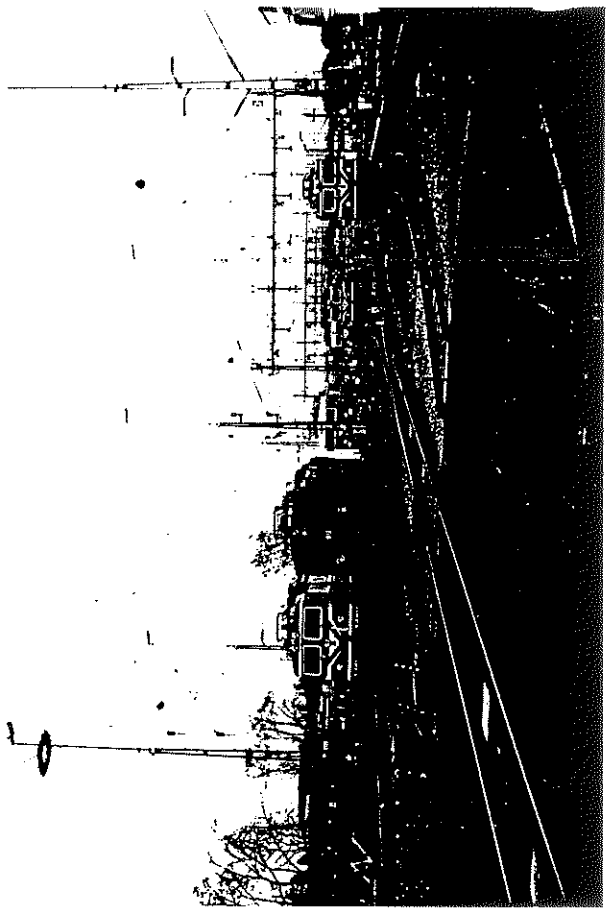
APPENDIX II

PHOTO REFERENCES FOR SJ VISIT

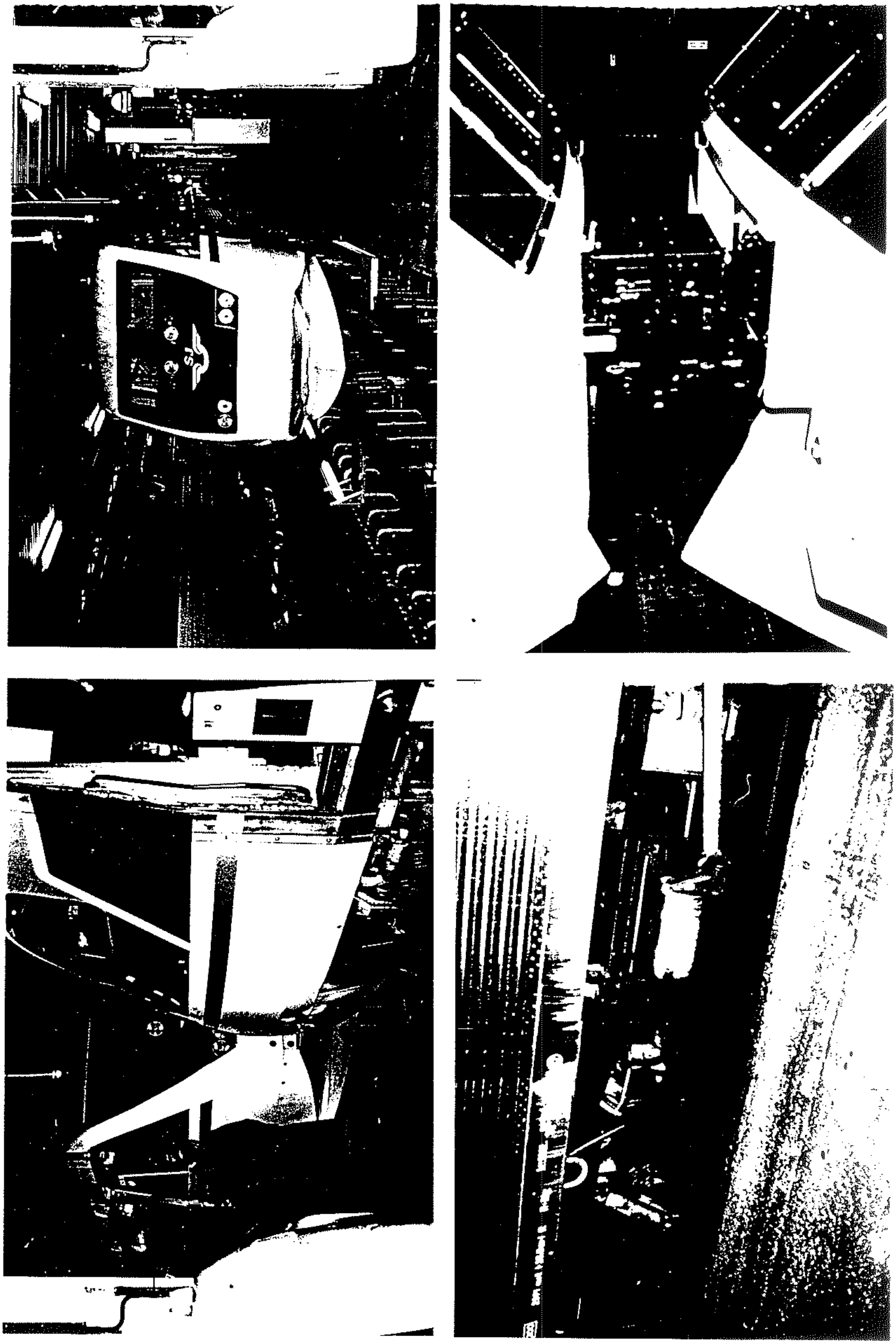




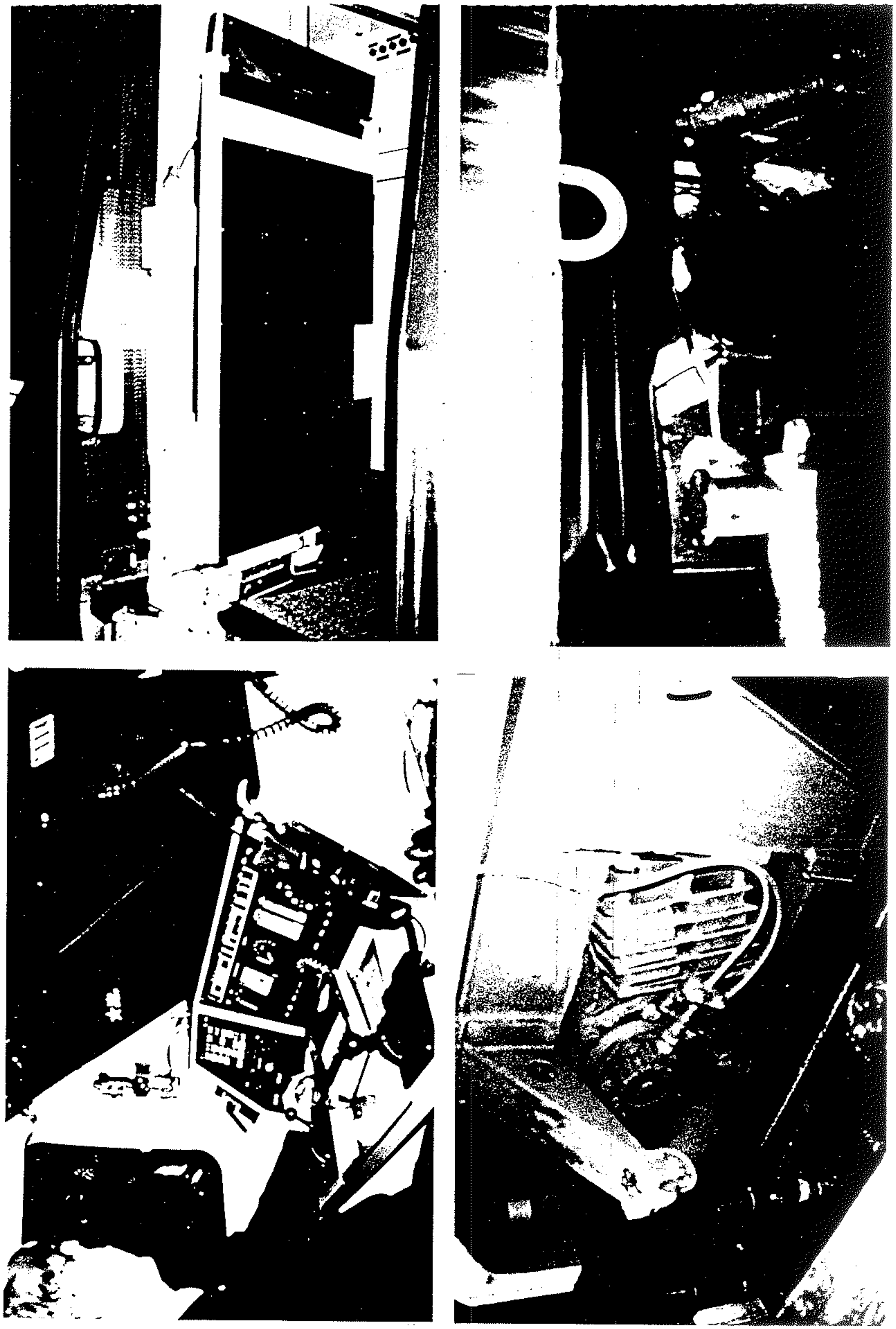




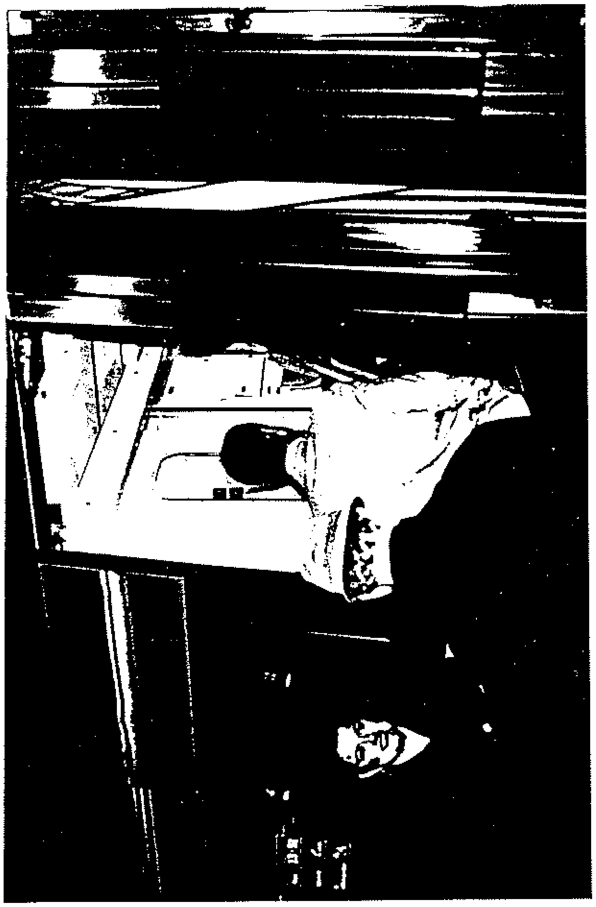
Photos II-1.1 — II-1.4

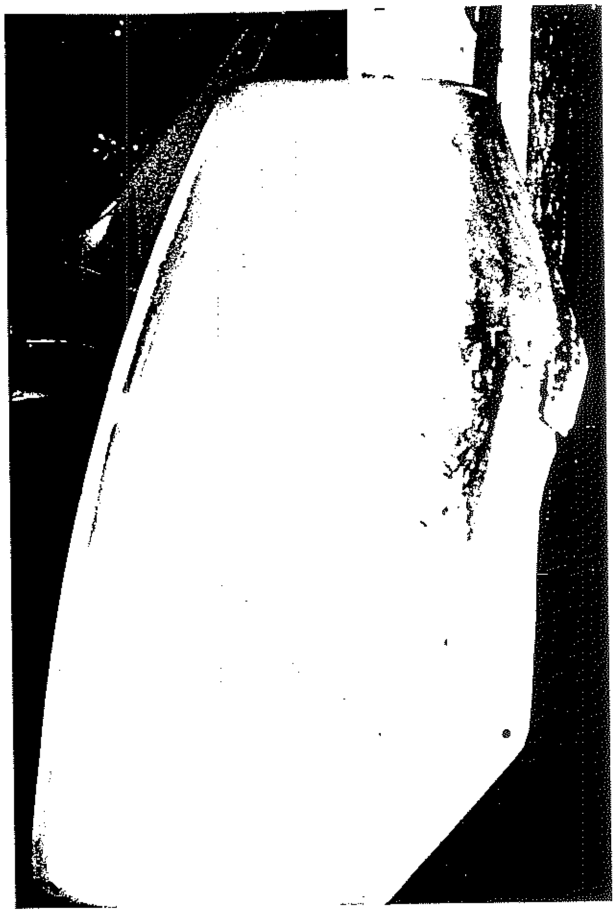


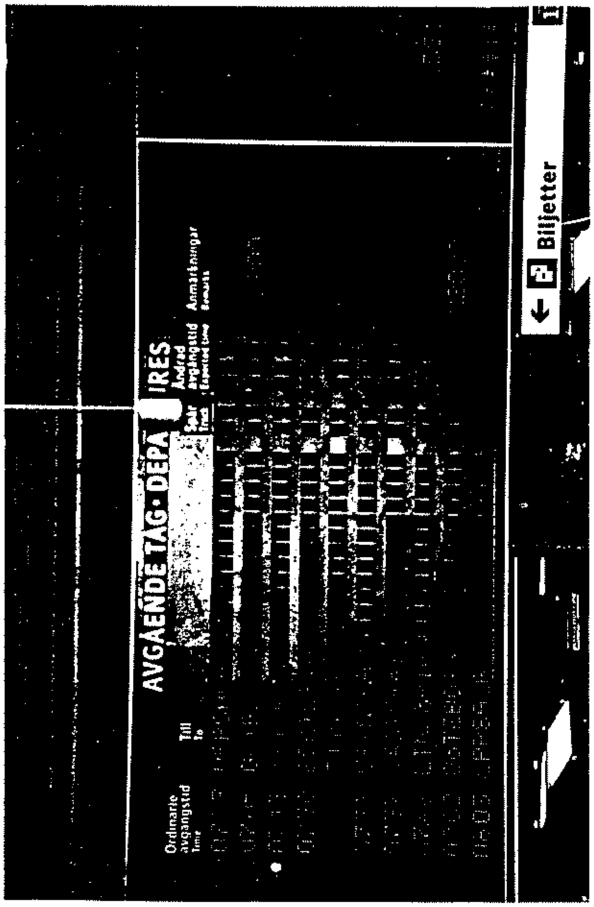
Photos II-2.1 — II-2.4

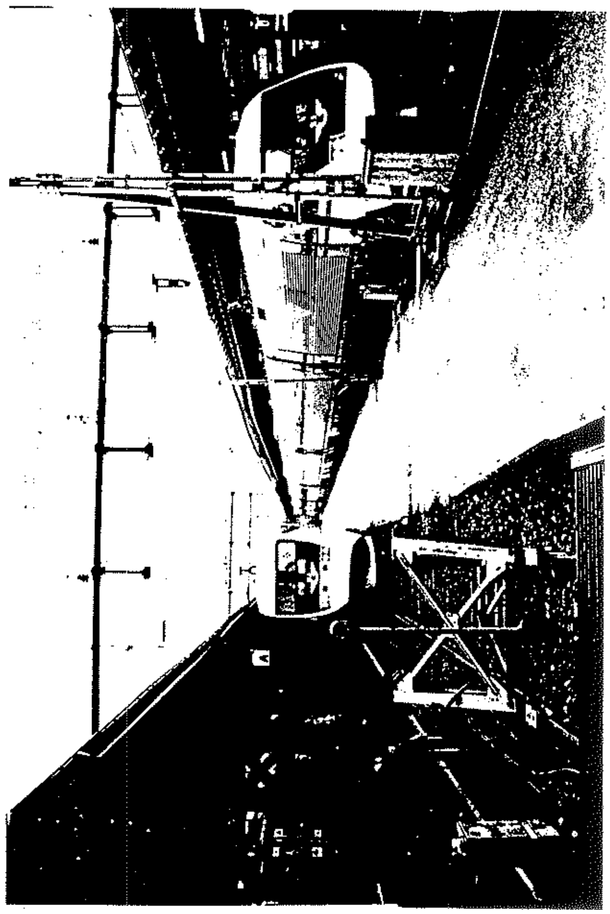


Photos II-3.1 — II-3.4









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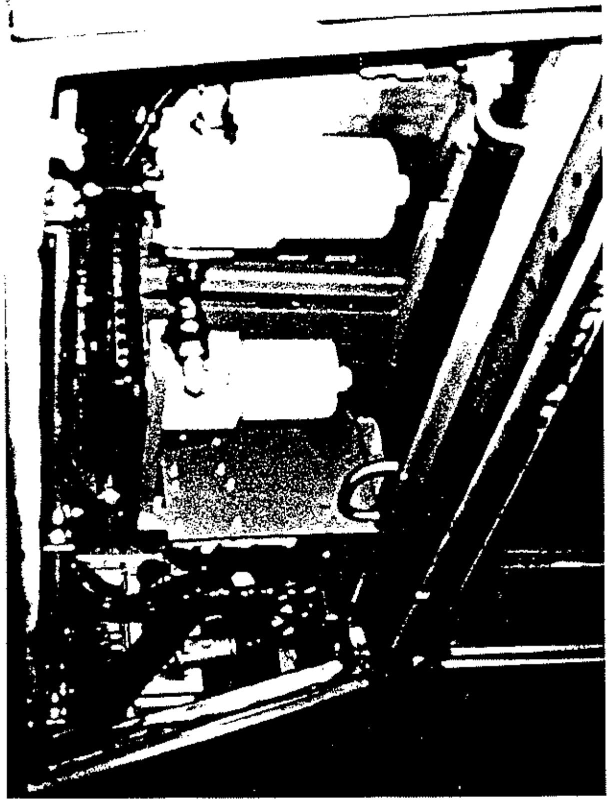

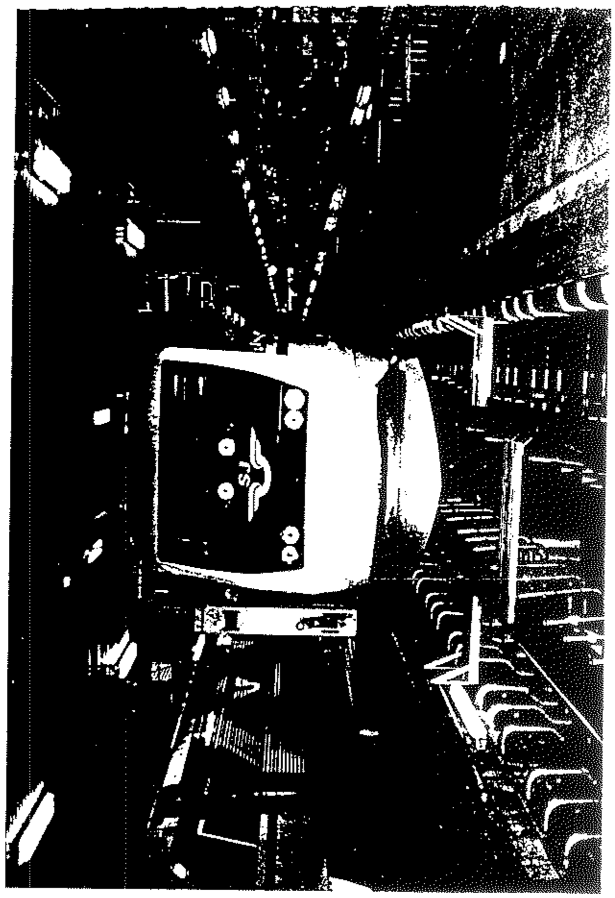

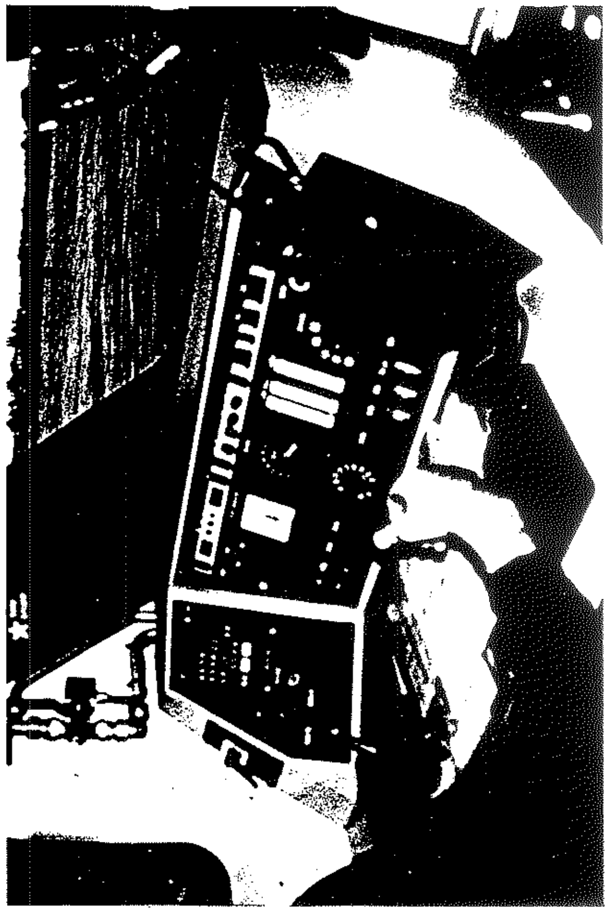

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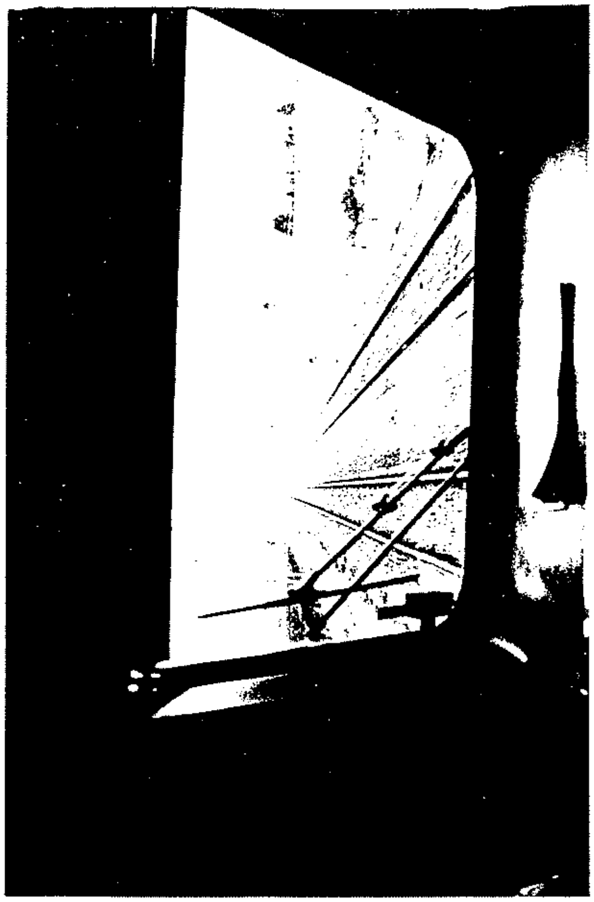
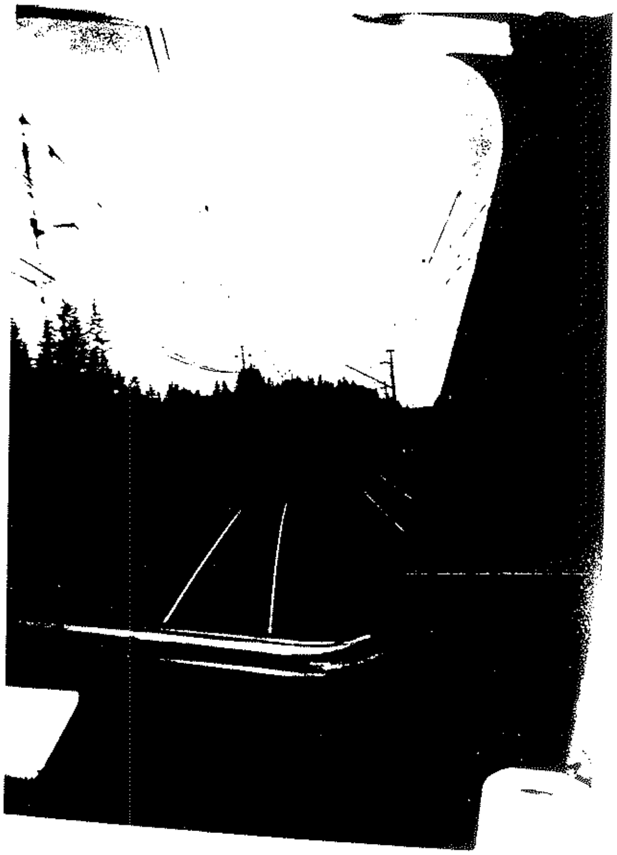
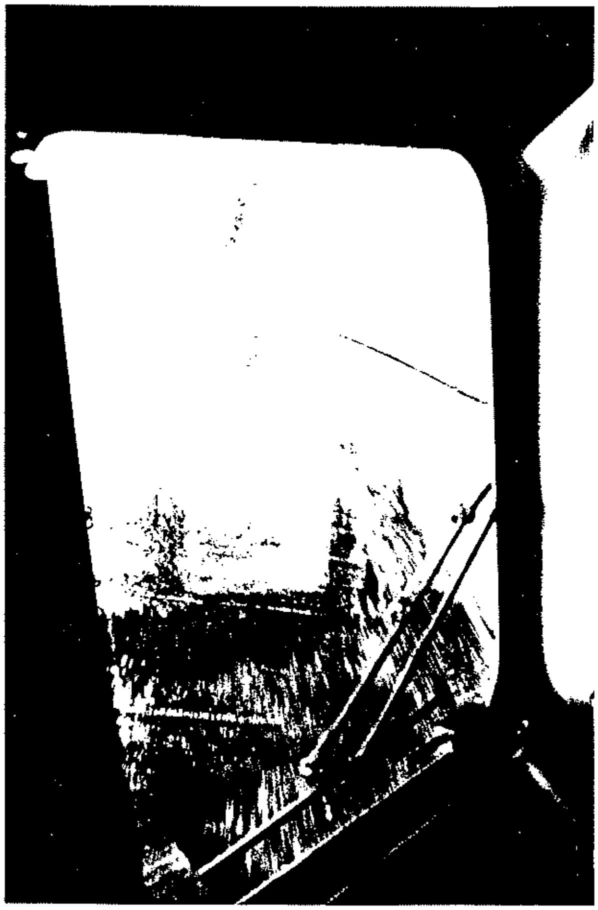
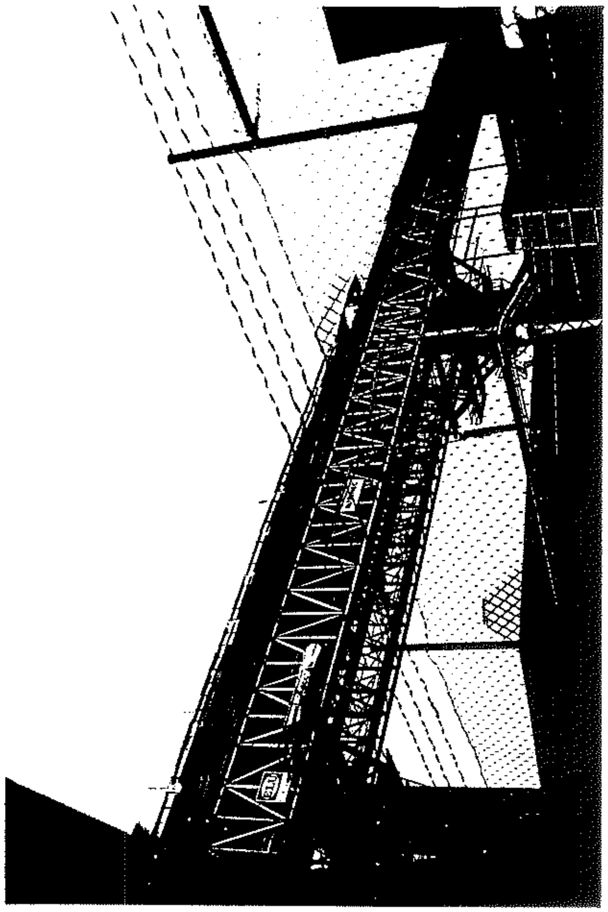

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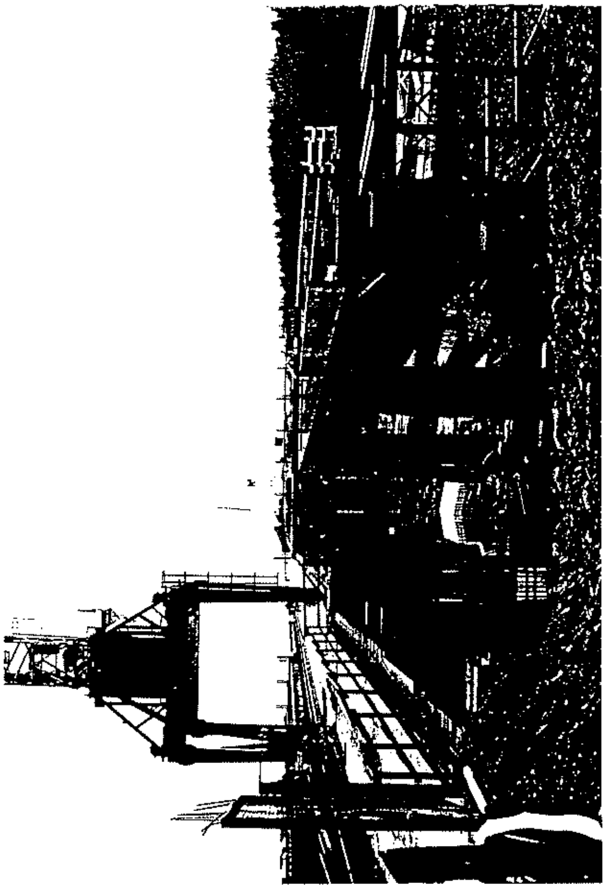

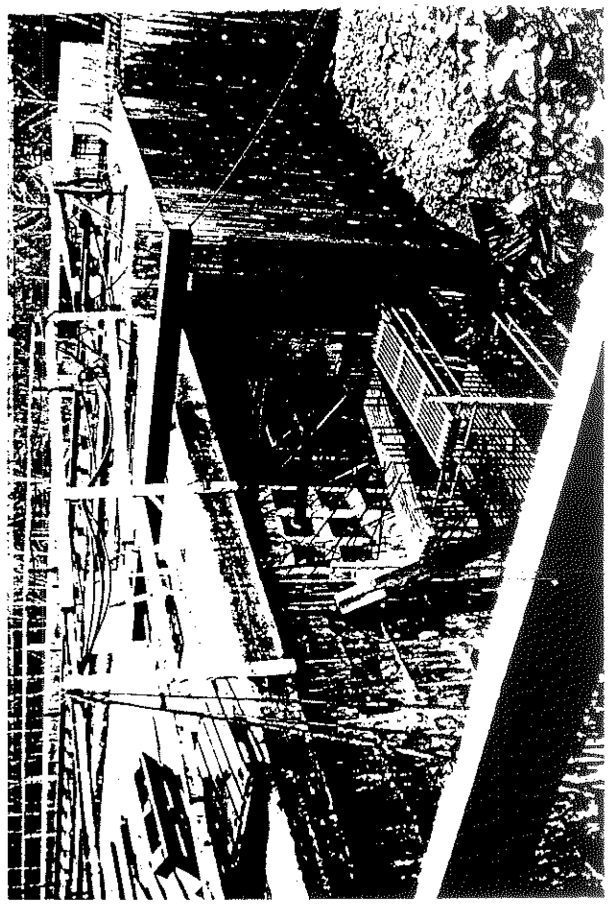

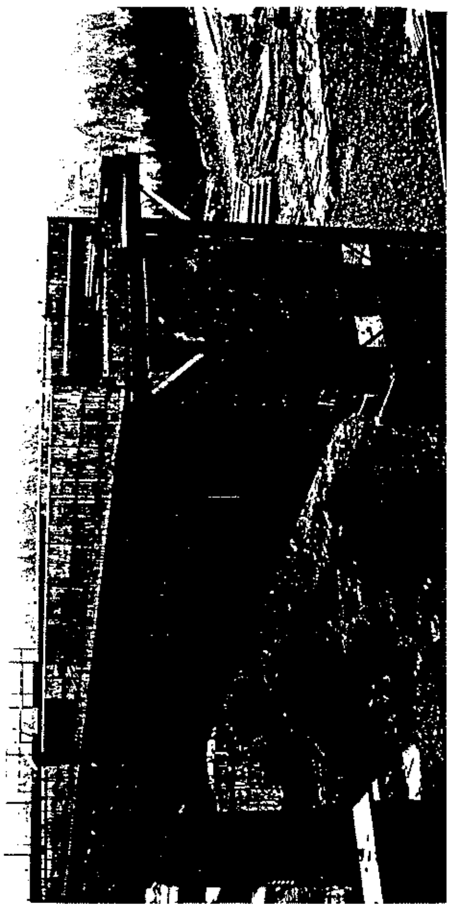

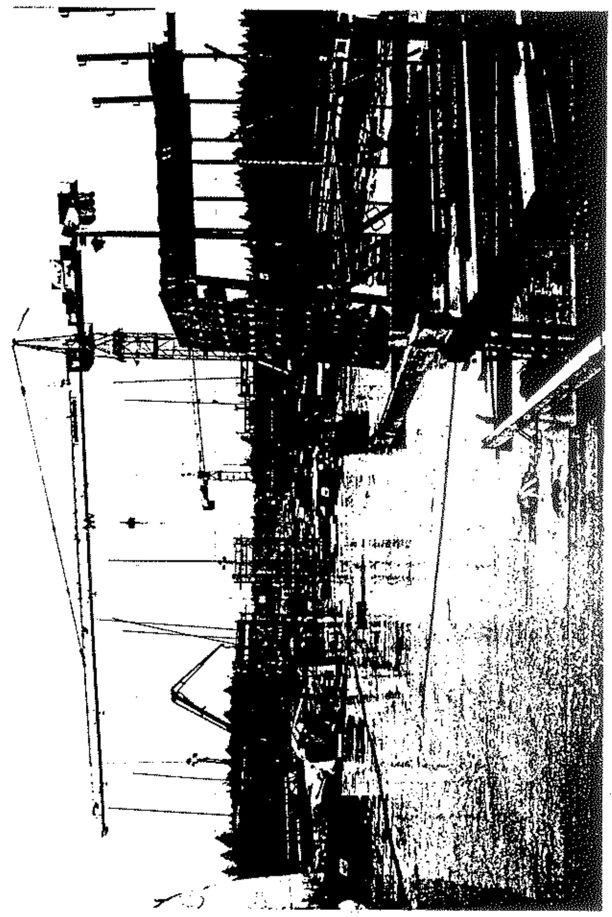

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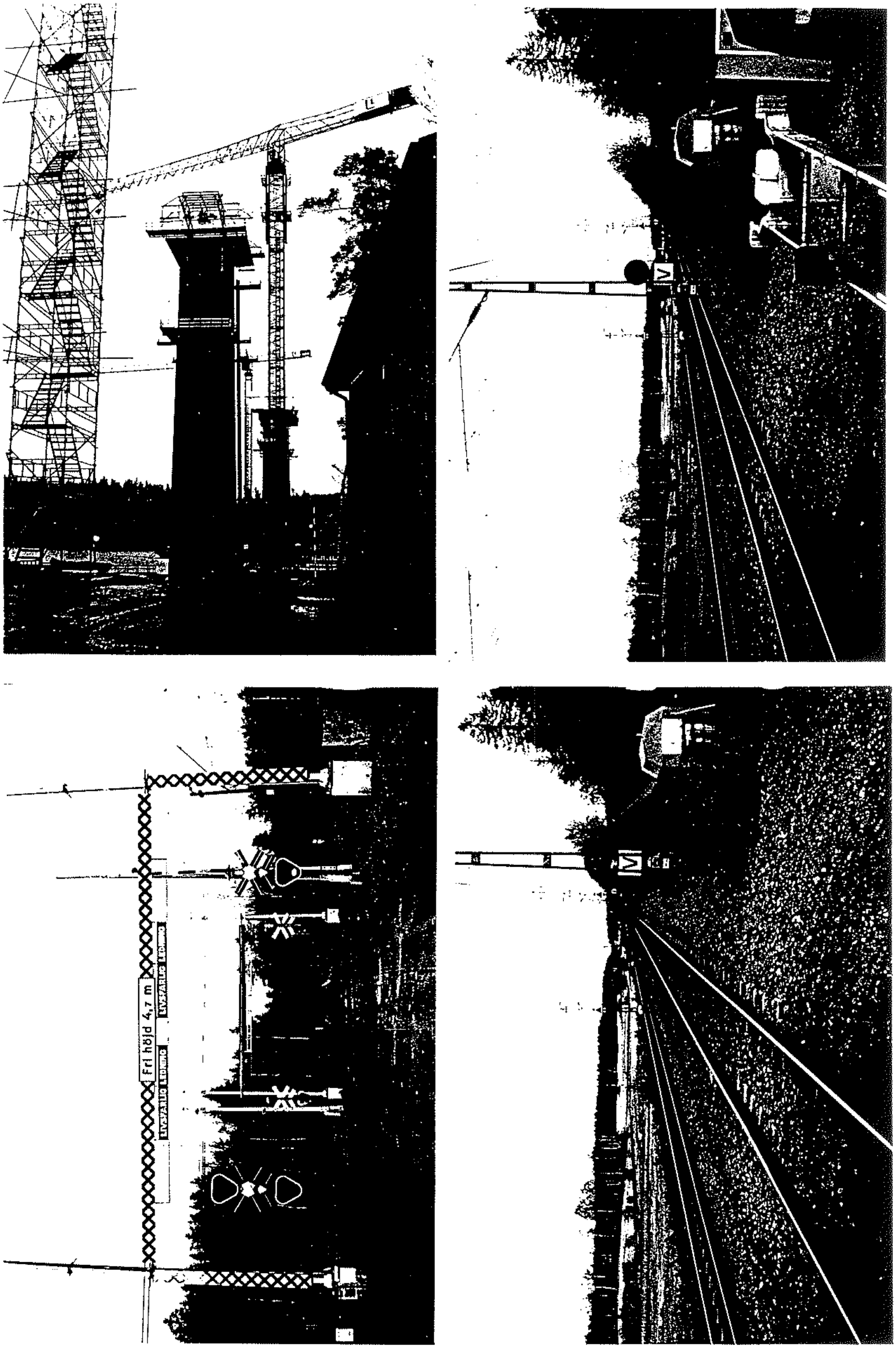

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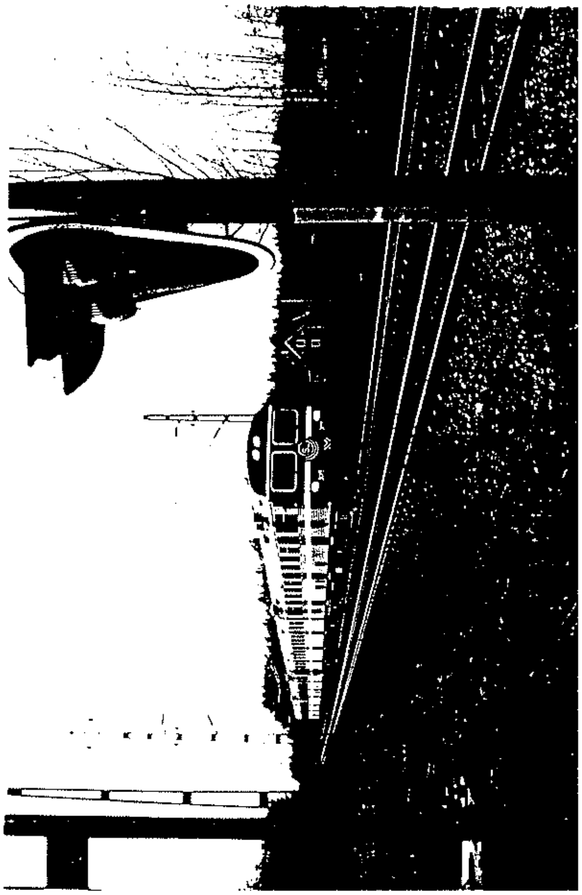

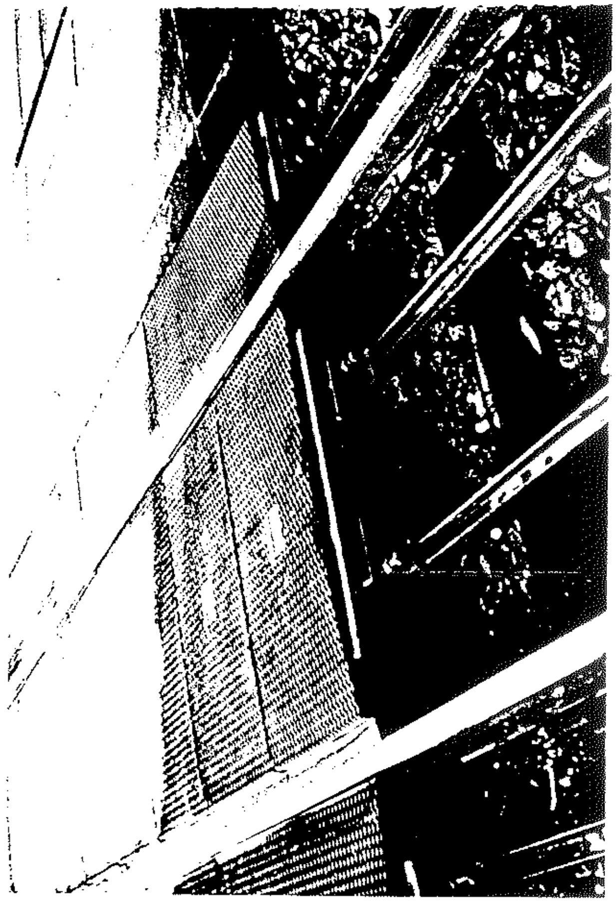

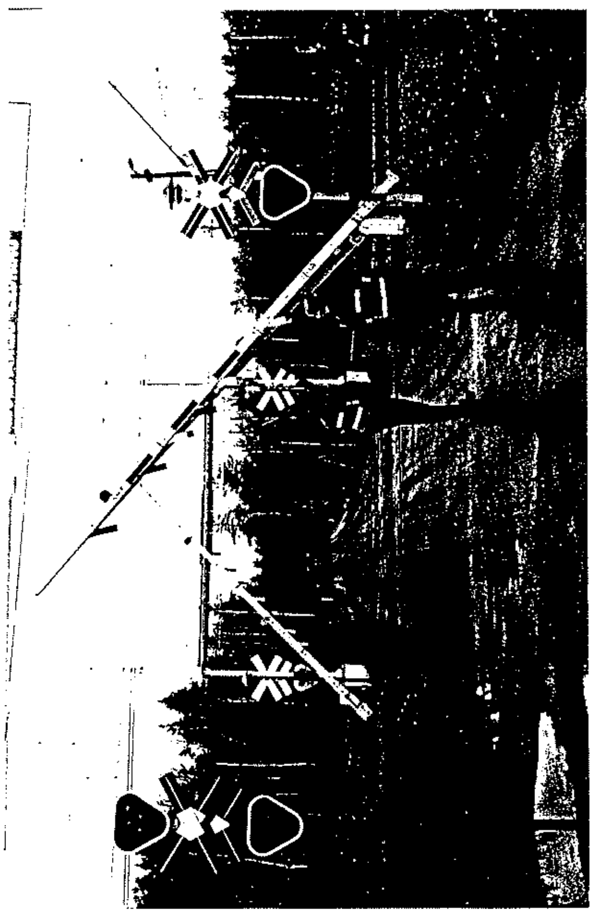

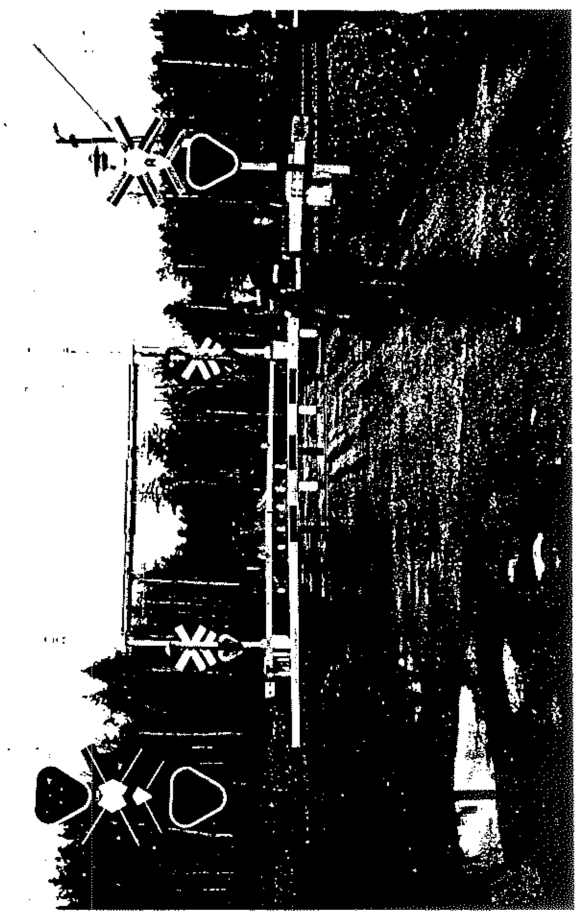

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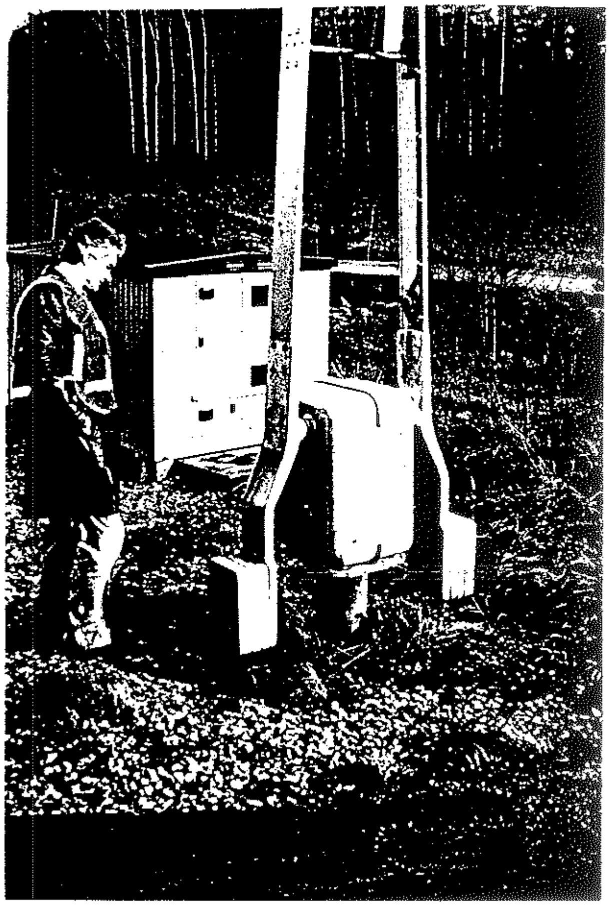

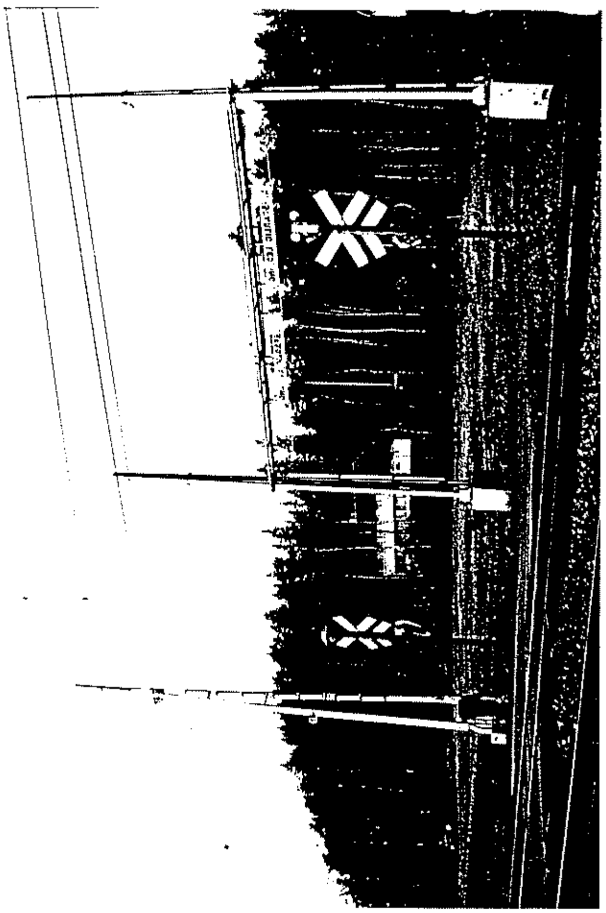

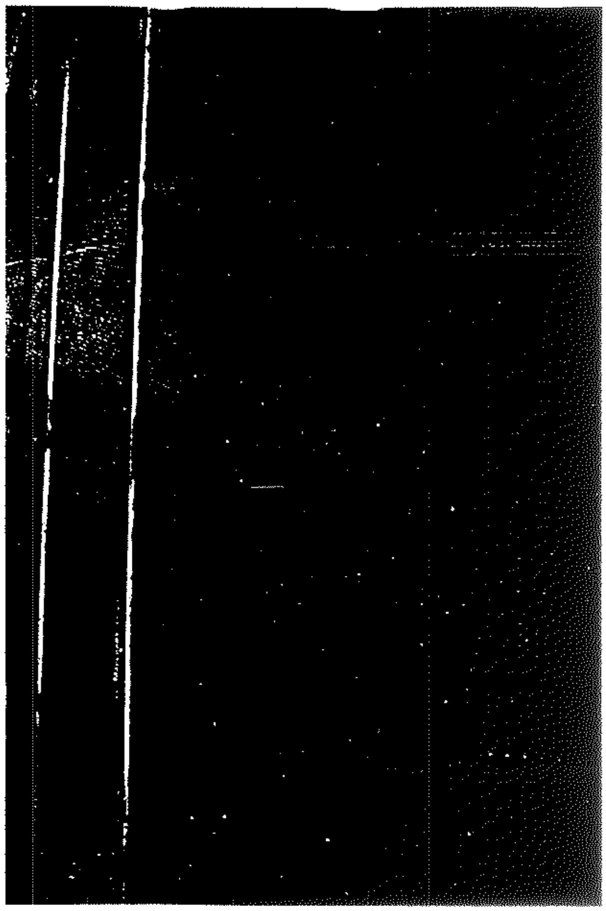

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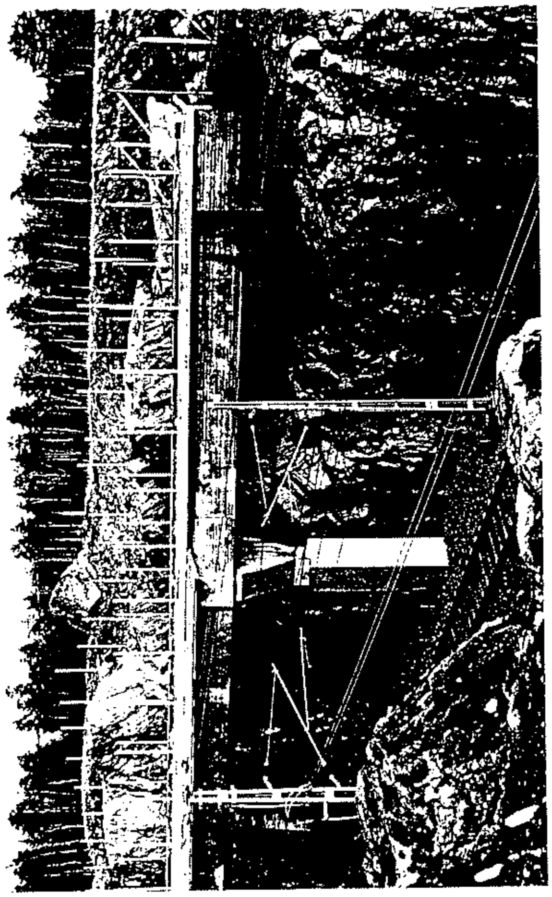
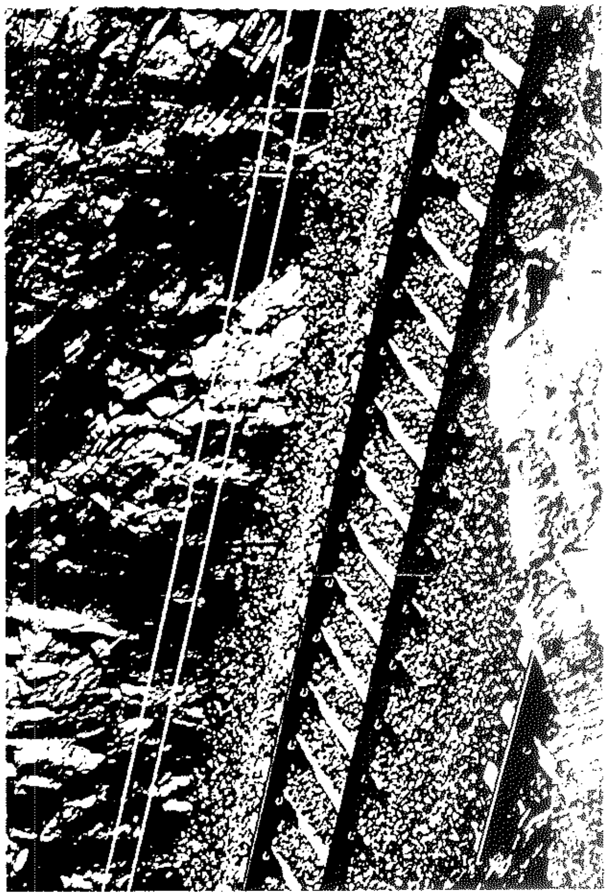
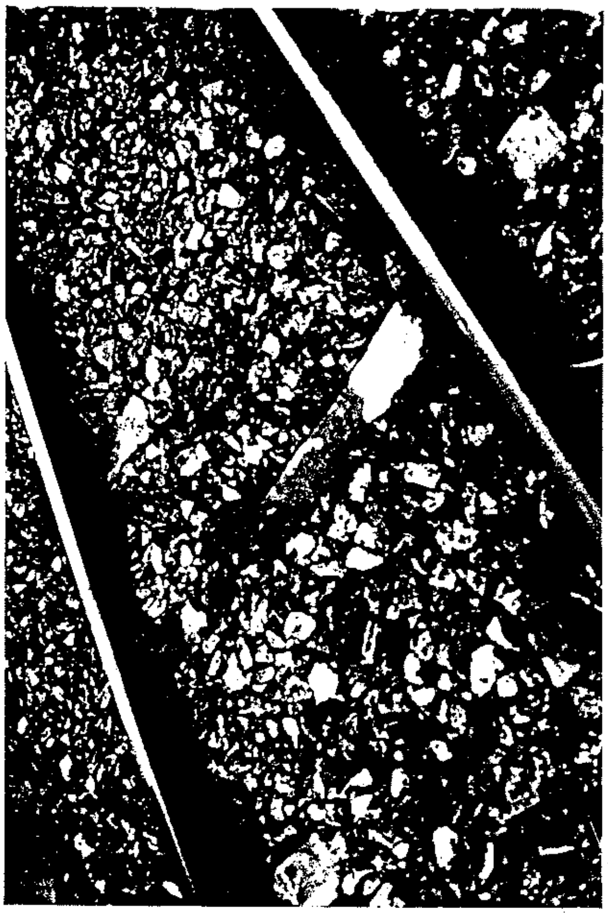


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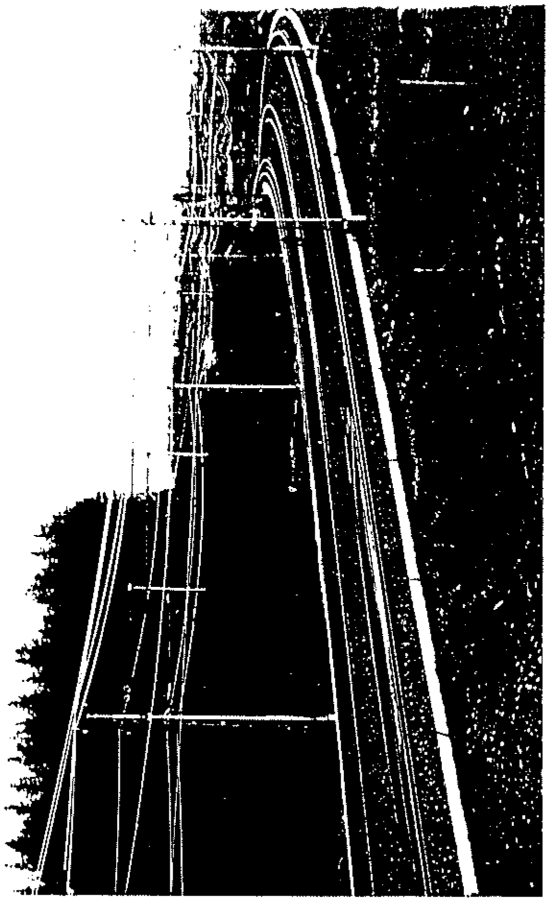

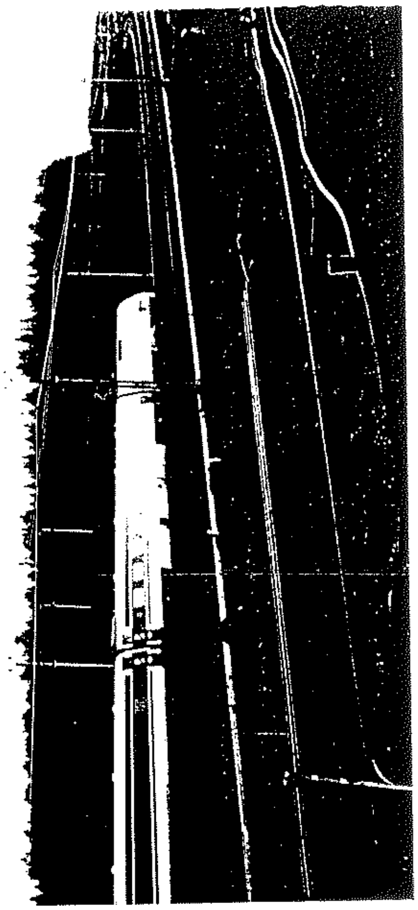

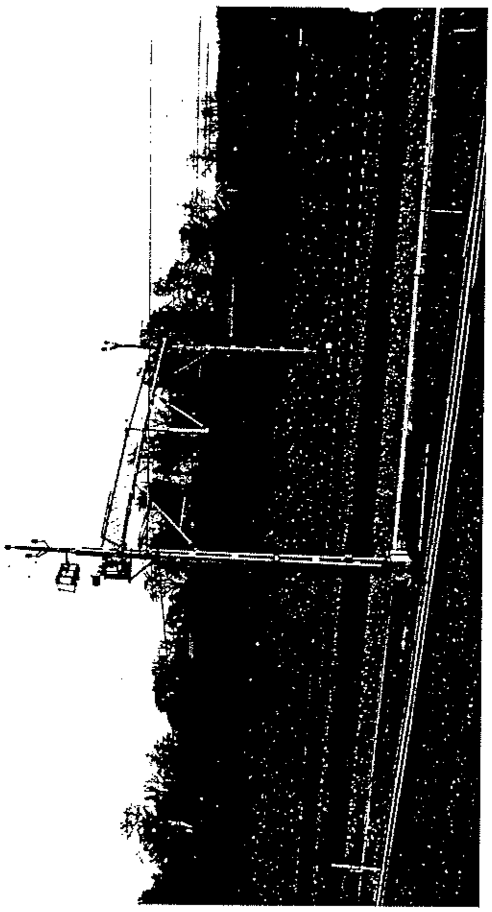

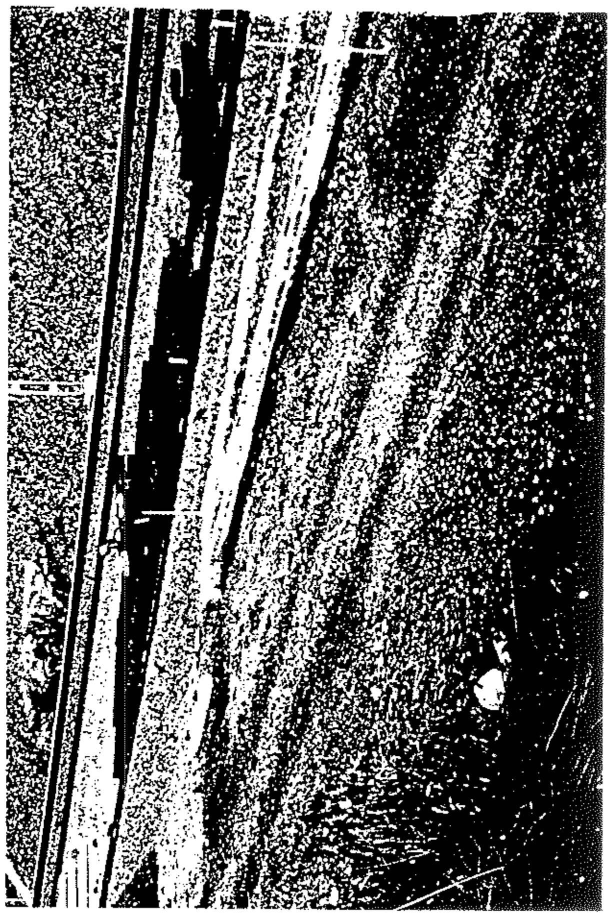

Photos II-12.1 — II-12.4

III: TRIP TO ITALY

DECEMBER 7 - 12, 1992, ITALIAN STATE RAILWAY & FIATFERROVIARIA

1.0 PURPOSE

To obtain the detailed operating history of the ETR 450 and the infrastructure over which it is operated, especially as regards failure events and frequencies, maintenance and inspection cycles and input factor types and quantities (person hours by skill type and class, materials as % of initial vehicle cost., etc.) for the tilt mechanism and controllers, pantographs, and other major vehicle subsystems excluding traction motors, and also the same detailed data for infrastructure (track structure, rails, ties, catenary, power substations, and so on).

As with the SNCF and SJ visits, a list of questions was sent to both Mr. Mazzotto, Commercial Manager of Fiatferroviara, Savigialno, and to Dr. M. Cavagnaro, Director of High Speed Rail Systems, Italferr - sis. t.a.v.

2.0 ITINERARY

The itinerary is included as Appendix B. It involved meetings with Italferr (a new organization responsible for High Speed Rail on behalf of the Italian State Railways), Fiat Ferroviaria (manufacturer of the ETR 450), and Breda (manufacturer of the ETR 500). Trips were also taken on the Pendolino both on the Direttisima Line and on normal operating lines i.e., between Florence and Torino.

Attendees at the various meetings are listed in Appendix C and the minutes are included in Appendix D. The list of some 20 different documents and data items are listed in Appendix A.

3.0 OUTSTANDING ITEMS

On December 12, 1992, copies of the question lists were sent by fax to both FIAT and Italferr. In these, the outstanding items were indicated and both organizations were asked to forward the outstanding information as soon as possible. Follow-up requests were made the week of January 18th.

4.0 CONCLUSION

Italferr is a new organization recently set up by the government with responsibility for managing the projects on high speed rail. As a new organization it is going through the normal gestation period. The intent is to remove the high speed rail projects from the bureaucratic process that encumbers the Italian State Railway (FS). This approach has already succeeded to the extent that an implementation plan has been approved and contract negotiations have begun for both track installation and vehicle acquisition.

The train trips by Pendolino convinced the writer of its stability and ride comfort on both the special track (Direttisima) and conventional track. Having had the opportunity to travel in the locomotive cab, it was possible to observe the functions of train control and the quality of design of the operational interface, both of which were impressive in their simplicity and effectiveness.

The creation of a special private consortium for financing and construction of a High Speed Rail project is hoped to reduce the dependency on government funding and therefore, lead to speedier progress with their plans.

Fiatferroviara Savigialno has within the past few years won orders for high speed rail equipment in Finland and in Germany. Both orders were won in competition with domestic, German, French and Swedish companies. Thereby showing that their equipment is functionally and cost competitive with other European manufacturers. Fiat are becoming more aggressive in exports and are likely to enter the North American market.

APPENDIX III-A

LIST OF BROCHURES / DATA SUPPLIED

1) Breda brochure ETR 500
2) TREVI brochure ETR 500
3) FIAT brochure ETR 450
4) FIAT general brochure
5) Collegio Ingegneri Ferroviari Italiani
6) Fiat ETR 450 Train operation information
7) Parizzi information on electrical equipment for Pendolino
8) FIAT Pendolino Reliability and maintenance data
9) FIAT Pendolino train resistance curve
10) FIAT Pendolino passenger comfort data
11) Safety coefficient for standard railway vehicles
12) Comparison of tolerance of different European railroads
13) FIAT formulae for calculating train resistance
14) Information from Finish officials regarding contract award to Fiat
15) Design of electrification system for 25 kV 50 Hz
16) Maintenance of ETR 450
17) Command & Control for Italian High Speed Train
18) MIT Subgrade classification method as used by Italian State Railway
19) CESIT report of February 17, 1992 "Technological Plant" for High Speed Service
20) FIAT information on the Pendolino tilting train set

APPENDIX III-B

TRIP ITINERARY

DATE	ARRIVAL	CITY	MEETINGS
Mon., December 7th	Evening/Afternoon	Rome	Meeting with Prof. Chiesa of CESIT
Tues., December 8th	Dinner time	Rome	FIAT (Mazzotto)
Wed., December 9th	9:30 - 17:00		ITALFERR SISTAV (Mingozzi and staff)
	19:00 - 1:00		Trip by "Pendolino" to Torino
Thurs., December 10th	9:00 - 18:00	Savigliano	Fiat Engineering staff Tour trucks, coach and locomotive manufacturing plants
	19:00 - 21:00		Trip by train to Milano
Fri., December 11th	9:30 - 13:00		Trip by Pendolino to Firenze
	13:00 - 16:00	Pistoia	High Speed Rail Project Director - Breda
	18:00 - 24:00		Trip by train to Milano
Sat., December 12th	9:00 - 12:00	Milano	Meeting Review with Prof. Chiesa

APPENDIX III-C

MEETING ATTENDEES

italferr-sis. t.a.v. s.p.a.

Ing. ENRICO MINGOZZI
Responsabile
Servizio Materiale Rotabile

Sede Sociale via Lamaro 13 • 00173 Roma • tel (06) 722951 • fax (06) 7229521360

FS

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italferr-sis. t.a.v. s.p.a.

PAOLO FAZIO
Servizio Impianti TE - SSE

[illegible] Roma • tel (06) 722951 • fax (06) 7229521360

FS

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italferr-sis. t.a.v. s.p.a.

Ing. MATTEO SCORDATO
Responsabile
Servizio Controllo-Comando,
Telecomunicazioni

Sede Sociale via Lamaro, 13 • 00173 Roma • tel. (06) 722951 • fax (06) 7229521360

FS

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italferr-sis. t.a.v. s.p.a.

Ing. MAURIZIO DE PAOLIS
Project Engineer tratta Roma - Napoli

Sede Sociale via Lamaro 13 • 00173 Roma • tel (06) 722951 • fax (06) 7229521360

FS

BREDA COSTRUZIONI FERROVIARIE

Dr. Ing. MARCELLO PECORINI
DIRETTORE PROGETTAZIONE
ALTA VELOCITÀ

GRUPPO EFIM

Breda Costruzioni Ferroviarie S.p.A.
Via Ciliegiole 110b - 51100 PISTOIA
Telef. (0573) 3701 - telex 570186 BCF I
fax (0573) 370292 - telegr. FERROBREDA

AVIOFER BREDA

Andrea Mazzotto

Commercial Department
Export Sales

FiatFerroviaria

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Ing. Alessandro Elia

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Telex 215020 Fiatsv I - Telefax (0172) 718.385

Ing. *Alberto Magnani*

Direzione
Progettazione e
Prove

FiatFerroviaria

12038 Savigliano (CN)
Piazza Galateri, 4 - Tel. (0172) 718.~~365~~ 359
Telex 215020 Fiatsv I - Telefax (0172) 718.372

Ing. Roger Gansekow

Direzione Prodotto

FiatFerroviaria

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Piazza Galateri, 4 - Tel. (0172) 718.407
Telex 215020 Fiatsv I - Telefax (0172) 718.385

APPENDIX III-D

MINUTES OF MEETINGS

MEETING WITH ITALFERR

a) FS owns 40% of Italferr and remainder is owned by private companies

The financing group which will construct the HSR projects consist of private banks

The government, Italferr and financing group have agreed to proceed with
Milano - Napoli,
Torino - Venezia, and
Milano - Genoa lines

Three contractors will equally share the building and they are:

- ERI
- ENI
- FIAT

The line from Milano to Napoli will be the first built.

The maximum speed will be 300 kph.

The Firenze to Roma line operation started in 1965 and has a maximum speed of 250 kph.

b) Signalling and Communication (Scordato)

Design Criteria
- 2.5 minute headway
- 2 way working
- continuous speed on-board
- braking curve on-board
- continuous transmission of data between track and train
- safe replication on-board of speed
- adaptability to future European standards
- ability to operate a lower performance when there is a fault
- quality assurance
- RAM standards - in particular, MTBF for each subsystem
- track circuits use audio frequencies of 1700 and 2600 hz
- 30 different modulation frequencies (similar to TVM 430 signalling)
- ATP for continuously welded rail

Another method will give 100 bits of useful information. It has FSK modulation.

In cab signalling (without track side signals)

c) Discontinuous information sent by passive transponder to advise change of voltage and changes of track conditions (curves etc.).

d) Active transponder will be used in future to back-up continuous signalling system.

e) Radio communication train-to-central is automatic for data transponder. Phone is used for verbal communication with driver.

f) Present system is BACC System

- track side signalling
- 1500 m sections
- coded block circuits
- 50 Hz circuits } not possible with
  178 Hz circuits } 25 kV 50 c/s
- ok for 250 kph
- 5.5 km between trains of 250 kph (4 blocks)
  3 blocks for 220 kph
  2 blocks for 180 kph
  1 block for 150 kph
- no at-grade crossings on lines above 200 kph
- on condition maintenance
  10 people/km for everything at present, includes all personnel operating/ engineering/management. Goal is about 5 people/km
- One central control centre for Milan to Naples line with 2 subcentres for each of Milan to Florence and Rome to Naples sections (approx. 250 km each).
- Centre comprises 3-4 consoles operated 24 hr/day and requires 5 to 6 people constantly

g) R&D

- ETCS European program,
- 1996/7 program may end,
- sub elements of project:
  Eurocab std for cab sign (1995),
  Euraballisle TBL stds (1996), and
  Euroradio radio stds (900 MHz).

h) Electrification

- 25 kV monophase - 50 c/s
- 12 MW/train/direction
- 5 minute headway
- 1.2 - 1 MW/km
- higher design margins for double size trains to give 20 MW
- uses bi-phase 25 kV as in France with autotransformer
- 50 km/substation
- 4 subsection of 12.5 km with an auto transformer
- substations do not operate in parallel
- open air substations
- no people in s/s
- 3-4 person for Power System controls
- will use more diagnostics
- 15 km per 3 kV DC S/S Fir-Roma; 12 km for new lines
- MBTB for every 100 km of track there are 3 failures/year
  or 1 failure/day for 10^4 km
- failure defined as anything that stops the train
- Telecoms interference follow the standards of CITT
- have formed an accord with SIP (Italian phone company)
  300 m limit for interference in cities
  3 km limit for interference outside high population areas
- ac currents may cause problems for 3 kV system signals
- 0.3 person/km for electrification maintenance (probably some for signalling)
* goal is 1 person/km for maintenance for civil/signalling/electrification
- energy consumption 4 10^6 kW hr for whole system
- 30 kW hr/km/1000km average for ETR 450
- 50 kW hr/km/1000 km is target for ETR 500
- the benefits of regeneration are insufficient because braking is too infrequent

i) Track

- simply support beams because continuous beams require a special joint for the fracture of the track
- deflection max - 1/3000 for sections longer than 5 spans
- for bridges of 1 - 5 spans 1/1500
- 2000 kg/cm^2 main factor is choice of sleeper weight 400 kg monoblock
- are considering a concrete plate for in-tunnel use
- use MIT standards A1 - A8 with A8 being the worst classification
- gradual transition from embankment to beam
- 5-7 cms settlement in 10 years for embankment
- use insulated bearing and joints on columns in area of 3 kV
- layers of 50 cms & compacted, density is the criteria for selecting amount of compaction
- test 400 kg/cm^2 pressure standard test in Europe
- upper part - 30 cms 1 inch compacted is 800 km/cm^2
- in Europe the standards will be 1200 kg/cm^2
- 12 cms of asphalt and small gravel

- then ballast of 35 cms minimum below the sleeper
- there is a problem in France of breaking gravel due to light dual-block sleepers

j) Construction Specification

- 5400 m minimum radius for lateral acceleration of 0.6 m/s^2 at 300 kph
- 16 cms cant. max.
- transition 0.15 m/s^3 at 300 kph
- slope 1.8% line slope
- vertical radius R 20-30,000 m between curves
- 0.022 °/m at 160 kph } transition at switches
- 0.015°/m at 220 kph }
- switches have moveable track
- 60 kg/m UIC rail
- Pandrol fastener type K used by FS
- Pandrol - Vostock is being tested
- Pandrol English type is also under consideration
- normally don't use geogrids because of hydrolysis
- 50 cms excavation and substitute with anti-capillary material and press until 200 kg/cm^2
- low speed track has $CaCO_3$ type ballast
- high speed uses volcanic, silicate ballasts
- Italian Railways have best ballast in Europe as studied by ERI (European Research Instittue)
- change ballast on basis of measurement of holes in ballast
  30 - 60 in weight
  3% - 6% in weight
  Los Angeles method of testing
- make an impact on cubic shape on 3 cms sample
- make also a compression test first when material is laid and then when problems are anticipated
- conduct tests 35 cycles of temp -10 to 25° C and on new material compare with existing material which must be with 20% of new material
- 15 years theoretical life
- 12 years practical life
- every 25 years replace track and 35 years the ballast
- maximum vert dyn. load 170 kN
- Prundhum' rule 1.0 for locomotive and coaches and 0.85 for freight
- maximum weight/axle 130% of static andY/Q ratio 0.8 in tangent track and 1.2 in curves with 80% inclination of flange (UIC or ORE rule)
- 144 m sections of rail weld when installed, 10°C is temp of equilibrium
- maximum allowable temperature in summer 70% above this speed is reduced
- have had a few rail breaks on Dirittisima
- thermite or electric sparking is perferred
- thermite is used as the replacement weld
- use electric switch heaters which are manually turned on
- hydraulic pistons on high speed switches
- for existing lines will use tilting body train ETR 450
- new lines will use ETR 500

- 15 ETR 450 already made and 10 more are being made
- Swiss SBB and FS have a common specification (prepared by FS) for tilting train for run between Milano and Bern. and with Geneva

MEETING WITH FIATFERROVIARIO

a) Vehicle Data

- Drag coefficient $C = .304$ lead car
  without roof R $C = .144$ intermediate car
  with roof R $C = .231$ intermediate car
  $C = .282$ final car

  $$R = C_0 \; M \; + \; C2 * v^2 \; +$$
  (4 40T) V (kph)
  $$C_2 = 0.000686 \; KN/kph^2$$

- pantograph is furnished by railways
- reliability figure includes "accident" which was a pantograph problem with FS 52 type
- 6005 A*l* extrusion with Mg & Si content
- a stock used for frontal beam - 7020 A*l* fabricated

b) Design Cases

- calculations based on 2 different FEM on 1/4 or 1/2 of car
- ICE 566 stds , vert load has 30% margin, 12 mm defl. at centre of sidewall, 7 kg/mm^2 max. stress for material with yield at 22 kg/mm^2
- Compressive load at buffer of 200 tonne - 14 mm shortening and 22 mm deflection in a stock, has small area of max. local stress of 27.4 kg/mm, with 28 kg/mm^2 yield material
- compressive load of 40T above buff level but not at mid point 5 mm shortening of car, 1-2 mm bending of post 24 kg/mm^2 max load stress in 7020 A*l*
- compression load is 30 tonne at mid point of collision post same level of stress max. as for 40T compression load
- compression load 40T at cant. trail 12 kg/mm2 max stress level
- pressure loading of 6000 pascal external for tunnel operations almost insignificant
- Lifting from 4 lift points of body shell with attached bogies almost same stress conditions as vertical loading

c) Rerailing

- fatigue calculation 10^7 cycl.
- crash design condition - 6 kph velocity
- vertical load from fatigue is most difficult design case
- Post load is most difficult case from max. stress criterion

d) Maintenance

- maintenance is based on line replacement unit
- maintenance people must have troubleshooting ability but not repair skill

e) Suspension Characteristics

- car body with px	3976 kpd/S^2/m
bogies	253 kpd/s^2 /m
axles trail	133.6 kpd/S^2/m
axles drawer	159 kpd/S^2/m
- pry. susp.vert	715 kpd/mm total/bogie
- sec. vert susp	88 kpd/mm
- Sy. long susp.	900 kpd/mm/bogie
Sy long.	1350 kpd/mm

- there is also active lateral suspension
- motor in carbody gives low primary weight

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* kilopounds

ANNEX III-E

SINGLE VOLTAGE PENDOLINO DATA specs 6 MW VERSION

Train Configuration

# of cars	- 9
# of power cars	- 6
# of trailer cars	- 2
# of service cars	- 1
Total weight	- 442 tonne
# motor/train	- 12

Traction

Total power at wheel	- 5880 kW
Max. force at wheel	- 207 kN
Power/axle	- 500 kW
Max. motor torque/axle	- 3335 Nm
Max. motor speed	- 3500 rev/min
Length - active part of motor	- 370 mm

Braking

Total power at wheel	- 5156 kW
Max. force at wheel	- 143 kN
Max. power/axle	- 421 kW
Max torque/axle	- 2209 Nm

Operating Conditions

Normal line voltage	- 3000 VDC
Wheel diameter (av. use)	- 870 mm
Transmission efficiency	- 98%
Gearbox ratio	- 2.296
Resistance at 250 kph on level track	- 64.57 kN
Residual acceleration at 250 kph on level track	- .045 m/S^2