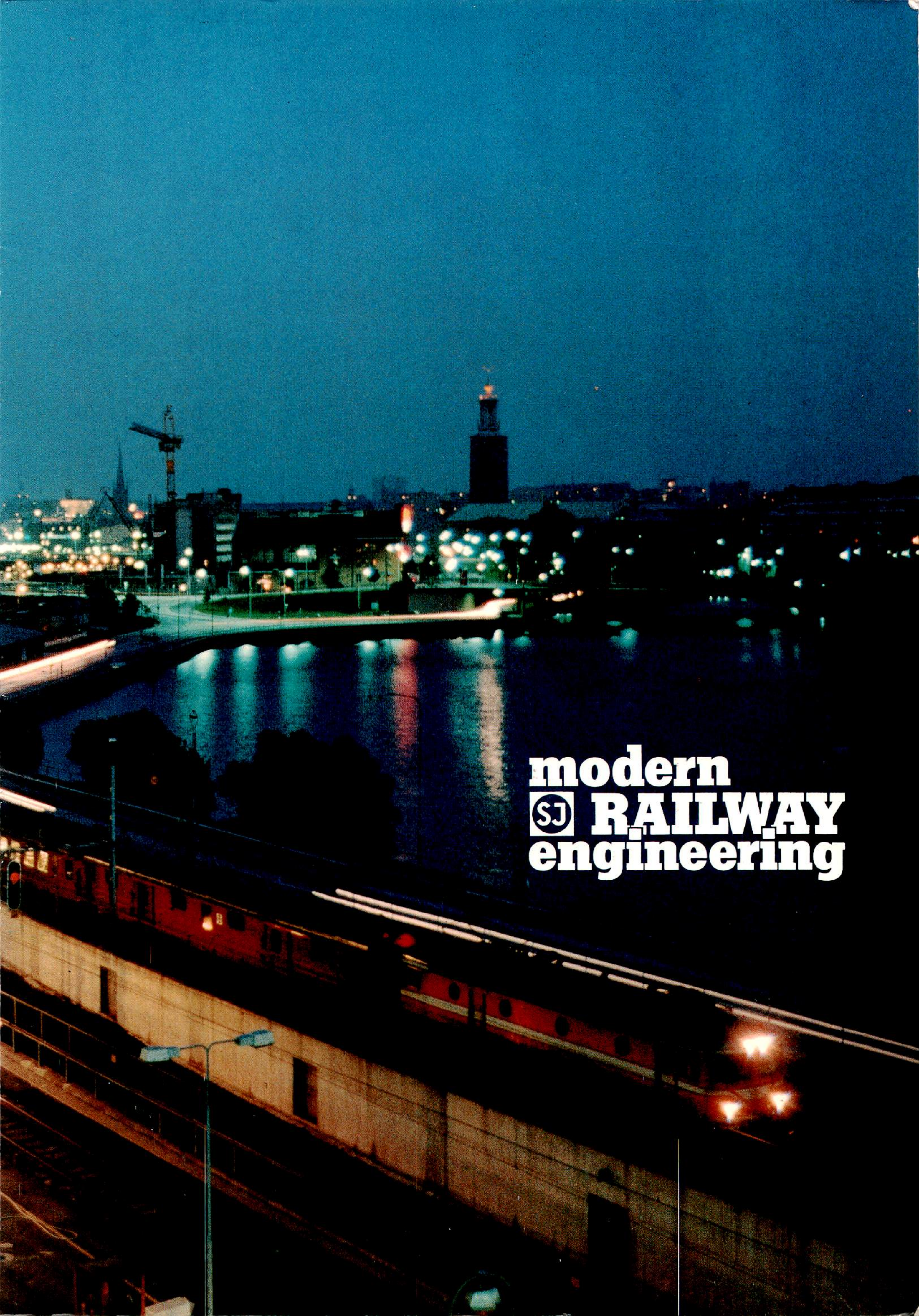
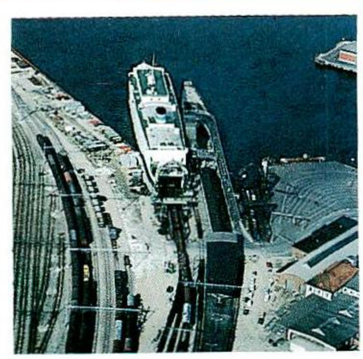


modern SJ RAILWAY engineering

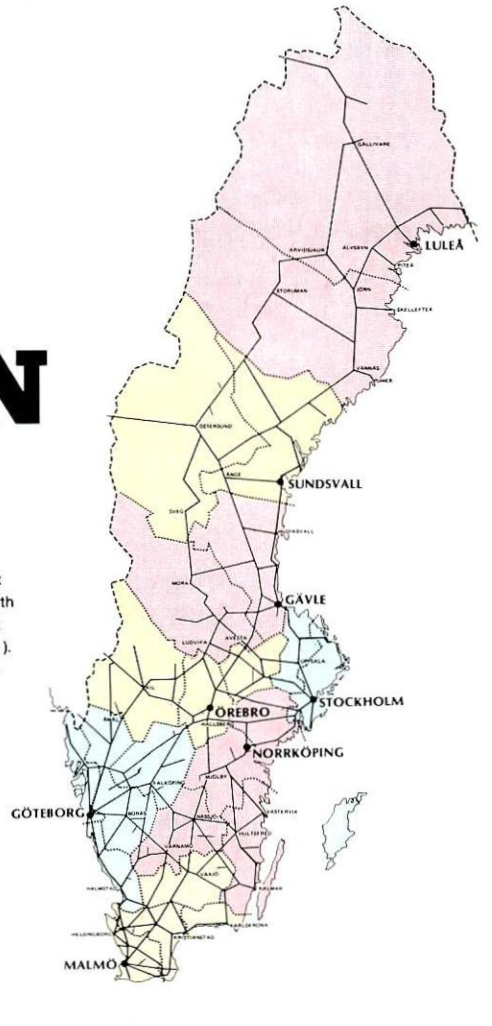
Contents



Cover: Stockholm Central Station. Photo: Björn Enström
Layout and drawings: Tage Egertz
Published by
Swedish State Railways (SJ), Administrative Secretariat. 1981

BRIEF INTRODUCTION TO SJ

This brochure presents a brief description of Swedish State Railways (SJ) and its activities. However, it should be noted that in addition to the operations covered here, SJ offers many other important services. These include an extensive network of bus lines, lorry services, ferry traffic and travel bureaux, as well as railway R & D.



SJ Operating and Fixed Installations Regions

At regional level SJ is divided into eight Operating and eight Fixed Installations Regions with the same geographical extent and the same main centres (•). In principle, the Regions have been adapted to the county boundaries.

Frontier - - -
County boundary ....
Railway line ——

The Swedish railway network includes approximately 13 000 route kilometres (mostly with a 1435 mm gauge). Approximately 12 200 km of this network is owned by SJ, and SJ thus dominates Swedish railway operations. About 7 000 km of SJ's network is electrified and these 7 000 km carry approximately 95 % of the total railway traffic.

Automatic block systems are installed on about 4 700 km, and Centralized Traffic Control (CTC) on about 3 800 km. There is about 4 000 km of continuously welded track mainline. Approximately 2 300 km has concrete sleepers.

The first major electrification step was taken in 1915. It embraced 129 route kilometres of ore-carrying lines located north of the Polar Circle, where climatic conditions are severe.

All mainlines throughout the rest of Sweden have since been electrified, thus enabling SJ to acquire broad experience in operation of traffic with heavy ore-carrying trains as well as of dense suburban traffic.

In Sweden, changeover to thyristor control of both locomotives and railcars is proceeding rapidly.

The SJ catenary system carries 15 kV at 16 2/3 Hz. A high-voltage AC system of this type was chosen because of the long distances and relatively light traffic involved. At the time when electrification was implemented, this low frequency was necessary to accommodate AC traction motors.

SJ substations convert 3-phase power to 1-phase. Many of these substations are now remotely controlled from centres that adjoin the CTC offices.

In Sweden, ground resistance is high and, in electrified systems, this causes difficulties involving telecommunications disturbances. It thus became necessary to study these problems in detail, and to solve them SJ introduced special return conductors and booster transformers.

The engineering know-how that enabled SJ to implement electrification so successfully has been kept up-to-date, even though Sweden's electrification epoch has evolved into sustained growth. As traffic becomes more dense, ever-more-stringent demands are imposed regarding speed, power output of tractive stock, operational reliability, etc.

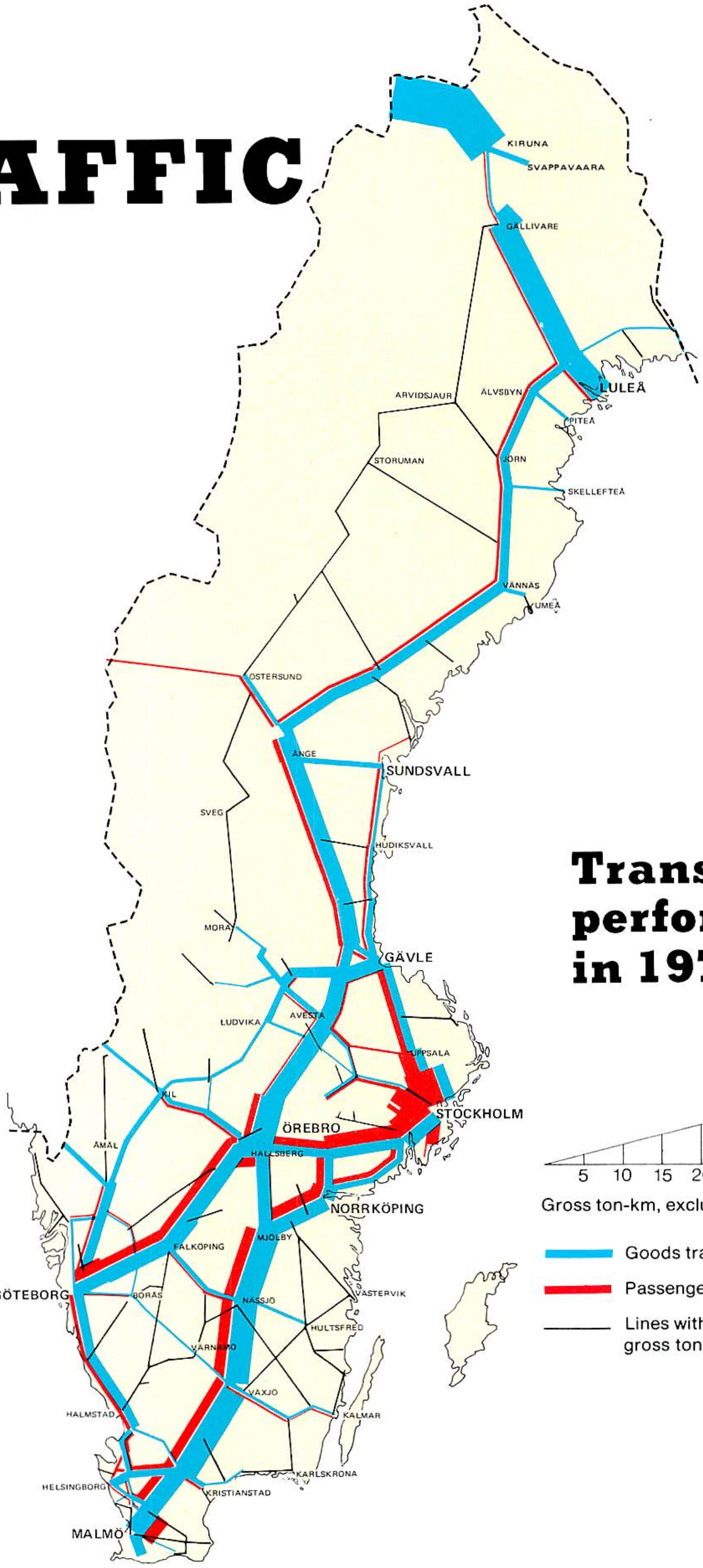
The data and illustrations presented on the following pages provide a general summary of facilities and operating procedures.

Principal SJ data
(1980)

Personnel	Number of employees	38 500
Track	Route length	
	Standard gauge	11 195 km
	of which double track	1 152 km
	Narrow gauge	182 km
	Total	11 377 km
	Track length	
	Mainline	12 529 km
	Sidings	4 965 km
	Private sidings etc	576 km
	Total (of which narrow gauge 453 km)	18 070 km
	Electrified route kilometres, mainline	7 063 km
	Number of wooden sleepers	22 240 000
	-"- concrete sleepers	3 720 000
	Number of points in mainline	6 060
	-"- -"- sidings	14 890
	-"- -"- private sidings	1 325
	Rails in mainline:	
	Weight 50 kg/m	5 540 km
	-"- 43 kg/m	3 750 km
	-"- 41 kg/m	1 240 km
	-"- > 34 kg/m	1 100 km
	-"- < 34 kg/m	944 km
Electrification	Total electric power consumed by SJ (3-phase, 50 Hz)	1 780 GWh
	Electric power for train operation (3-phase, 50 Hz)	1 530 GWh
	Energy consumption per gross ton-km incl. locomotive (3-phase, 50 Hz)	33 Wh
	Overhead contact lines 15 kV, 16 2/3 Hz	11 022 km
	Auxiliary power lines 10–20 kV 50 Hz	5 517 km
	Number of converter stations	58
	-"- remotely controlled converter stations	47
	-"- remotely controlled isolators, approx.	3 000
	-"- heated points, approx.	5 000
	Total rated power consumption of heated points	25 000 kW

Signalling and safety systems	Number of interlocking plants	
	Mechanical	481
	Mechanical and electrical	354
	Electrical	717
	Number of safety devices at level crossings	4 310
	Automatic block system	
	Route kilometres	4 702 km
	of which double track	1 123 km
	CTC	
	Route kilometres	3 859 km
	of which double track	361 km
	ATC	
	Route kilometres	213 km
	of which double track	43 km
Telecommunications facilities	Main cables	
	Owned by SJ	5 879 km
	Shared with Swedish Telecommunications Administration	5 375 km
	Local cables	2 517 km
	Number of automatic telephone exchanges	160
	-"- telephones	34 582
	-"- teleprinters	405
Rolling stock	Tractive stock	
	Electric locomotives (mainline)	624
	Locomotives (shunting)	130
	Railcars	40
	Railcar sets	146
	Diesel locomotives (mainline)	227
	Railcars	216
	Locomotives (shunting)	396
	Passenger coaches	1 618
	Coaches for railcars	126
	Goods wagons	
	Standard gauge	43 252
	Narrow gauge	119

TRAFFIC



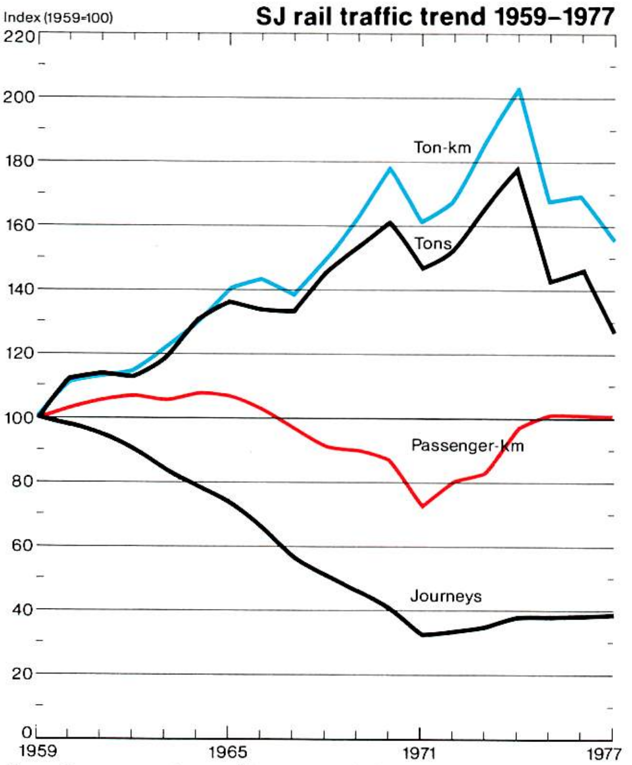
Transport performances in 1977

5 10 15 20 25 30 35 40 million

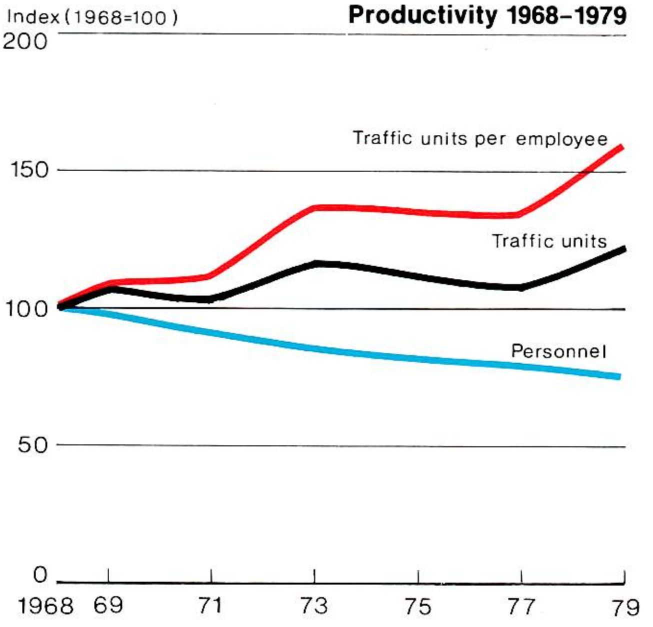
Gross ton-km, excluding locomotives

Goods trains
Passenger trains
(at least 0.6 million gross ton-km per route-km)

Lines with less than 1 million gross ton-km per route-km



Note. Passenger-km and journeys relating to commuter services operated by SJ under contract to Stockholm Transport (and corresponding figures before 1967) are not included.

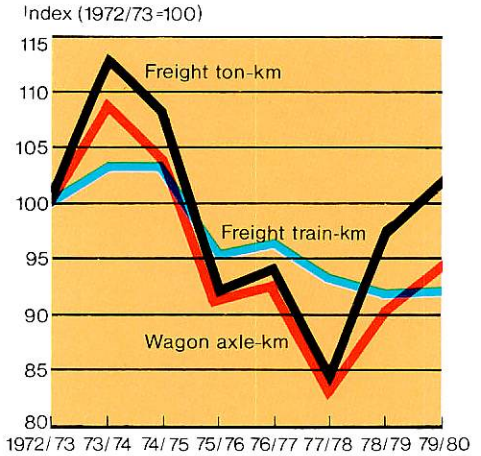


Productivity
The number of traffic units (passenger-km + goods ton-km) per employee for operating and maintenance duties

		Year	*1975/76*	*1976/77*	*1977/78*	*1978/79*	*1979/80*
Freight traffic	Train-km	millions	40.8	41.2	39.9	39.4	39.4
	Wagon axle-km	millions	2 679	2 714	2 427	2 643	2 752
	Goods ton-km	millions	14 762	15 074	13 554	15 732	16 577
	Goods wagon loads, bulk tons	millions	52.4	53.1	45.2	53.5	56.8
	Unit loads, tons	millions	1.1	1.1	0.9	0.8	0.8
Passenger traffic	Train-km	millions	53.1	53.7	53.8	54.8	55.1
	Coach axle-km	millions	1 164	1 167	1 161	1 166	1 183
	Passenger-km	millions	4 489	4 555	4 548	4 415	5 763
	Journeys	millions	23.2	23.6	23.8	23.5	29.2
	of which in						
	Sleeping cars	thousands	1 095	1 016	978	908	1 104
	Couchette coaches	thousands	320	335	366	368	436
Ferry traffic	Tons of goods on railway wagons	millions	5.12	5.20	4.96	5.30	5.89
	Journeys on train ferry routes	millions	6.6	7.2	7.8	7.4	7.9
	Road vehicles carried	thousands	583	646	673	655	658
Bus traffic	Bus-km	millions	73.5	73.2	72.2	73.8	76.0

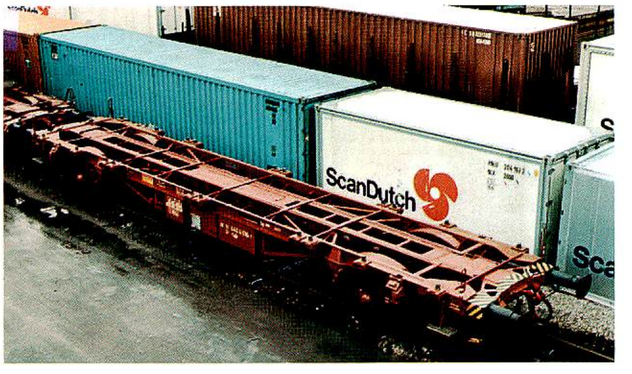
Freight traffic

Traffic trend



The predominant part of SJ wagon load traffic consists of the basic materials of the country – timber, iron and steel, and ore. Consequently the business cycles are also clearly reflected in SJ wagon statistics. Raw material and semi-finished products are always more affected by cyclical fluctuations than finished products.

In the last few years the energy situation – among other things – has provided opportunities for SJ to concentrate vigorously on combined transports. The traffic to and from the Continent is the part of SJ wagon load traffic that has shown the most favourable development and this tendency continues.



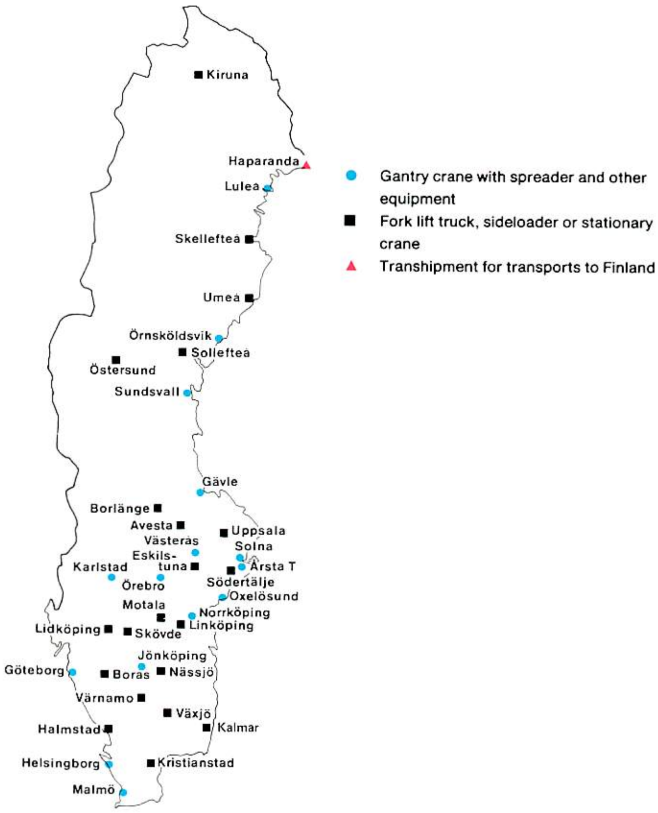
Two-axle special type wagon (class Lgjs). The frame is equipped with a long-stroke shock-absorbing device (length of stroke max 760 mm), which protects the container and the load in the case of shunting impacts.

Class Hbis wagon with sliding side walls. Movable transverse partitions ensure steadier loads and allow maximum utilization of wagon capacity.

Container terminals

In order to promote containerized transport SJ has created a network of container terminals. There are at present 37 terminals, of which 15 are equipped with gantry cranes with spreaders, with a lifting power of 30 tons. The remaining 22 terminals have sideloaders or fork lift trucks with a lifting power of 10–25 tons. Haulage units – tractors, trailers and semi-trailers – are also included in the equipment of the terminals. In collaboration with other European railways SJ has access to more than 400 container terminals linked to the railway networks.

In 1979, a total of 278 000 containers measured in TEU (Twenty-foot Equivalent Units) were transported on SJ. Almost 190 000 containers were transported in combined traffic land-sea to/from abroad. More than 90 000 were handled in domestic service. SJ has today about 600 20' containers and 600 7.15 metre swap bodies, as well as 160 9–12 metre platform containers.



Combined transports

It becomes more and more obvious how easy it is to *combine* different means of transport and to make the most of the advantages of each of them.

To some extent this is due to the difficulty in judging the energy situation. The rising costs with respect to personnel and tractive stock are also of prime importance. In view of constantly rising fuel prices long-haul transports which combine low energy consumption with access to all shippers and consignees are likely to come to the fore. SJ is already equipped to meet such demands after introducing i.a. swap bodies and suitable railway wagons. See picture below.

There is furthermore a whole spectrum of purpose-built containers which can be transferred from lorry to railway wagon.

Semi-trailer and road tractor

Long wagons accommodate six containers (two rows of three)

In order to stimulate still further the interest in combined transports the Swedish Parliament has decided on a special tariff for the regular conveyance (110 turnrounds per year) of containers and semi-trailers between such terminals as belong to SJ. The target group which SJ tries to capture by this offer comprises: road hauliers, associations and firms of hauliers, grouping agents etc.

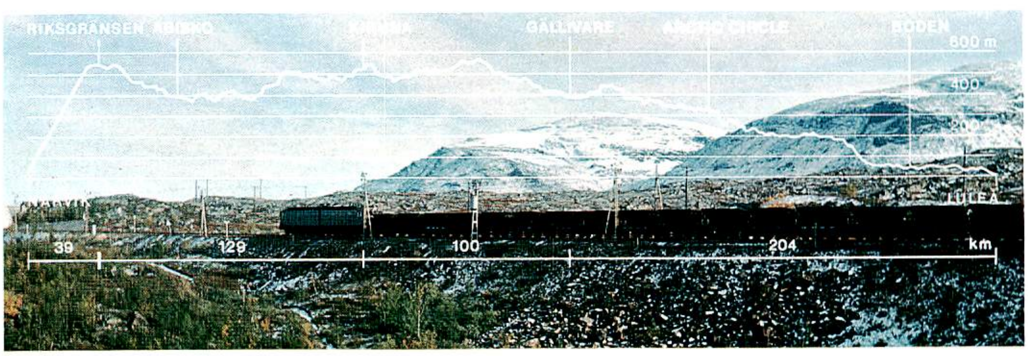
The specially-built containers – illustrated below – used to haul car bodies between Trollhättan and Arlöv are one example of today's specialized unit loads.

Ore transports

The single track Luleå-Kiruna-Narvik line in northern Sweden is of special interest due to the fact that heavy ore-carrying trains run in extremely severe climatic conditions. The entire route, approximately 490 km, is electrified.

The following are excerpts from 1979 operating statistics:

Gross ton-km, including locomotives, Luleå-Riksgränsen (449 km):	6 560 million
Maximum gross ton-km per km:	32.0 million
Total power for train operation:	165 GWh
Power consumption per gross ton-km, including locomotives:	25.1 Wh



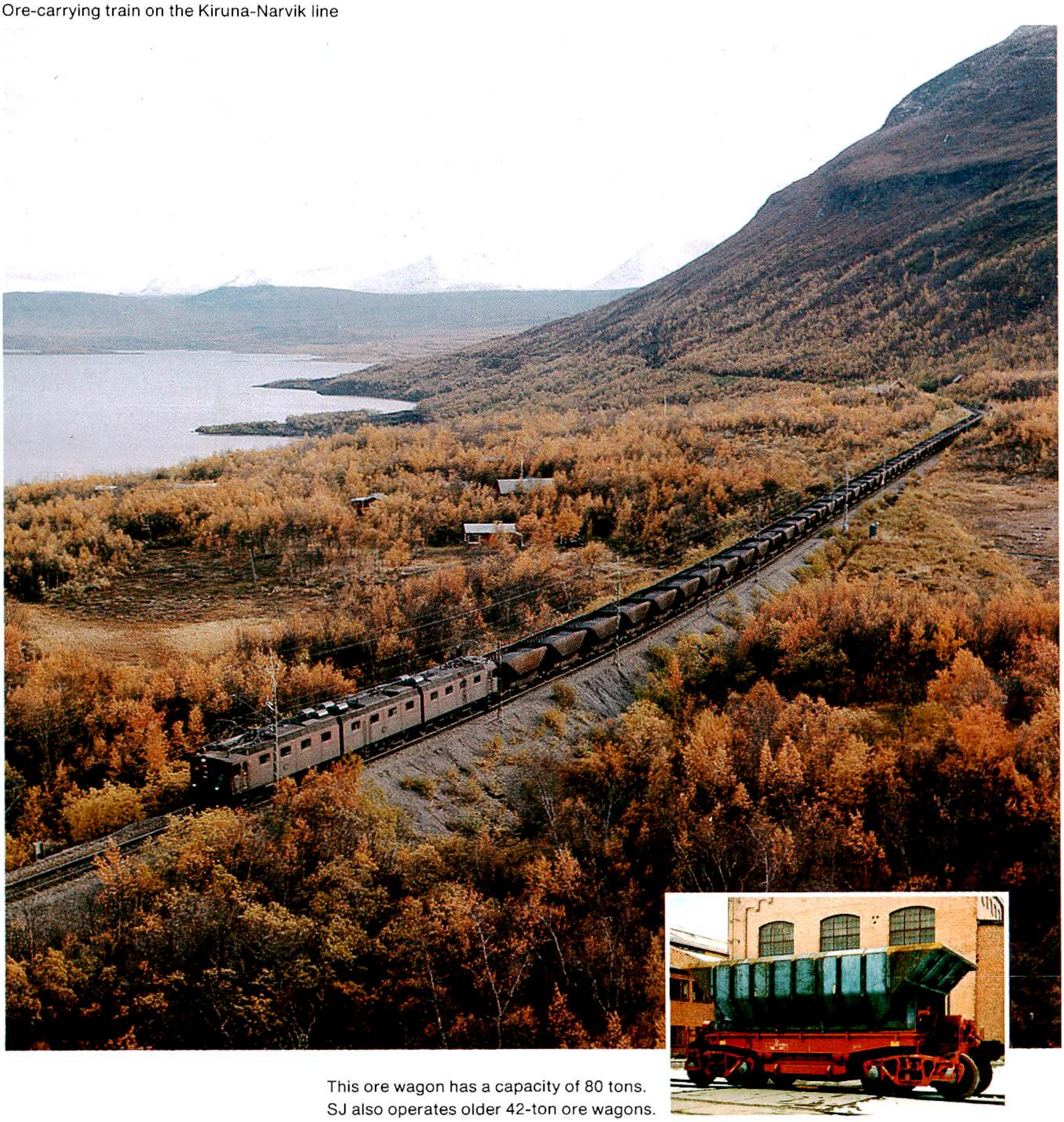
Route distances and elevations above sea level

About 30 million tons of iron ore are transported annually on the Kiruna-Narvik route alone (170 km). Throughout a typical 24-hour day, six passenger trains and up to 32 ore trains travel this route in one direction. Gross wagon weights in an ore-carrying train can range up to 5 200 tons.

The maximum gradient for a loaded ore-carrying train is 10‰.

This route is provided with CTC. Signals and points on the single track Luleå-Riksgränsen line are operated from CTC offices at Boden and Kiruna.

Ore-carrying train on the Kiruna-Narvik line



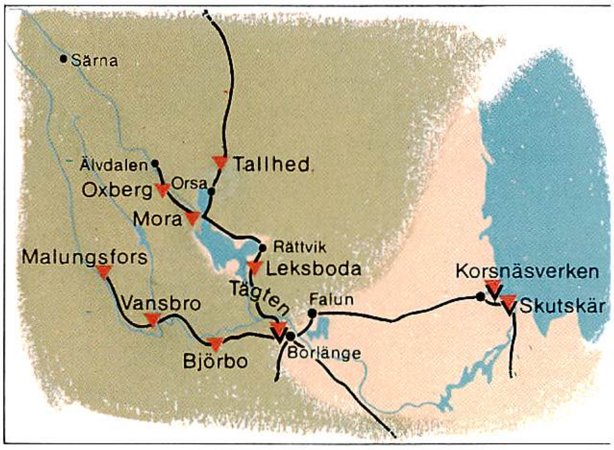
This ore wagon has a capacity of 80 tons.
SJ also operates older 42-ton ore wagons.

Timber and pulpwood transports

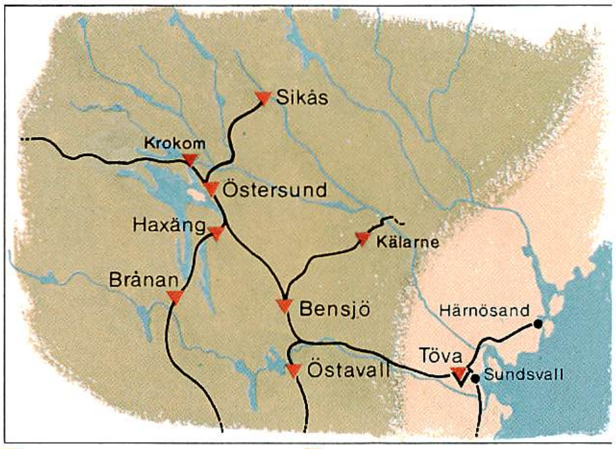
In two regions of Sweden where river driving has been abandoned, SJ's systematized railway transport now includes high-volume shipments of timber and pulpwood.

Loading round timber

Timber-carrying train hauled by two Du locomotives



DALA RIVER AND INDAL–LJUNGAN RIVER



▼ Loading terminal ▼ Unloading terminal

TIMBER AND PULPWOOD DEPOTS

Within the Swedish forest industry, efforts are being made to provide year-round employment for men and machines and continuous transportation to the wood-processing facilities. This has led to a system whereby timber and pulpwood are hauled by road to depots from which they are sent on by rail. The forestry industry finds this arrangement advantageous because it reduces the costs associated with forest landings, barking, drying, marking, etc. Moreover, loss of timber and pulpwood is reduced. This system enables SJ personnel and equipment to be utilized more efficiently.

The two most highly developed systems are the Dala River system and the Indal-Ljungan River system. Each year, they carry more than 2 500 000 tons of timber and pulpwood.

Two new systems are under projection, the Ångerman River system and the Ume River system. They will carry about 1 000 000 tons of logs.

Car weighing system

Electronic scale during installation

SJ changes now gradually its old mechanical car weighing machines with their big and heavy concrete-foundations for a new full-electronic scale without extra foundation. The surface mounted rail weighbridge, capacity 75 tons, can be used for statical weighing as well as for in-motion weighing, up to a speed of 10 km/h.

The 4.25 m long weighbridge is installed in a steel-frame of a total length of 8.5 m and with a depth of 400 mm. This steel-frame is installed as a track unit using standard track construction practice. The scale is delivered completely assembled and tested.

Since a concrete pit is not nesessary, the installation costs will be very low. Normal installation time is 2–3 days, and track downtime can be reduced to a few hours.

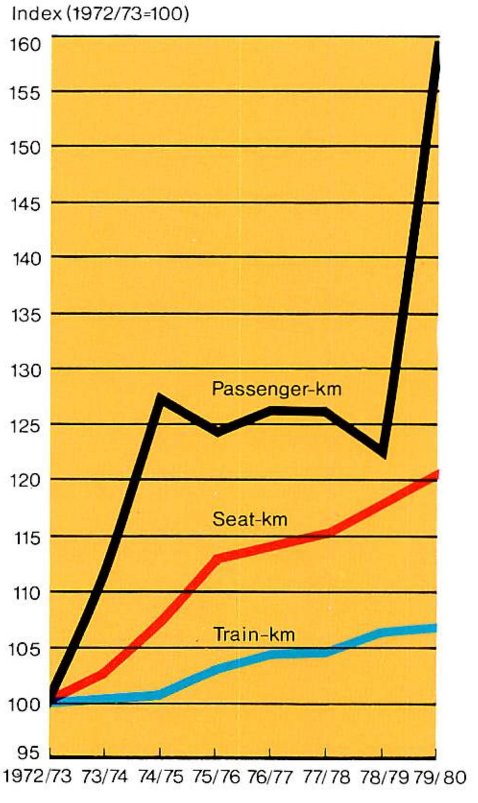
The weighbridge has 4 load cells from which its signals, via a cable, are amplified in a weighing instrument, with digital display and where the weight is shown with a sensitivity of 100 kg. The system also has a central unit and a printer. In the central unit information about tare-weights, wagon number, date and time can be stored and automatically be printed out by weighing.

Electronic scale in use

Central unit

Passenger traffic

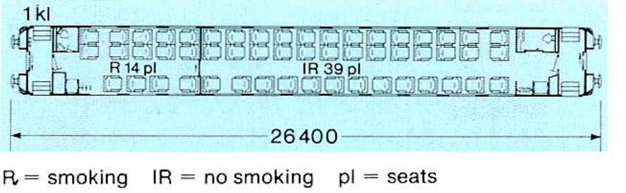
Traffic trend



Since 1972 rail travel has increased considerably, also outside local traffic areas.
The largest traffic increase, relatively speaking, was achieved on the routes Stockholm-Dalecarlia and Stockholm-Upper Norrland. The lines Stockholm-Göteborg and Stockholm-Malmö have also shown an important growth.
There are many reasons for the positive trend in traffic: improved range of services offered: increased number of mainline trains, faster and more frequent services, modern coaches, attractive products, i.a. the new second-class reduction card, intensive marketing of business travel involving i.a. sales visits to firms and authorities, and not least the Low-Price Drive with considerable reductions on Monday-Thursday and Saturday.

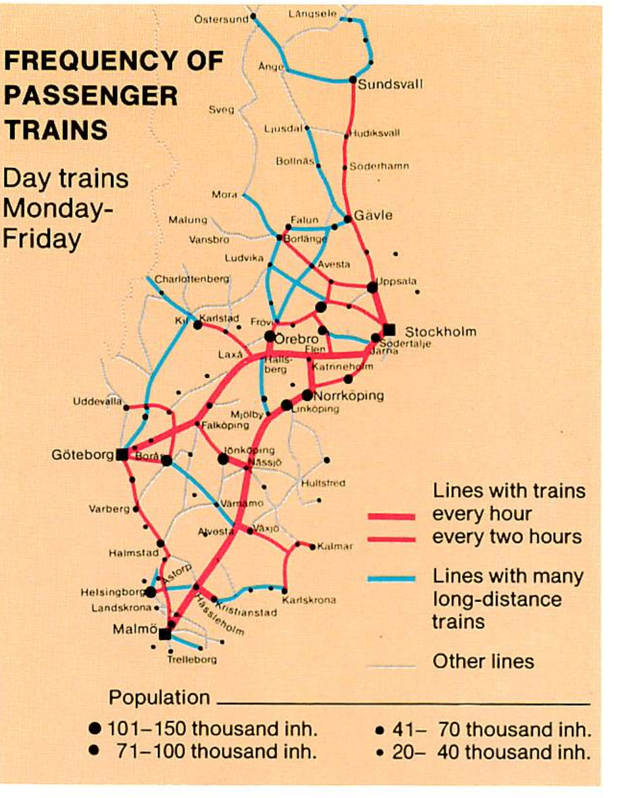
Passenger coaches
SJ has approx. 2 000 passenger coaches and railcar vehicles with some 107 000 seats (including some 26 600 in local traffic vehicles), 6 700 sleeping berths and 3 400 couchettes.
100 new 2nd class coaches B 7 are being delivered successively since 1979. Delivery of 50 Ist class coaches A 7 started at the end of 1980.
The coaches have, among other things, wide doors, steps and toilets specially adapted to disabled persons, adjustable seats, individual lighting and loud-speakers. The coaches are fitted with vacuum toilets.

Coach class A 7



R = smoking IR = no smoking pl = seats

Frequency of passenger trains (1979)
The number of passenger trains has increased on the busiest sections of line. The picture to the right shows, among other things, the lines where hourly and two-hourly services have been introduced.

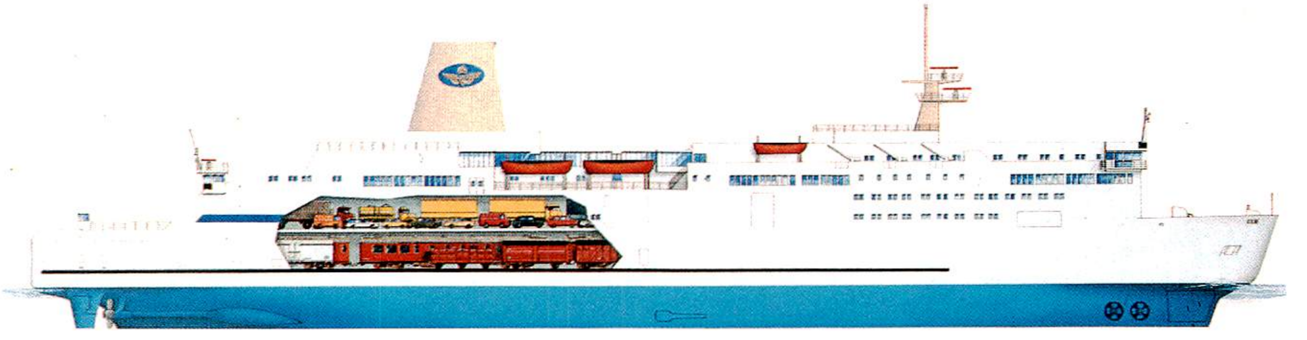


SJ Low-Price Drive
The Low-Price Drive started on 27th June, 1979, when a low-price card was introduced in 1st and 2nd class, valid for 12 months and entitling the holder to 40 % discount off the normal fare on Monday – Thursday and Saturday. Travel on the low-price days has shifted from the normal-price days Friday and Sunday.
Close on 500 000 low-price cards were sold during the first 12-month period. During the same period the number of journeys increased by approx. 5 million, or 25 % of the total number of journeys in long-distance and regional passenger traffic.

Train ferries
For the direct freight traffic to and from the Continent Sweden has the following train ferry services:

Helsingborg-Helsingør	Trelleborg-Sassnitz
Malmö-Copenhagen	Ystad-Swinoujscie

The capacity is measured by the number of 2-axled wagons that can be carried in *each* direction every 24 hours.
Helsingborg-Helsingør: approx. 430 wagons. Operated by Danish State Railways (DSB) with 6 passenger, car, lorry and train ferries.
Malmö-Copenhagen: approx. 60 wagons. Operated by SJ (the "Malmöhus"). Freight traffic only.
Trelleborg-Sassnitz: approx. 540 wagons. Operated by SJ (the passenger, car, lorry and train ferries "Skåne", "Götaland" and "Svealand") and by Deutsche Reichsbahn (DR) (the "Rügen", "Rostock" and "Sassnitz").
Ystad-Swinoujscie: approx. 90 wagons. Operated by Polish State Railways (PKP) (the lorry and train ferries "Mikolaj Kopernik" and "Jan Heweliusz"). Freight traffic only.



At the beginning of 1982 SJ will have a new train ferry for the line Trelleborg-Sassnitz. It is the biggest passenger-carrying train ferry in the world, as well as the first 5-track rail-ferry arranged for passenger trains.
The length of the ship will be about 170 metres (overall), the beam 22.5 metres. The train deck will have a capacity of about 700 metres train length. On 2 of the 5 tracks passenger rolling stock may be carried, the remaining 3 tracks being arranged for freight traffic only.
On a separate trailer deck above train deck up to 800 tons of lorries, trailers and accompanied private cars may be carried.
Passenger capacity will be 800. Only a small number of passenger cabins will be arranged as the crossing time is only $3^1/_2$–4 hours.

SJ Travel Bureaux

SJ Travel Bureau (SJR) is part of the SJ group. The travel bureaux are located in 40 places all over the country. They have some 600 employees and – as far as the turnover is concerned – they are Sweden's largest travel bureau chain.
The total annual turnover amounts to SEK 1 250 million, of which some 520 million are attributable to domestic journeys and some 730 million to journeys abroad. Rail travel in Sweden and other SJ products account for roughly SEK 200 million and rail travel abroad for roughly 30 million. All SJ travel bureaux have IATA rights, which means that they sell air tickets for all airlines affiliated to IATA.
The activity is primarily concentrated on business travel, which accounts for 70 % of the turnover. SJR has its own production of travel arrangements, such as journeys to trade fairs and other customer-tailored journeys.
Collective tours, cruises, long journeys and weekend trips account for the remaining 30 % of the activity. SJR cooperates or is in partnership with the principal tour operators in Sweden.

SJ Travel Bureau at Örebro. The Bureau is equipped with all modern aids, i.a. data terminals for rail and air travel, and for collective tours.

TRACK

Approximately 90 % of the total route kilometres comprises single track lines, but the mainlines in southern and central Sweden have double tracks. Typical stretches of modern track consist of continously welded 50 kg/m rails on concrete sleepers resting in broken stone ballast. At the beginning of 1980, there were more than 4 000 km of welded track and approximately 3.7 million concrete sleepers.

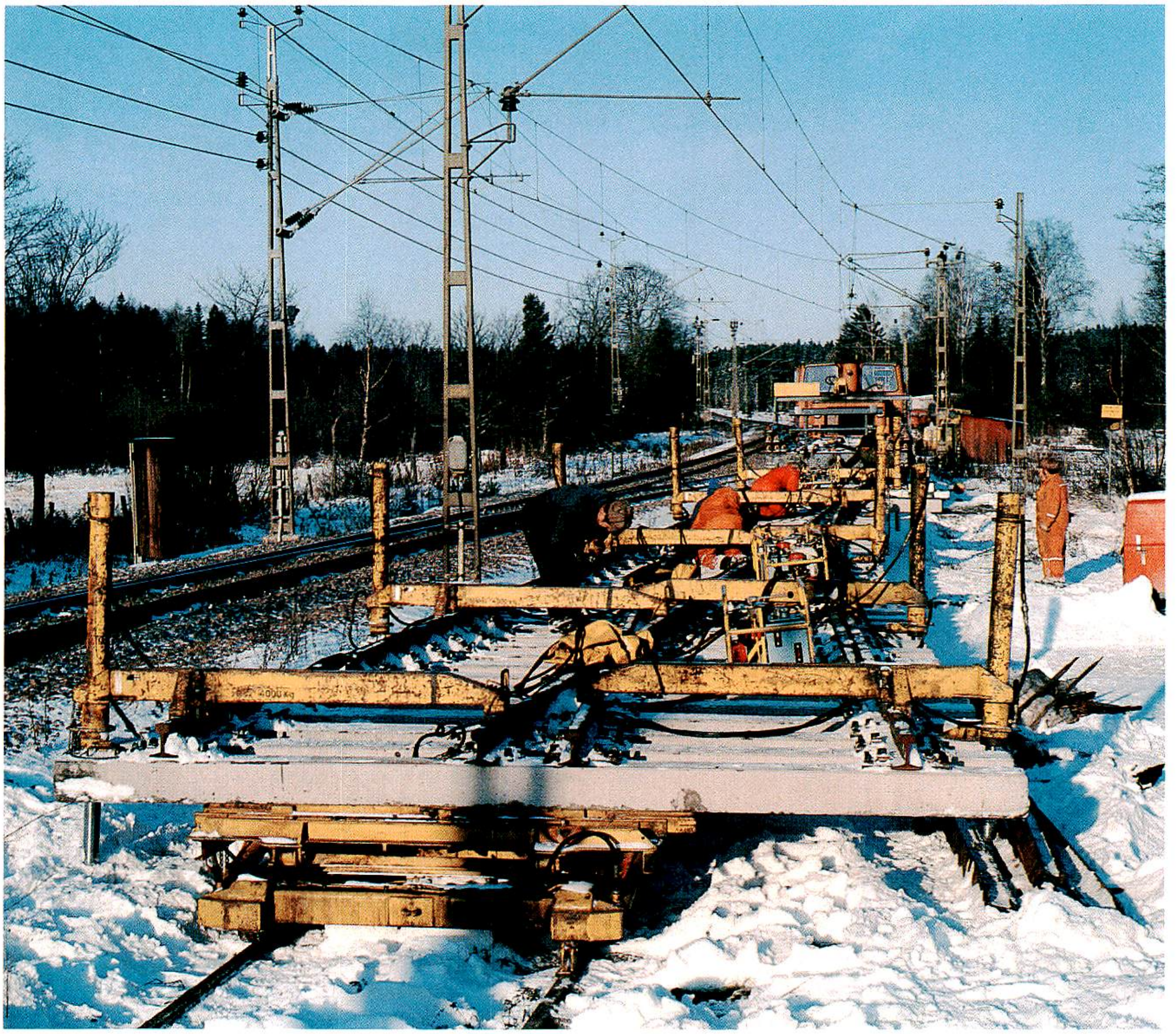
Double track with concrete sleepers

Laying track

All track laying and maintenance is carried out by SJ personnel and machines. Many of these modern machines are made by internationally-known manufacturers.

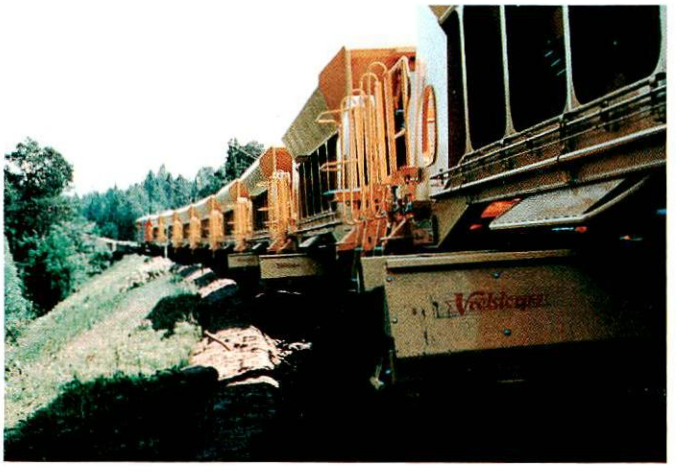
Because of high wages and the stringent ergonomic requirements imposed in Sweden, it is sometimes difficult to find the desired machines on the market. Many new types of machines have thus been developed within SJ.

Turnout exchanger being used to lay prefabricated point



Handling of ballast

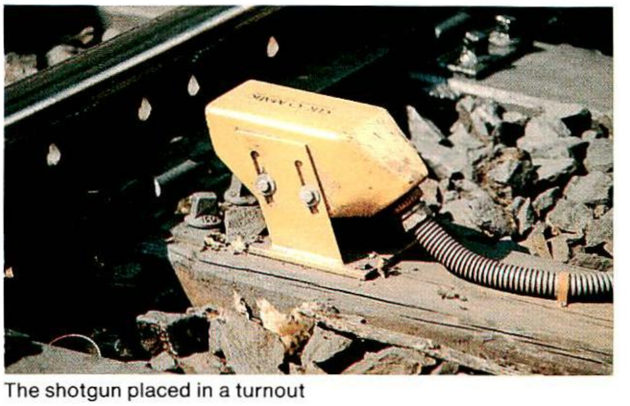
A new ballast wagon class Qbx has been developed in Sweden. The wagon is equipped with a sophisticated universal discharge system suitable for bulk material and used in permanent way maintenance and construction works. The system is provided with an adjustable feeder and a conveyer turnable 180 degrees.



Rail lubrication

Greasing equipment in a curved track

Reduction of wear on rails and wheel flanges in curved tracks and during passages in turnouts is of great economic importance. Efficient lubrication increases the service life of rails, wheel flanges and turnouts.



The shotgun placed in a turnout

A new rail lubricator has been developed to meet the requirements of modern railways – reliable operation and optimal and controlled lubrication.

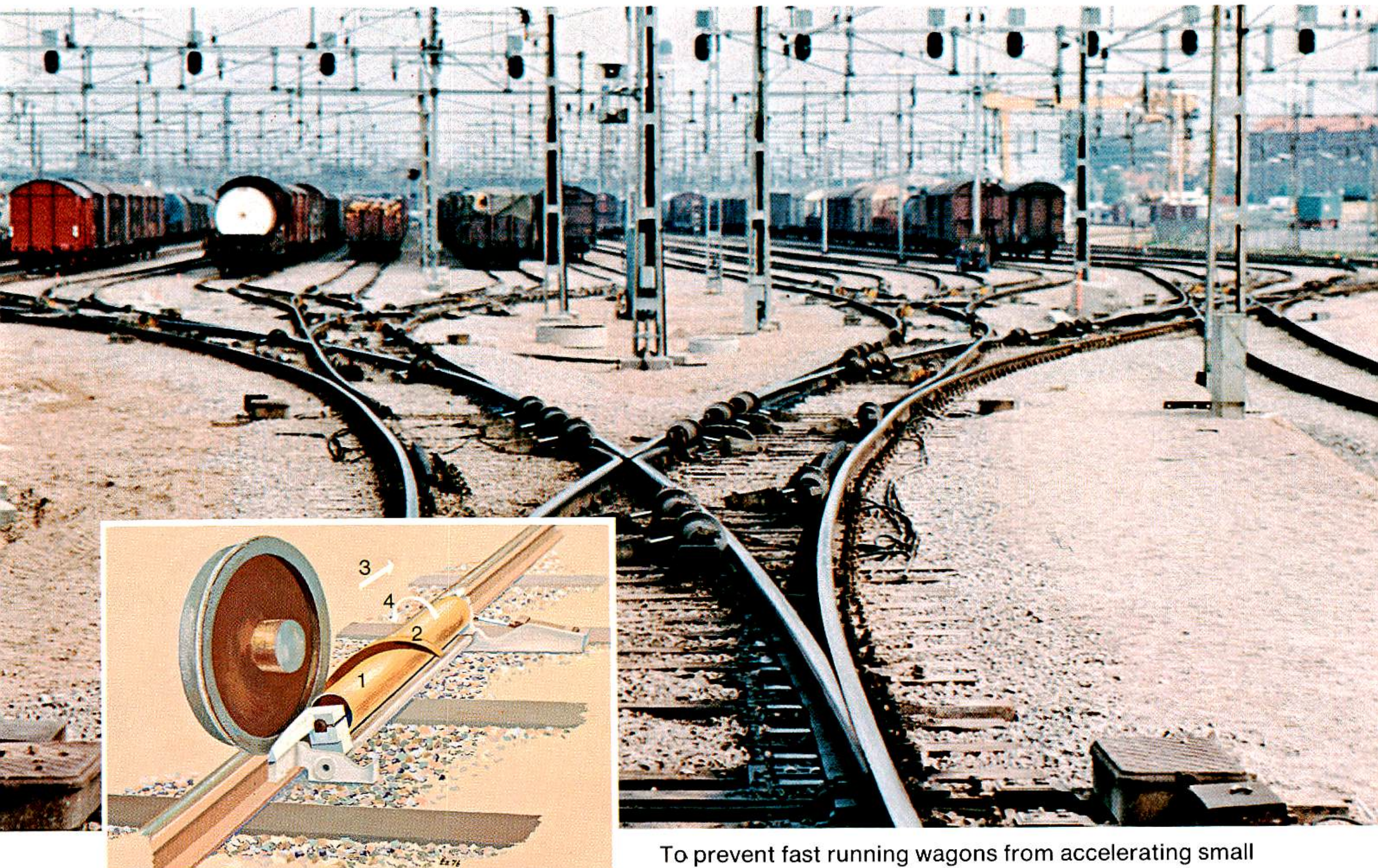
The lubricator, Clic-O-Matic, operates normally at pre-set time intervals with a possibility to select different time settings but can also be traffic activated. The lubricator has special features.

- Correct application of grease
- Minimum grease consumption
- Simple maintenance and servicing at long intervals
- Easy mounting
- No mechanical connection to rail or wheels

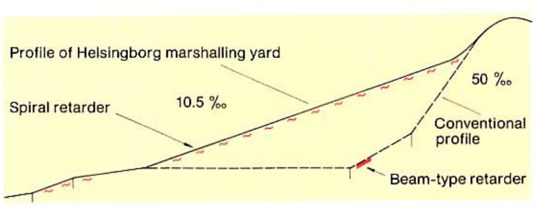
Marshalling yards

The Helsingborg marshalling yard has been totally renovated and it now incorporates many features not found in conventional marshalling yards.

A short, relatively steep gradient follows the hump. The switching area zone is on a gentler slope, which is nonetheless steep enough to make certain that the slowest running wagons will keep rolling with undiminished speed.



Spiral retarder consists of hydraulic brake cylinder (1) with spiral cam (2) used for braking. Wagon is moving in direction (3). Brake cylinder moves in direction (4).



Comparison of profiles of Helsingborg marshalling yard and conventional marshalling yard

To prevent fast running wagons from accelerating small spiral retarders, provided with a very simple automatic control, are spaced at close intervals along the track. A speed-sensing hydraulic valve determines whether or not the retarder is to be applied. By using many such retarders, speed can be regulated as desired. When the wagons enter the sorting sidings, they are decelerated by a number of retarders, which have been set to act at a lower speed limit than the retarders in the switching area, thus reducing the speed to about 1.5 m/s. At speeds as low as this, shoe-braking becomes unnecessary.

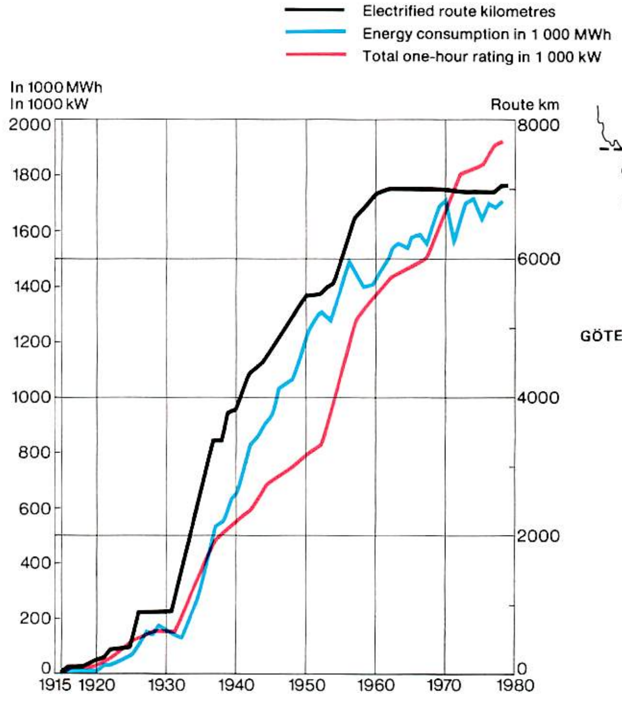
This new system reduces the number of personnel needed, while simultaneously reducing the risk of bumps that can damage goods.

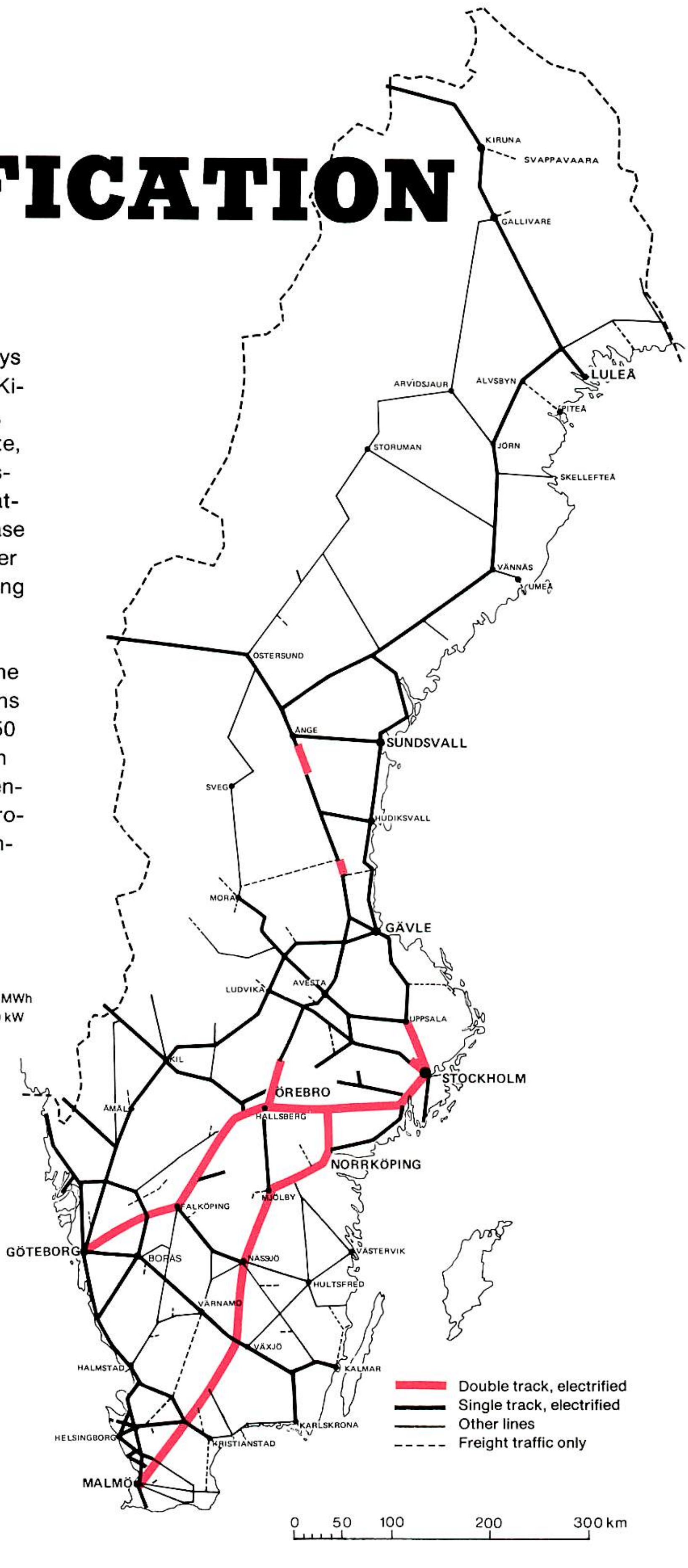
ELECTRIFICATION

Electrification made its debut on Swedish railways in 1915, when the single track Kiruna (including Kiruna-Svappavaara)-Riksgränsen route (140 km), which carries heavy ore traffic in an Arctic climate, was electrified (15 kV at 15 Hz). This 1-phase system was supplied from SJ's own generators located in the Porjus power plant, via an 80 kV, 1-phase transmission line running to 80/15 kV transformer stations. Further electrification on routes adjoining the Kiruna-Riksgränsen route incorporated the same principles.

As electrification continued in other parts of the railway network, it was decided to use substations with rotary converters supplied from the public 50 Hz, 3-phase grid. This system, which operates on 15 kV at 16 2/3 Hz, is now used throughout the entire SJ electrified network. During recent years, rotary converters have been replaced by static converters in some substations.

Energy consumption and total one-hour rating of electric traction stock

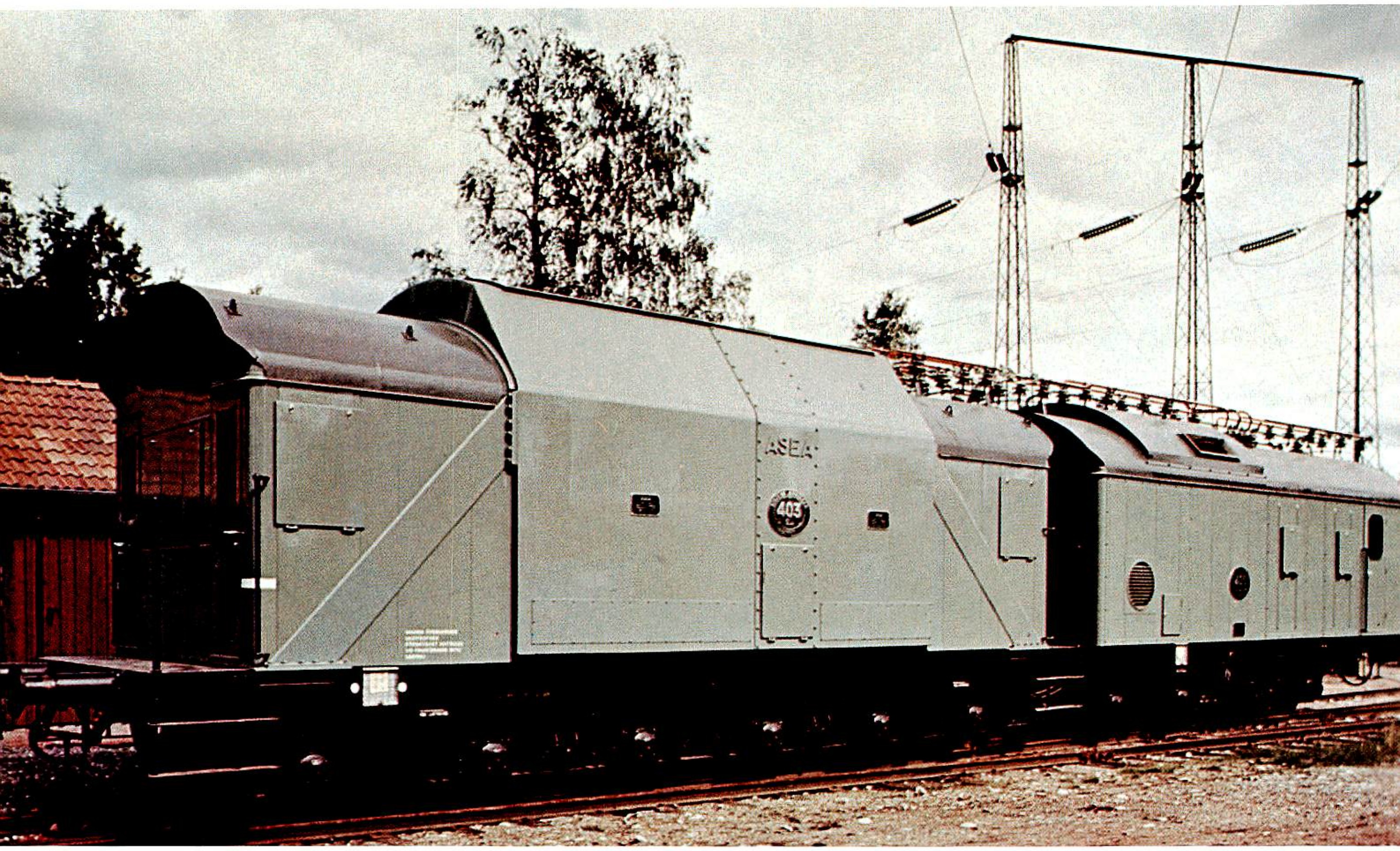




Converter stations

Rotary frequency converters

Converter unit (10 MVA) ready for transport with the converter wagon at left and the equipment wagon at right. The converter weighs 195 tons and maximum speed is 20 km/h.



Three sizes of synchronous converters are used – 3.1 MVA, 5.8 MVA and 10 MVA.
Each converter (3-phase motor, 1-phase generator and exciters) is mounted on a 5–6 axle railway wagon. An equipment wagon containing high-voltage breakers, a 1-phase transformer, control equipment, etc. is coupled directly to each converter wagon. Together, they form a mobile converter unit.

The converter units are installed in a converter station hall, 2–5 units per station.

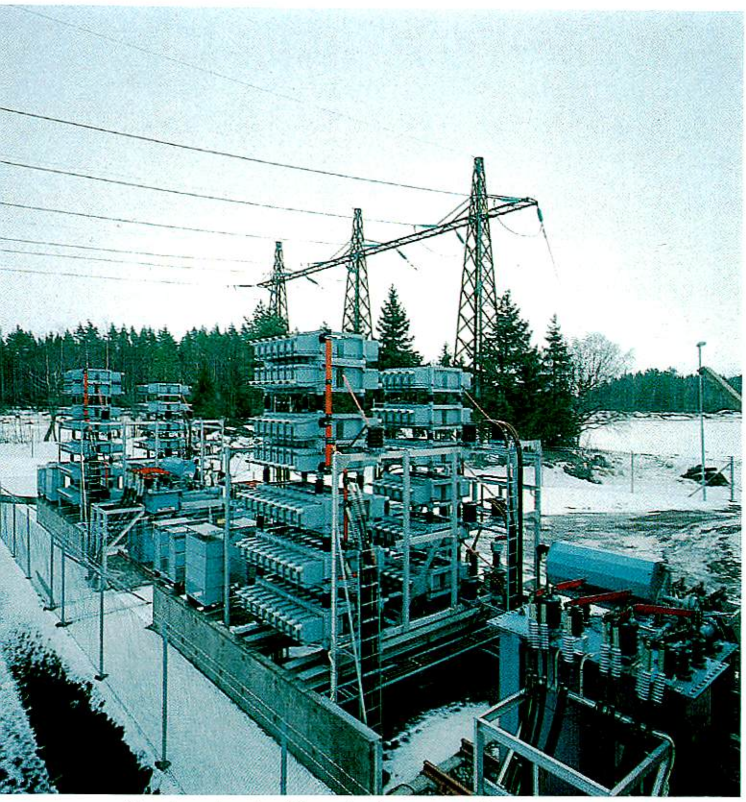
In addition to the converter units, each converter station also contains switchgear equipment that receives the incoming 3-phase, 50 Hz, 6 kV power and sends out 1-phase, 16 2/3 Hz, 16 kV to the overhead contact line network. Space is also provided for control and auxiliary equipment and there are accommodations for operating personnel.

The converter stations are interconnected via the overhead contact line network in combinations of two or more, depending upon the network configuration.

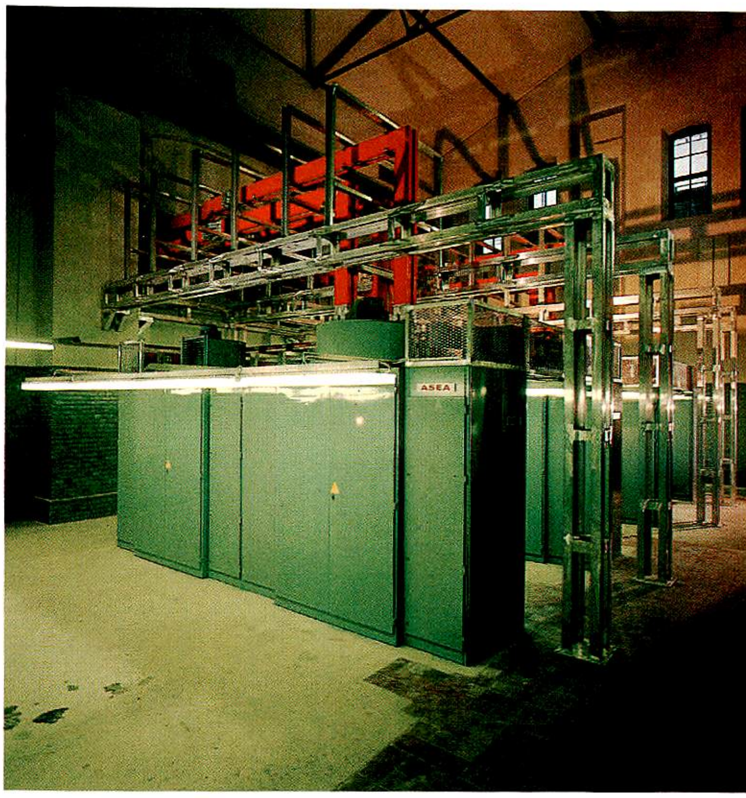
Converter station interconnection helps to:
- Reduce voltage drop in the overhead contact line
- Smooth out peak loads

Remotely controlled switching stations located between the converter stations are provided with breakers that cut out the appropriate circuits in the event of a fault.

Static frequency converter



Shunt and series filters for two converters



Thyristor cubicles for one converter

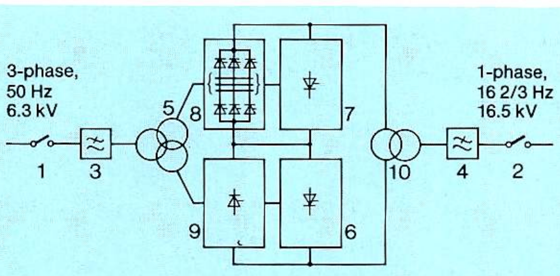
Towards the end of the 1960's, it became technically possible and economically feasible to design static frequency converters for railway use.

After extensive testing, SJ has decided to install static converters to replace rotary converters as the latter wear out.

The first generation of static frequency converters have capacities of 15 MVA. These converters are stationary and offer the following advantages compared with rotary converters:

- Higher efficiency
- Quicker starting (additional units can be connected as power requirements rise)
- Less preventive maintenance
- Less expensive per MVA

Block diagram of static frequency converter



1–2 Main switches
3 Shunt filter with phase compensating battery
4 Shunt and series filters
5 Transformer
6–9 Thyristor bridges
10 2-phase transformer

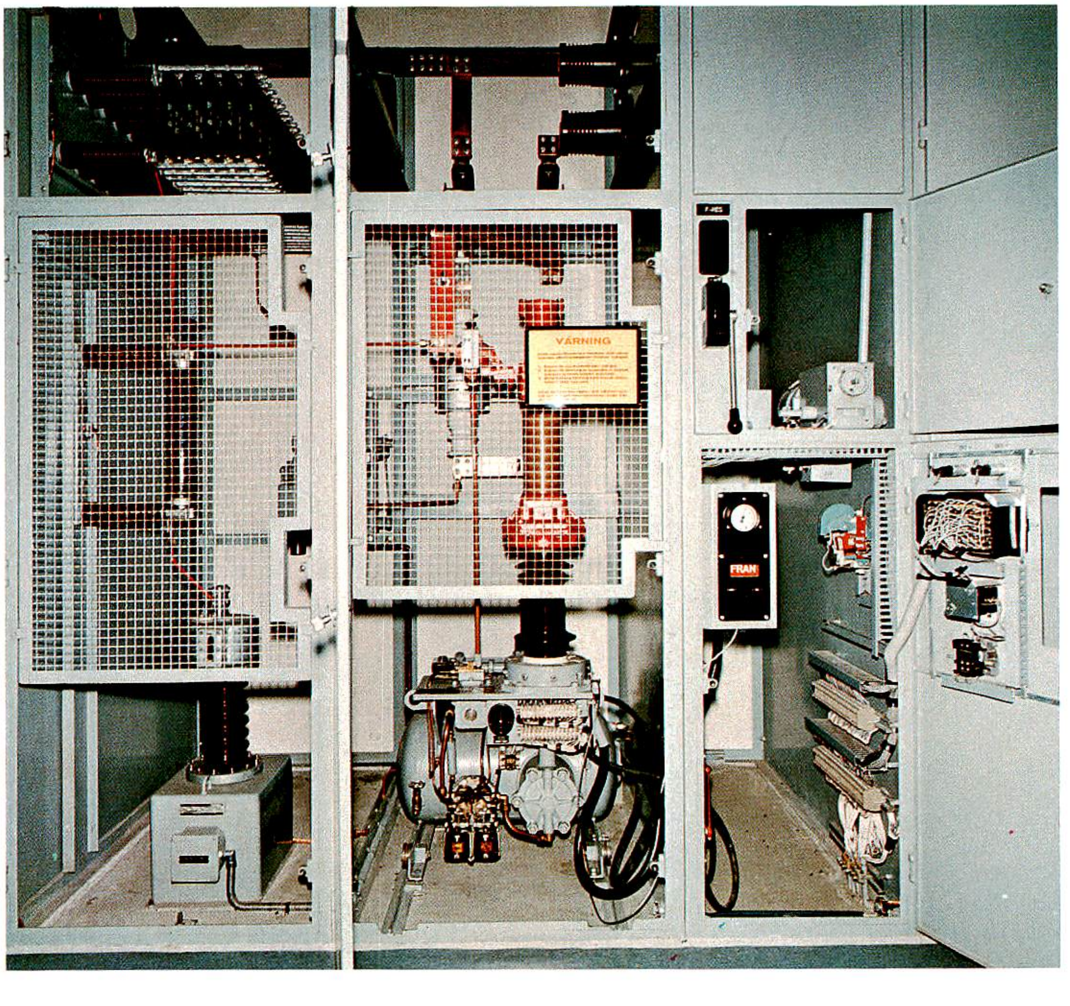
Circuit breakers
supplying the overhead contact line

The overhead contact line circuit breakers enable normal loads to be connected and disconnected. Moreover, they quickly break the circuit if a fault current (short-circuit current) occurs, thus minimizing damage at the point where the fault occurred. When the short-circuit current is high, as it is when faults are nearby, the circuit breaker trips within two half-periods.

After it has been tripped by a fault current, the circuit breaker automatically makes three attempts to close again with reduced current within about four minutes. Experience has shown that more than 90 % of all faults on an overhead contact line are transitory and vanish within about five seconds without any remedial measures being taken, i.e. prior to the first re-closing attempt.

Some overhead contact line circuit breakers are provided with a *thermal overload cut-out* for extra protection against overload of the contact line.

Generally speaking, the maximum short-circuit current on an overhead contact line network is about 10 kA, but within dense traffic areas it can be as high as approximately 18 kA.



Control centres

The converter stations are usually controlled remotely from centres which also exercise remote control over switching stations and isolators in the contact line network.

When the system has been fully expanded, it is expected that there will be 10–12 such centres.

Each centre can control up to eight converter stations and an average of 350 km of electrified line including switching stations and isolators.

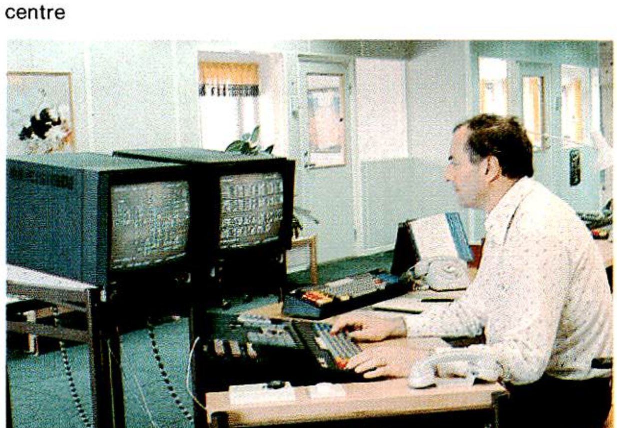
As a rule, these control centres are built together with traffic control centres, thereby providing:

- An overview of power needs
- Quick information about changes and disturbances in traffic
- Quick remedial measures in the event of a fault in the overhead contact line network
- A comprehensive picture of maintenance work on the permanent way, and optimum utilization of crews and equipment

The latest version of a control centre incorporates a computer which improves efficiency. Examples of applications for which computers are used include:

- Operating schedules for converter units
- Sectioning in the event of a fault on the overhead contact line

The pictures show the operators' room and the operator's desk with video screens and keyboard in the new version of a control centre



Overhead contact lines

SJ has acquired long-term experience in erecting and maintaining overhead contact lines. This work has been carried out entirely by SJ personnel. Since electrification extends throughout Sweden, with its varying climates and environments, designs and working procedures have had to be adapted to the conditions at hand.

During recent years, the overhead contact line system has been renovated to accommodate trains travelling at higher speeds, and working procedures have been vastly improved. This type of modernization requires foresighted planning.

Overhead contact lines designed for high-speed trains

Example of computer calculations

Computers have been utilized to calculate geometrical design details for the overhead contact line system. Computerization facilitates prefabrication of component parts and reduces the amount of installation work needed.

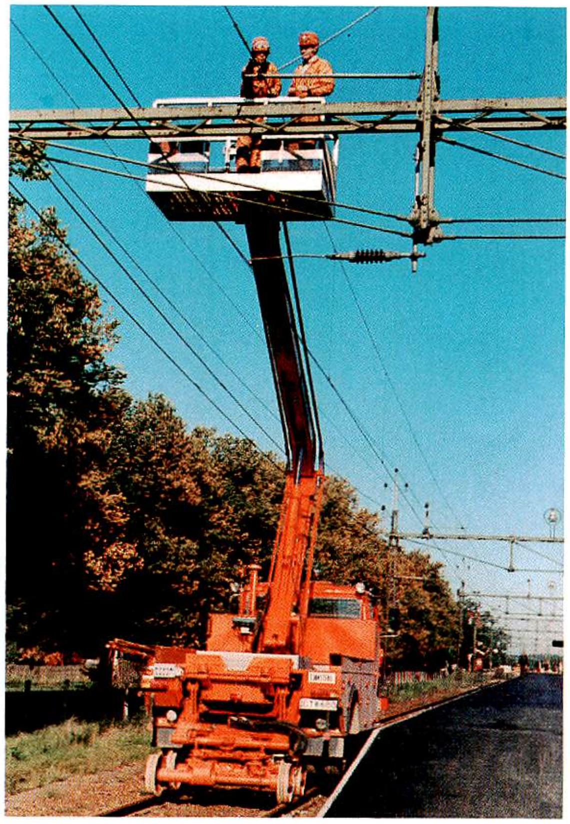
LINE/STATION: HALLSBERG TRACK NUMBER 3   PAGE: 1   NUMBER OF PAGES: 76-06-15

TENSILE STRESS: CATENARY = 9.8 KN , CONTACT WIRE = 9.8 KN . CONTACT WIRE AREA 100 MM2

MAST NUMBER	SYSTEM HEIGHT(MM)	STEADY ARM TENSION(N)	STAG-GER	SPAN(M)	CONTACT WIRE HEIGHT(MM)	SAG(MM)	DROPPER SPACING(M)	DROPPER LENGTH(MM)	REMARKS
1	1550	255	V2		5600				
						F1 = 28	D1 = 8.00	L1 = 1225	
						F2 = 46	D2 = 15.50	L2 = 1070	
						F3 = 57	D3 = 23.00	L3 = 980	
						F4 = 60	D4 = 30.00	L4 = 950	
				60.00					
						F5 = 57	D5 = 23.00	L5 = 980	
						F6 = 46	D6 = 15.50	L6 = 1070	
						F7 = 28	D7 = 8.00	L7 = 1225	
2	1550	255	V2		5600				
						F1 = 27	D1 = 8.00	L1 = 1230	
						F2 = 45	D2 = 15.50	L2 = 1080	
						F3 = 55	D3 = 22.50	L3 = 995	
						F4 = 59	D4 = 29.50	L4 = 965	
				59.00					
						F5 = 55	D5 = 22.50	L5 = 995	
						F6 = 45	D6 = 15.50	L6 = 1080	
						F7 = 27	D7 = 8.00	L7 = 1230	
3	1550	255	V2		5600				
						F1 = 27	D1 = 8.00	L1 = 1235	
						F2 = 44	D2 = 15.00	L2 = 1095	
						F3 = 54	D3 = 22.00	L3 = 1010	
						F4 = 57	D4 = 29.00	L4 = 985	
				58.00					
						F5 = 54	D5 = 22.00	L5 = 1010	
						F6 = 44	D6 = 15.00	L6 = 1095	
						F7 = 27	D7 = 8.00	L7 = 1235	

Equipment for overhead contact lines

New equipment has been developed to facilitate and shorten erecting and maintenance work on overhead contact lines.



The SJ rail/road vehicle is equally efficient on and off the track. It travels at normal speeds on roads and railway tracks. The lift of the vehicle can be moved in all directions. When in operation the vehicle can be driven from the working platform at a speed of up to 5 km/h. The platform is equipped for serving pneumatic, hydraulic and electric tools.

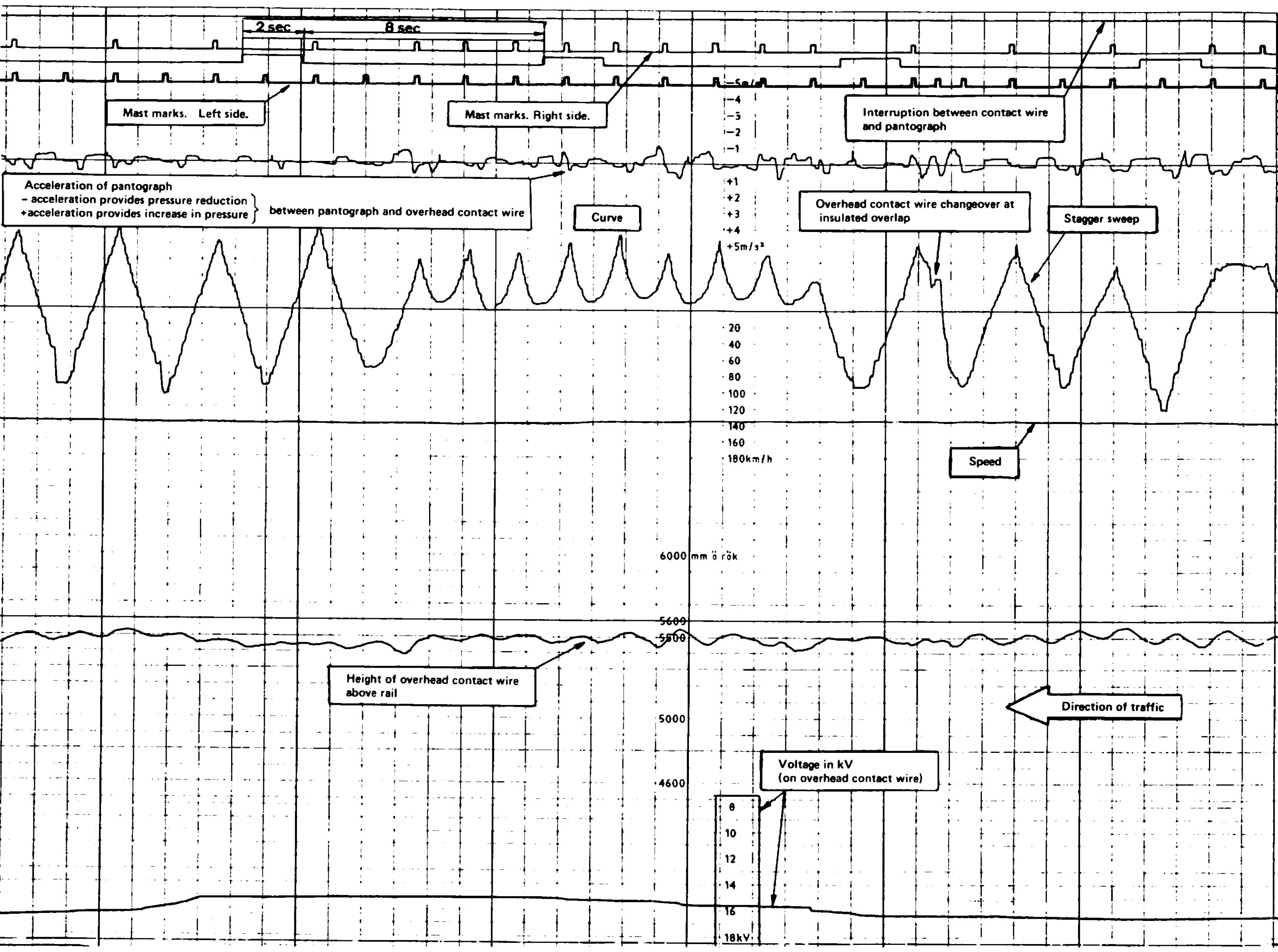
Illustrated above are:
- A self-propelled drum wagon, which can be operated entirely by one man
- Railcar with roof-mounted lift that carries a 2-man crew
Both the railcar and lift can be controlled entirely from the lift platform

Cable-laying from a trackbound vehicle. The cable plough is vertically and laterally controllable.

Diagram prepared by test wagon

Because of today's dense traffic and stringent scheduling requirements, an overhead contact line that is virtually maintenance-free is indispensable. However, it must be checked regularly, since it is vulnerable to externally-caused damage.

This diagram, which was prepared by a test wagon, provides valuable information about the condition of the line.



Computerized studies

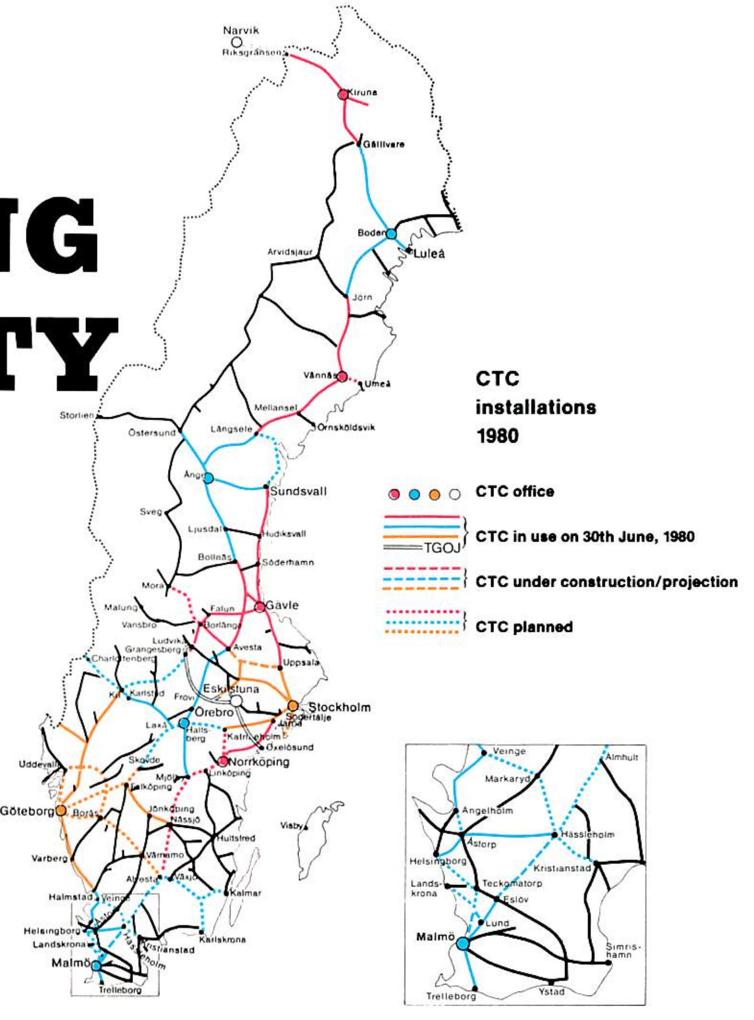
A computer programme that simulates any specified timetable for a substation area and calculates running times, amperages, power and energy consumption, overhead contact line voltage and temperature increases in the contact wire is being used to investigate the effects of timetable changes, heavier trains, more powerful locomotives and expansion of power supply equipment.

Printout of voltage drop calculation. Average values for each half minute are reported for each interconnected substation and for each train on the route supplied by the substations.

BASTUTRÄSK VÄNNÄS TDT 170

TIME	VALUES AT SUBSTATIONS						VALUES AT TRAINS						
	SUB-STATION	VOLTS	AMPS	MW	MVAR	EXCESS TEMP °C	TRAIN-NUMBER	POSITION KM	SPEED KM/H	POWER FACTOR	KW	LINE VOLTAGE	LINE CURRENT
31930	1	16500.	265.	3.90	1.98	7.5							
	2	16489.	250.	3.61	2.01	8.7							
							7604	867.0	67.31	0.812	373.	15646.	265.
							94	878.5	86.43	0.931	1352.	14644.	236.
							6155	911.1	78.41	0.918	1646.	12988.	137.
							6055	911.1	78.41	0.918	1646.	12988.	-4.
							6213	946.7	43.35	0.778	379.	14797.	-139.
							6113	946.7	43.35	0.778	379.	14797.	-171.
							6280	962.0	87.30	0.892	670.	15957.	-203.
32000	1	16500.	308.	4.51	2.35	7.9							
	2	16510.	313.	4.53	2.49	9.0							
							7604	867.5	67.90	0.901	1388.	15441.	308.
							94	879.2	86.89	0.899	596.	14537.	208.
							6155	910.5	68.27	0.907	1648.	12645.	163.
							6055	910.5	68.27	0.907	1648.	12645.	19.
							6213	946.2	54.36	0.871	889.	14285.	-124.
							6113	946.2	54.36	0.871	889.	14285.	-196.
							6280	962.7	86.06	0.890	650.	15929.	-267.
TIME FOR TRAIN 94 BETWEEN STATIONS TVB AND TVA 9.2 MINUTES													
32030	1	16500.	360.	5.28	2.73	8.5							
	2	16510.	418.	6.08	3.26	9.9							
							7604	868.1	65.78	0.899	1349.	15190.	360.
							94	879.9	86.85	0.927	1178.	14046.	261.
							6155	910.0	62.30	0.895	1380.	12130.	171.
							6055	910.0	62.30	0.895	1380.	12130.	44.
							6213	945.7	63.92	0.910	1889.	13231.	-83.
							6113	945.7	63.92	0.910	1889.	13231.	-240.
							6280	963.5	87.30	0.782	266.	15848.	-397.

SIGNALLING AND SAFETY SYSTEMS



Most train movements and points are controlled by different types of signalling systems. Each station is provided with a more or less complete interlocking plant, which makes sure that the train moves safely through locked train routes which are checked for obstructions. Moreover, automatic block systems are provided on a considerable portion of the railway network. These systems improve safety, as well as increase capacity considerably.

Most of the SJ interlocking plants now in service are of the relay type, even though a number of older mechanical and electro-mechanical installations are still in operation. Relay-type interlocking plants not yet incorporated into the CTC system are prepared to accommodate remote control.

All block systems and most of the installations used at stations and level crossings are operated by safety systems based on track circuits adapted to the SJ electrification system.

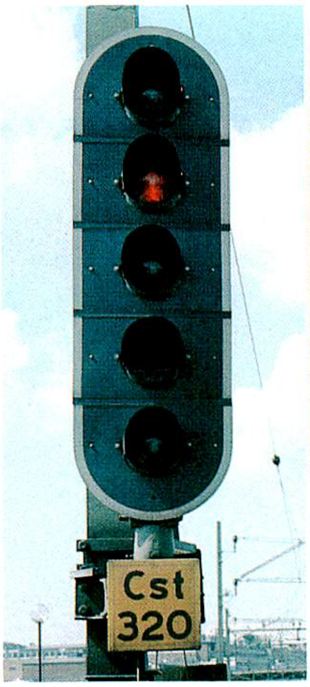
SJ's first CTC route went into operation in 1955 and the entire system is expected to be completed by 1990.

Most parts of today's system incorporate relay techniques which ensure excellent operational reliability and, in most cases, sufficient speed and transmission capacity. In areas where traffic is particularly dense, a computer-based system has been developed which, in addition to greater speed and capacity, provides – among other things – an electronic train describer system on which programmed train routing system is based.
All CTC systems are pushbutton-operated.

Because of its agricultural origins, Sweden still has great many road/railway level crossings, even though many overhead and underground crossings have been constructed and numerous small country roads have been combined. More and more of these level crossings are being provided with safety equipment adapted to traffic density, visibility conditions etc. These installations are always planned and constructed in collaboration with road users and road authorities. Today, there are no independently-operated, manned barriers in Sweden.

The signalling systems and many of their major components have been developed by SJ in collaboration with LM Ericsson, which has supplied most of the equipment.

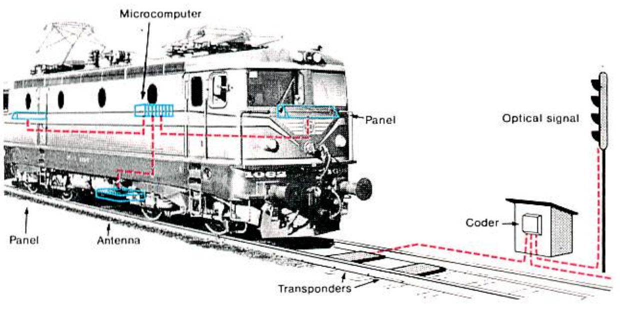
From 1980 most vehicles running on our mainlines will be equipped with Automatic Train Control (ATC). By 1984 the system is expected to be in operation on all mainlines. The system has been developed in collaboration with LM Ericsson and Standard Radio Telefon AB.



Main colour-light signal with four lamps. The number of aspects can vary, depending upon the purpose. The signal shown here is used as an entry signal. The lamps can glow steadily or flash. Only red, green and clear aspects are used for the main signals and their distant or warning signals.

Special auxiliary signals (of the digital display type, for example) can be used to specify the maximum permissible speed in areas where traffic is particularly dense

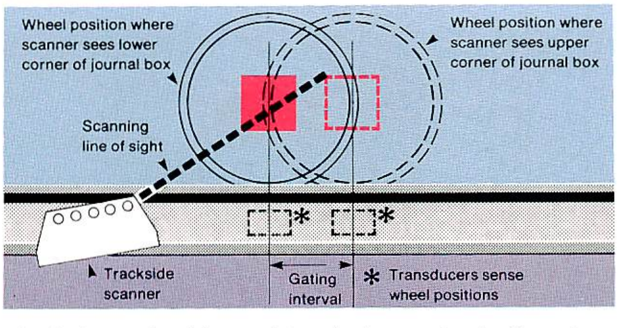
Automatic Train Control (ATC)



ATC is a safety system designed to transmit vital data – primarily concerning speed – from track to train. If necessary, the train is braked automatically.

Extensive functional tests have been carried out in fiscal 1977/78 and the system is now in operation in the Stockholm area. Installation of the system on mainlines carrying the heaviest traffic is scheduled to be completed in fiscal 1981/82 and on remaining mainlines in fiscal 1983/84.

Optical out-of-gauge loads detector



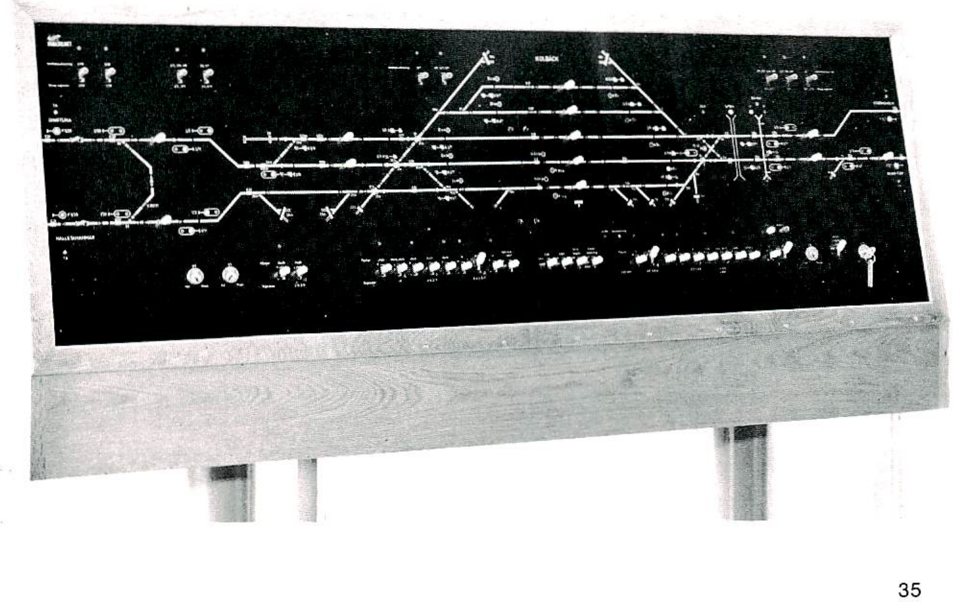
Detectors positioned along the track can reveal faults in the rolling stock earlier and more reliably than inspection by personnel as trains pass or while they are standing in stations. Fewer personnel are required and station waiting time can be shortened. Hotbox detectors record temperature increases in vehicle journals, and hot wheel rims detectors react to heat radiated from wheel rims. Detectors are being developed that will react to flat wheels, loose wheel rims and to out-of-gauge loads. Also microprocessor-based equipment for the evaluation of detector signals from detector stations (comprising detectors of different types) is prepared. At present 40 hotbox detectors are in operation and five are ordered; 30 hot wheel rims detectors are in operation.

Computer-based interlocking plant

The development of data processing technology during recent years has made it possible to create a high-performance computer-based interlocking plant that is less expensive than the relay interlocking plants used in the past. Thanks to the enormous processing capacity of the computer, the control and indicating parts of these new systems can be adapted to the operator. This means that tomorrow's train dispatchers will be able to use the computer to plan train operations several hours in advance. The computer will remember and establish the planned train and shunting routes at the right times, or as soon as conditions in the station permit. Moreover, computerized equipment will enable all events occurring in the system to be recorded on magnetic tape that can be used for retrospective analyses of traffic disturbances – a valuable feature.

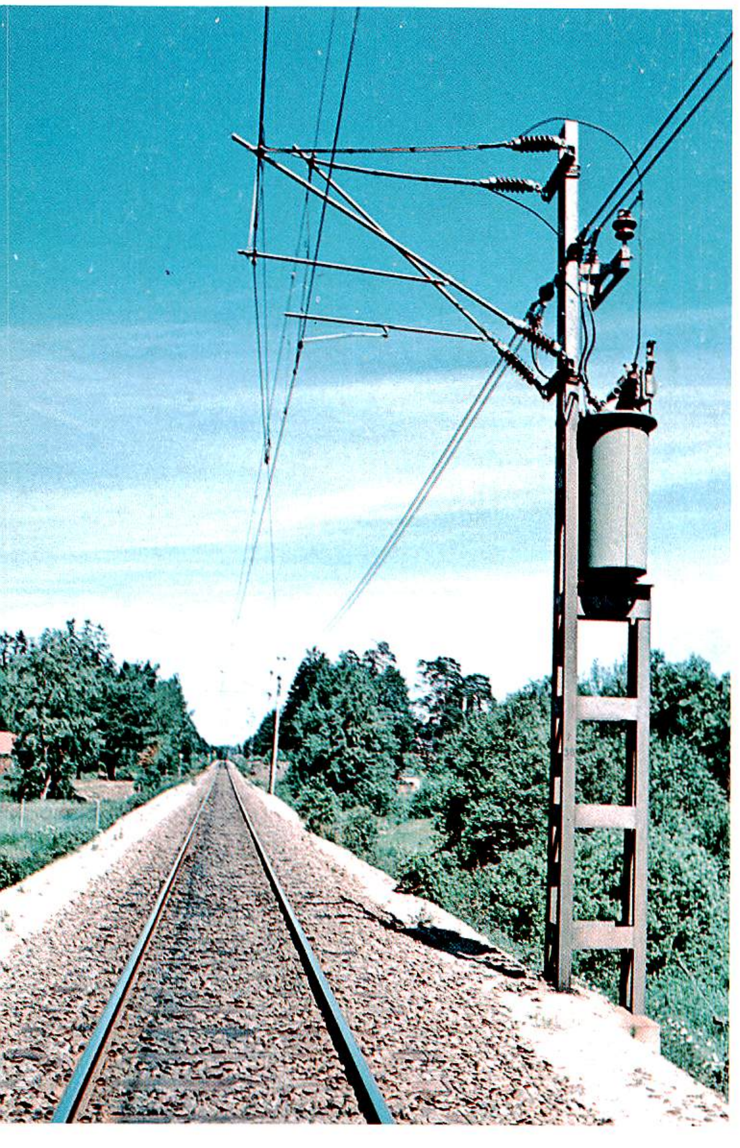
The computer-based interlocking system "SJ 75" at Göteborg

This picture shows the track diagram and operator's desk at one of the 10 CTC offices now in operation.
These offices serve about 3 800 km of continuous line. When the CTC system is completed it will control a considerable part of Sweden's railway network.



Combined control panel and track diagram at a typical signal interlocking plant of the type used in CTC-controlled mainline stations.
The interlocking can be operated either locally or remotely.
The control panel and relay equipment in this type of signalling installation are often housed in a special building.

TELE-COMMUNICATIONS SYSTEMS



On the first (1915–1922) electrified routes in northern Sweden, open wire lines running at a distance of 15 to 50 metres from the track were used for telephone communication. Booster transformers were connected to the overhead contact line and to the rails in order to reduce dangerous induction voltages and disturbances on telephone lines.

However, the noise level on telephone lines remained unsatisfactorily high, and in connection with subsequent electrification, the open wire lines were replaced by underground telecommunications cables. In addition, a special insulated return conductor was used, and the booster transformers were connected to this conductor and the overhead contact line.

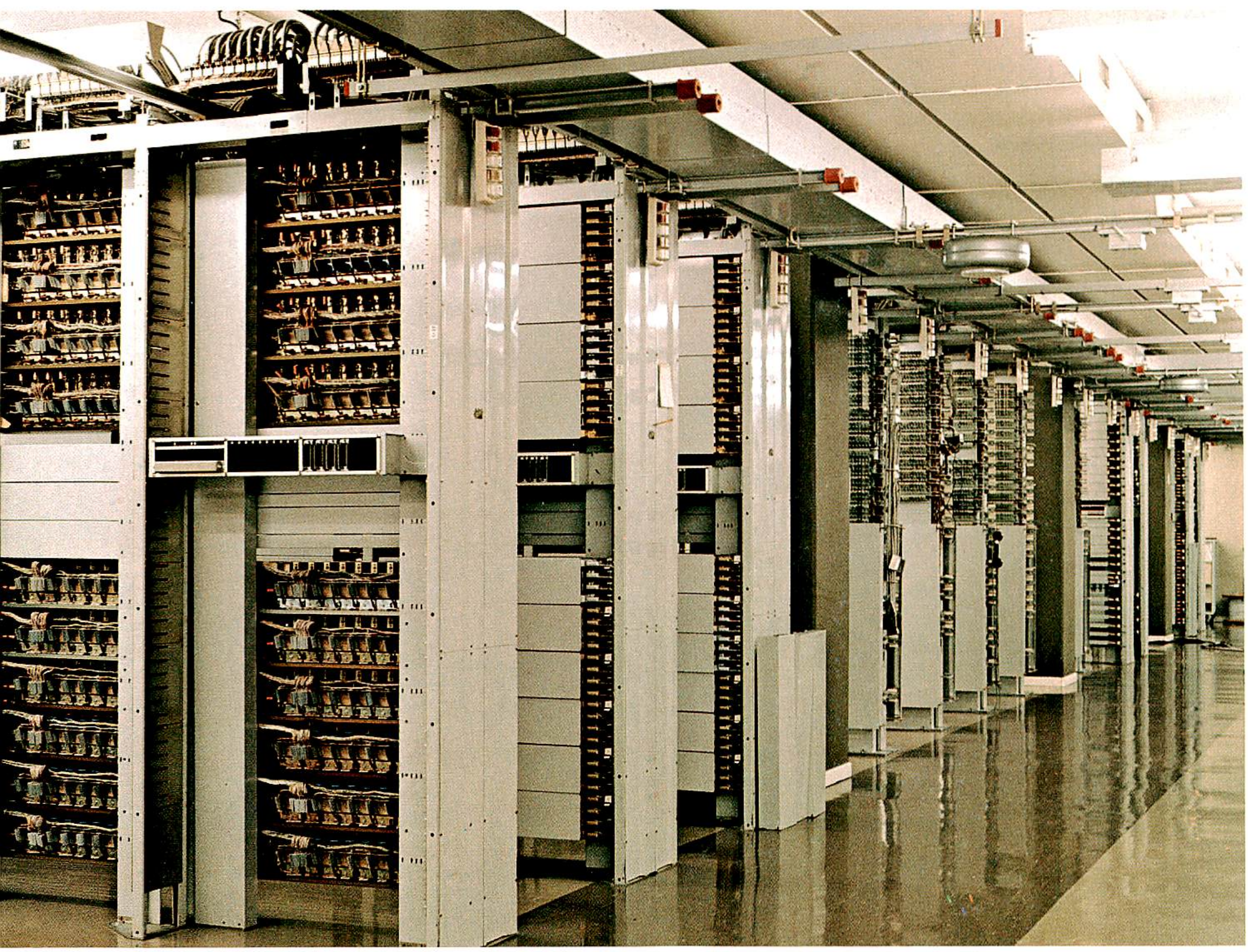
The high earth resistivity which prevails in most parts of Sweden caused particularly troublesome disturbance problems in connection with electrified railway operations. However, this problem was solved satisfactorily by using booster transformers and suitable telecommunications cables. Swedish Telecommunications Administration lines in the vicinity of railway lines have also been run underground. Along certain routes, SJ and the Swedish Telecommunications Administration have combined their lines within the same cable. This cable was laid alongside the track by railbound units. Both organizations thus acquired fully satisfactory line quality at reasonable cost.

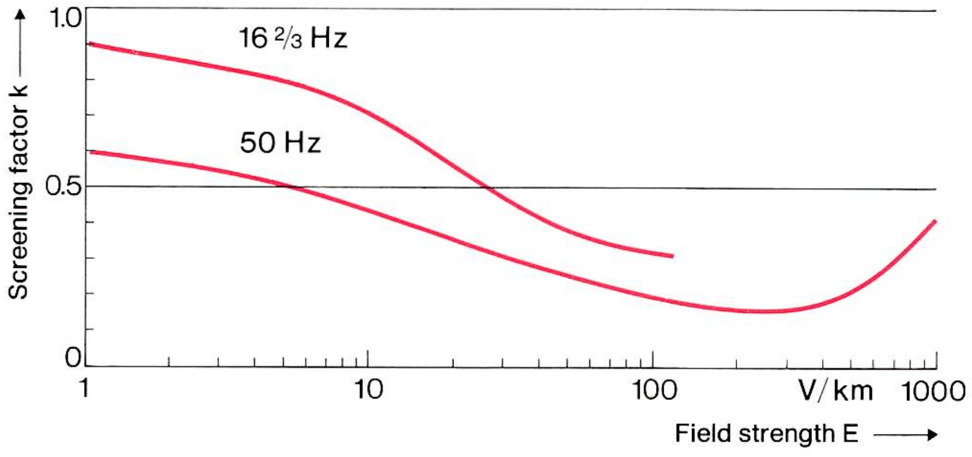
Booster transformers are installed approximately every 5th km. The booster transformers are connected to the overhead contact line and the return conductor.
The return conductor has an area of 130 mm² of copper or 212 mm² of aluminium. As a rule, dual return conductors are provided on mainlines.

SJ telephone exchanges

SJ has built up a fully automatic telephone system, consisting of long-distance telephone circuits between automatic telephone exchanges located in railway administrative centres and big stations, and selective-calling circuits running to railway stations and other places along the line. Data transmission is used for teleprinters, sleeping berth and seat reservations and the printing of passenger tickets.

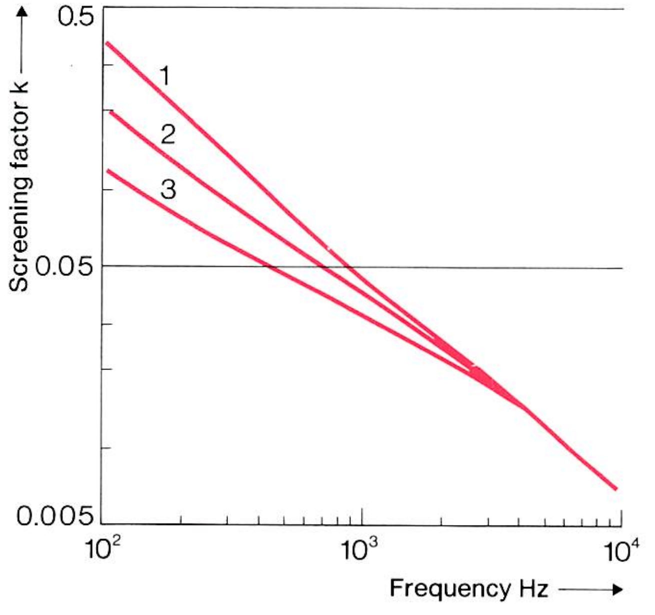
SJ uses carrier systems extensively for long-distance trunk circuits. SJ has thus been able to establish telephone communications of satisfactory quality using older cables, in which the number of conductors would otherwise have been insufficient for present requirements.





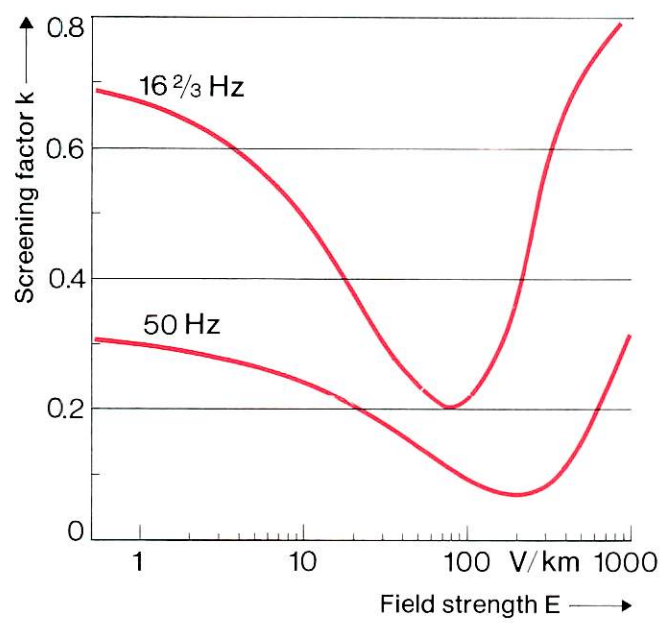
Screening factor for typical SJ cable at 16 2/3 Hz and 50 Hz, as a function of field strength

Screening factors for the same cable at some different field strengths, as a function of frequency.
The screening factor was measured at a field strength of 1 V/km (curves 1–3). Curves 2 and 3 show the screening factors obtained when two fields (10 and 50 V/km at 16 2/3 Hz) were applied simultaneously.



Normally, telecommunications cables are provided with lead sheath and steel-tape armouring.
This considerably reduces induction voltages and disturbances attributable to the traction current.

The locomotives previously used by SJ had AC motors. Consequently, the harmonics in the overhead contact line current had relatively small amplitudes. However, thyristor-controlled locomotives with DC motors have been used increasingly during recent years, and harmonics amplitudes in the contact line current have thus increased considerably. Nonetheless, it has been possible to keep disturbances under control by providing better balance on the telecommunications circuits.



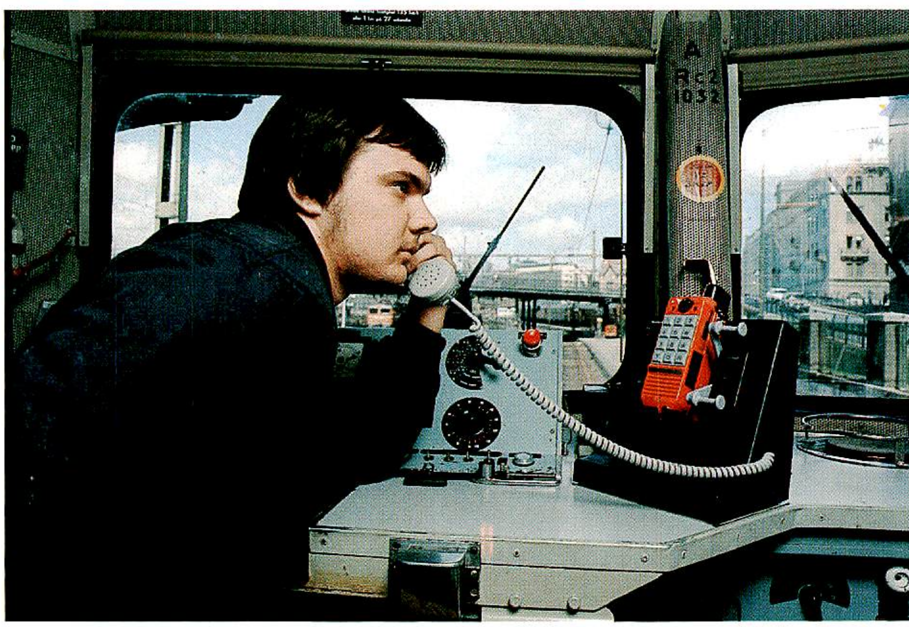
Screening factor at 16 2/3 Hz and 50 Hz, as a function of field strength, for a relatively slender cable with aluminium sheath and steel tape armouring

During recent years, telecommunications cables with aluminium sheath have been run underground along certain routes. The lower sheath resistance provides these cables with a more favourable screening factor.

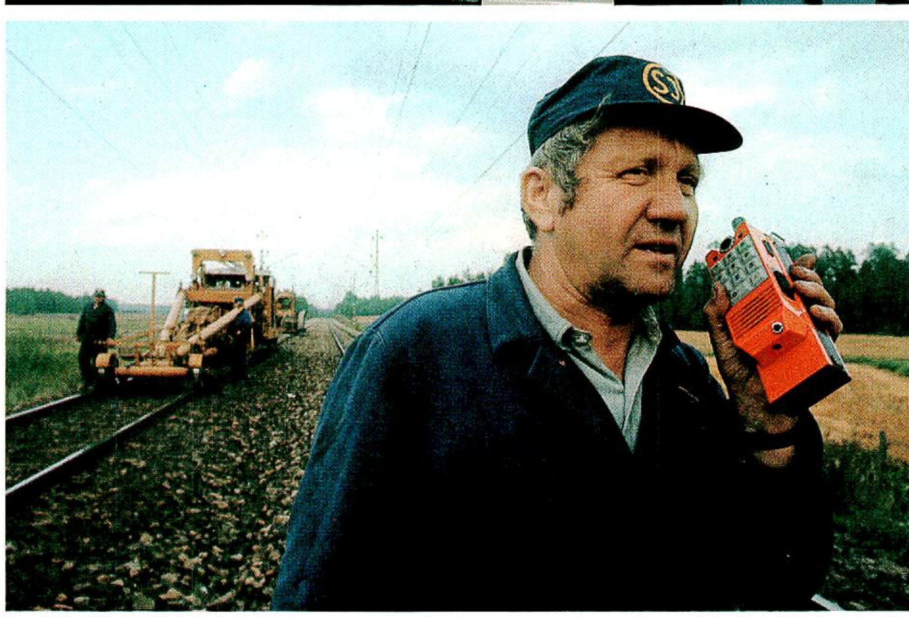
LINE RADIO SYSTEM

Train Radio and Service Radio are in operation on the same fixed network and are connected to SJ-PABX telephone system. A small push-button radio telephone is used for both purposes.

The same system will be carried out with regard to SJ buses and lorries in order to make transports more efficient.



Train radio enables traffic control centres to communicate quickly and efficiently with personnel in locomotive cabs



Maintenance people have easy access to the whole telephone network

DATA TRANSMISSION AND RESERVATION SERVICE

On-line data processing system

Since 1970, SJ has been operating a passenger reservation system. In 1973 this system was expanded to include the selling of passenger tickets.

The system incorporates about 250 data terminals installed at stations and travel agencies throughout Sweden. These terminals are connected directly to the central computers via permanently connected telegraph circuits for data transmission at a rate of 75 or 225 bauds. Dual central processing equipment is provided.

This system processes about 450 000 reservations and 550 000 ticket transactions per month. Virtually all types of domestic reservations can be made. The time needed to process and print a ticket depends almost entirely on the transmission rate. About 8 seconds are needed at 225 bauds and 24 seconds at 75 bauds.

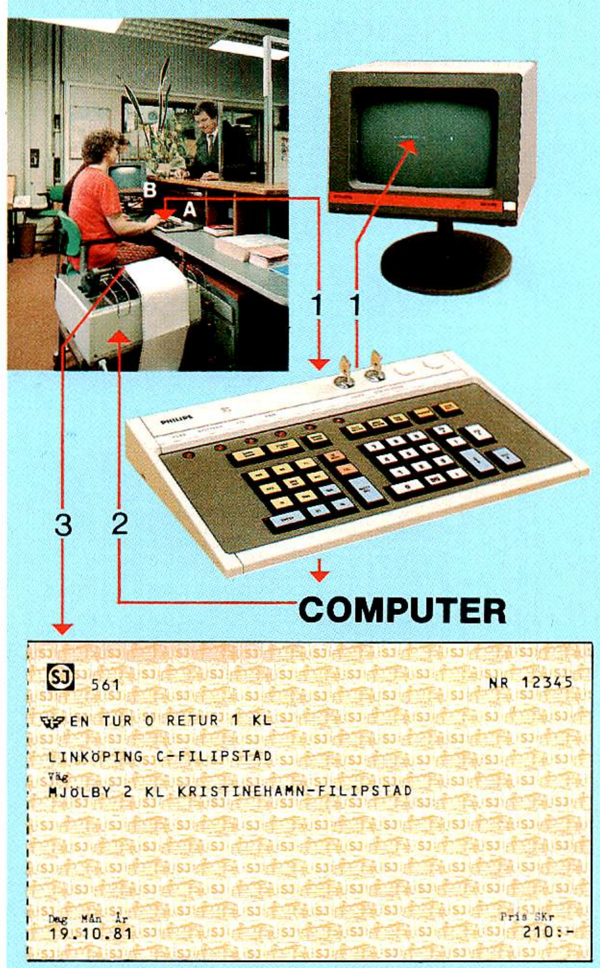
SJ is engaged in developing a further improved reservation and ticketing system with a much greater transmission speed. Timetable information and international services are likely to be integrated into the system.

The airline companies (Scandinavian Airlines System and Braathen's SAFE) and SJ are preparing a joint terminal system for travel agencies. Reservations and document printing can be made in one and the same terminal for all kinds of travel services, hotels, insurances etc.

In 1968, SJ installed an information system for freight traffic intended primarily to keep continuous track of the location of each goods wagon and its assignment. Data was collected via the SJ teletype network. Punched tapes were transferred manually between the teletype network and the computer.

Automated ticket sales

The customer places the order. The ticket agent enters the order on the terminal keyboard (A) and can control the input data on the display (B).
The coded order is sent to the computer (1). The computer calculates the ticket price, records the sales and sends a translated message to the terminal printer (2). The customer receives the ticket.



In 1973, SJ introduced a new teletype system incorporating about 250 teletype units connected to the computer that is used for reservations. It is a combined message-switching system and data collection system.
Data can be transferred in the computer between the message-switching system and various computer programmes.

Accounting and rate calculations are concentrated at six regional SJ accounting offices. A seventh accounting office handles stock control and purchasing. These offices are equipped with a total of about 35 minicomputers, which communicate via permanent circuits (transmission rates of 1200 or 2400 bauds) with the central computers.
To each minicomputer is connected locally a maximum of six operation desks, each equipped with keyboard, display and a special consignment note printer.
In collaboration with major customers SJ has developed information systems which automate and integrate a number of communications and administrative routines for both sides by means of the computer.
SJ also collaborates in a research project within the framework of the Swedish Transport Research Delegation, aiming at replacing the consignment notes by an on-line system for the transmission, processing and storage of the data concerned.

Operation desk equipped with keyboard, display and consignment note printer. This terminal is used at regional accounting offices for rate calculations, accounting etc.

TRACTIVE ROLLING STOCK

Thyristor locomotives, type Rc

During recent years, the procurement of electric locomotives has been oriented entirely towards all-round locomotives which can haul express passenger trains, express goods trains and regular goods trains virtually anywhere in Sweden. SJ's most modern electric locomotives are designed as thyristor locomotives.

More than 100 thyristor locomotives have been in service on Swedish railways since 1967. By 1982, more than 280 are expected to be in operation.

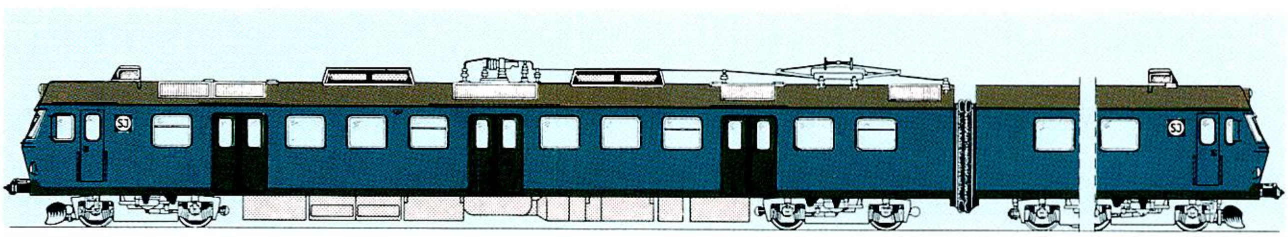
Principal data:	Wheel arrangement	Bo' Bo'
	Total weight	78 tons
	Continuous motor output	3 600 kW
	Maximum speed	135 (160) km/h

Railcar sets for suburban traffic

Since 1968, tightly-scheduled railcar trains have been providing commuter service on four different routes in the Stockholm area. This commuter service is being provided by SJ on contract for Stockholm Transport.

These railcar sets, just as SJ's modern electric locomotives, are thyristor-controlled. During rush hours, each train consists of four railcar sets coupled together, thus providing a capacity of about 1 200 passengers.

Delivery of the next generation of railcar trains, class X10, is due to start in 1982. Up to the present, SJ has ordered 14 units, but an additional order is being considered.



		↓ XI	↑ X10
Principal data:	Wheel arrangement	Bo'Bo' + 2' 2'	Bo'Bo' + 2' 2'
	Length over buffers	49.6 m	49.8 m
	Total weight	80 tons	94 tons
	Motor output	1 120 kW	1 340 kW
	Maximum speed	120 km/h	140 km/h
	Number of seats	196	184

Tractive stock maintenance

SJ has been able to reduce maintenance costs by designing efficient maintenance into vehicles from the outset and providing work-saving aids and equipment in maintenance shops.

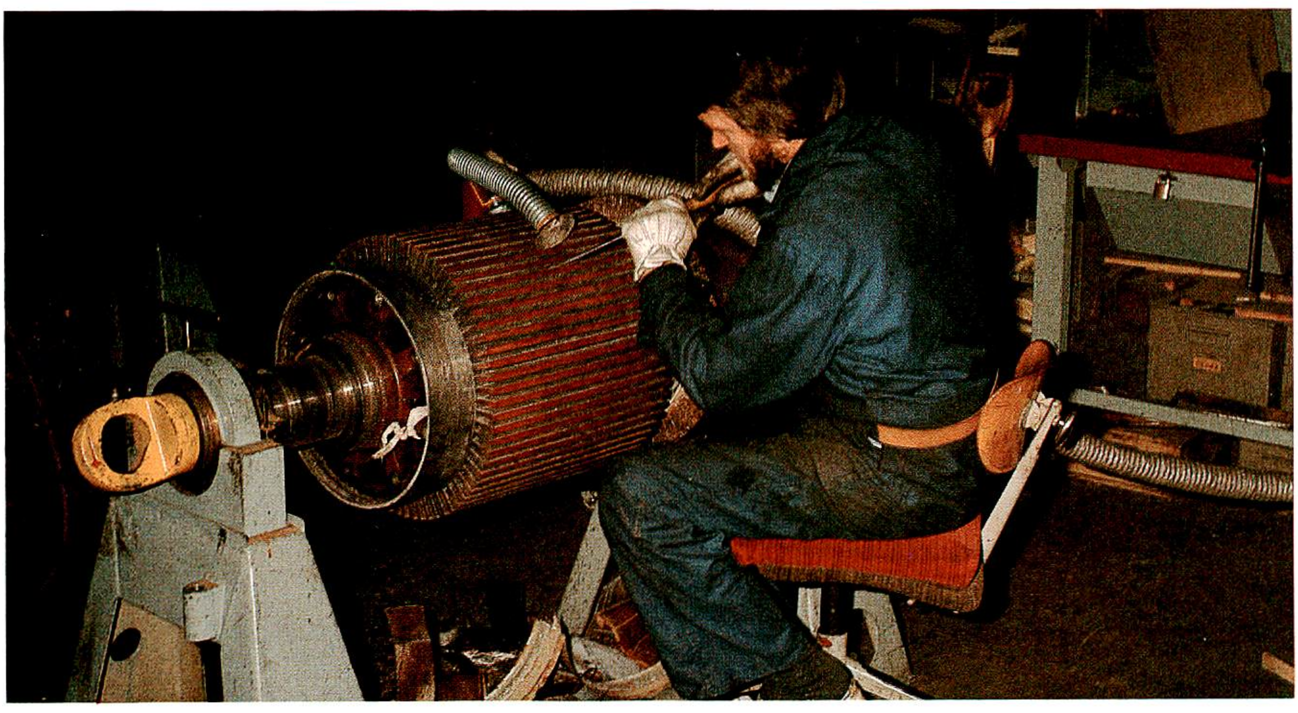
Servicing an electric locomotive in a maintenance shop

Locomotive wheels are turned on under-floor lathes, thus eliminating time-consuming wheel dismounting

All vehicle-borne electric and electronic equipment, speedometers and air-blast circuit breakers are serviced at the SJ shop at Åmål. The shop is provided with advanced electric and electronic testing equipment and has highly trained personnel.

Sophisticated electronic equipment facilitates the servicing of circuit boards

Cleaning of rotor core before building up a new winding



Measurement of forces between wheel and rail

The forces in the contact areas wheel-rail are a fundamental base for the endeavours to guarantee safety for all train speeds as well as to optimize the design of railway vehicles in order to decrease maintenance (and capital) expenses. This specially holds for the design of running gear but also for the assessment of wheel and rail wear and for the choice of track geometry parameters (for instance curve radius, cant and twist).

For this purpose SJ has successively developed measuring equipments which can separately measure all three components of these forces. Incremental strains excited by these force components in the wheel disc are utilized. These incremental strains are picked up by strain gauges and detected in measuring bridges. The choice of places on the disc and the coupling together of the strain gauges – as well as the following signal treatment – give as a result a signal output proportional to the force components.

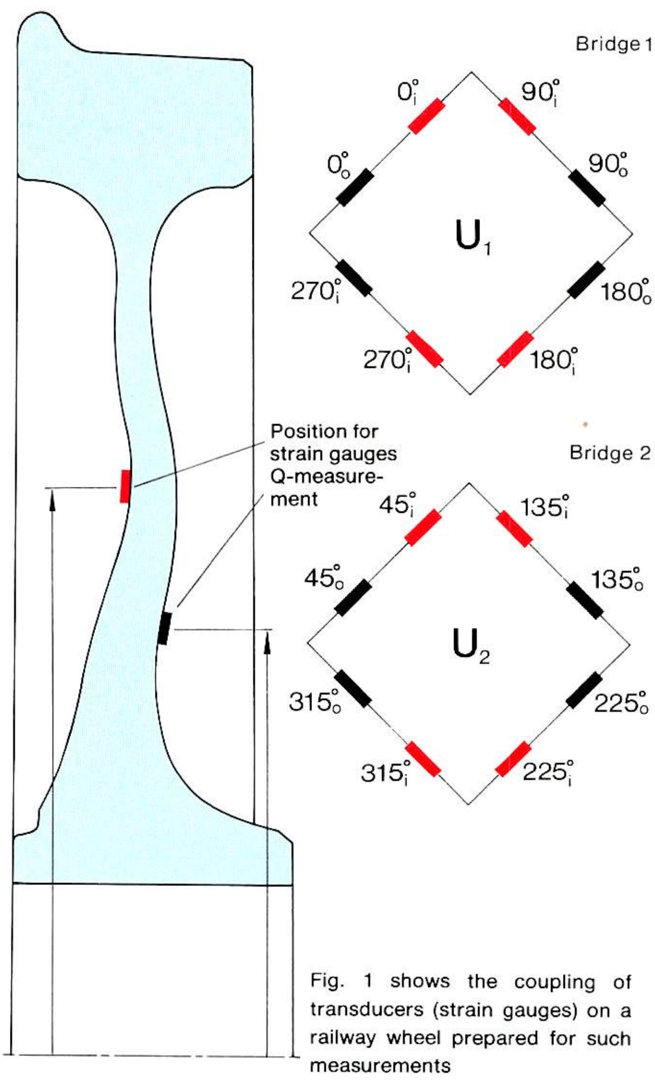


Fig. 1 shows the coupling of transducers (strain gauges) on a railway wheel prepared for such measurements

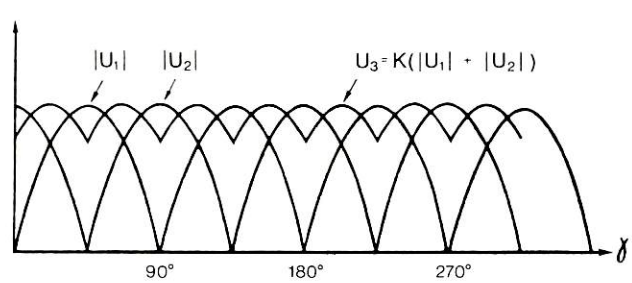
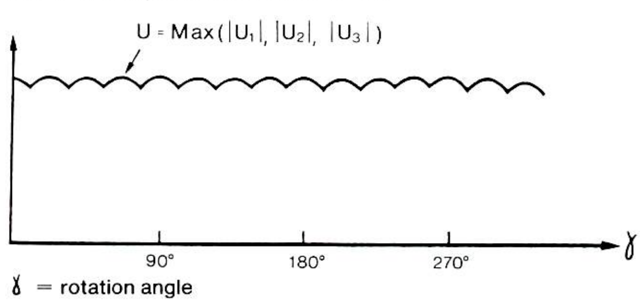
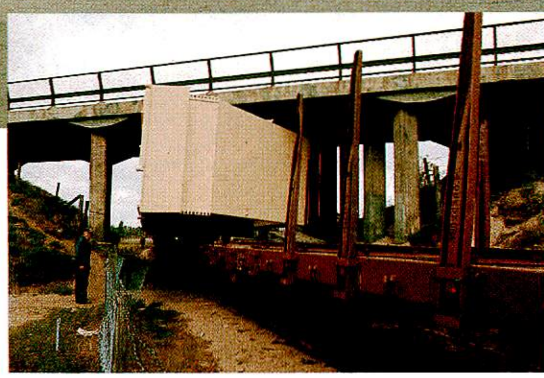


Fig. 2 a shows the signals from the measuring bridges for measurement of the vertical force component, Q (this one developed in co-operation with the Swedish company ASEA).

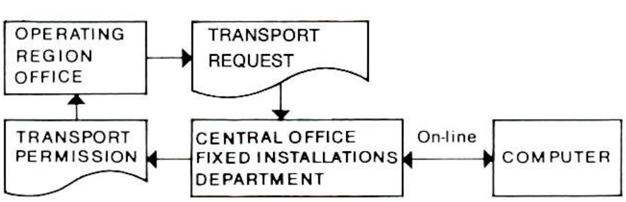
Fig. 2 b shows the output signal after the signal treatment, when this force component is constant in time



OUT-OF-GAUGE DETERMINATION SYSTEM

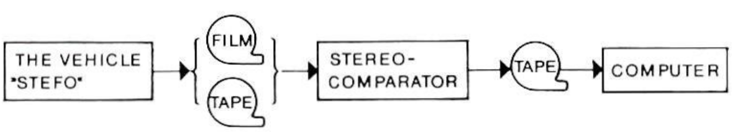


Wagon loads that project beyond the normal loading gauge are not normally allowed, but SJ grants special permits for about 1 500 out-of-gauge shipments per year. Transports of this kind have to be planned in detail. SJ has introduced a computer-aided procedure for the planning. A flowcart of the process is shown below.



Railbound gauge clearance recording unit

A special method of collecting and recording data has been developed in order to quickly and in a high degree of accuracy update the fixed-structure file. A special railbound gauge clearance recording unit based on stereophotogrammetric measurement of fixed structures along the permanent way has been developed.

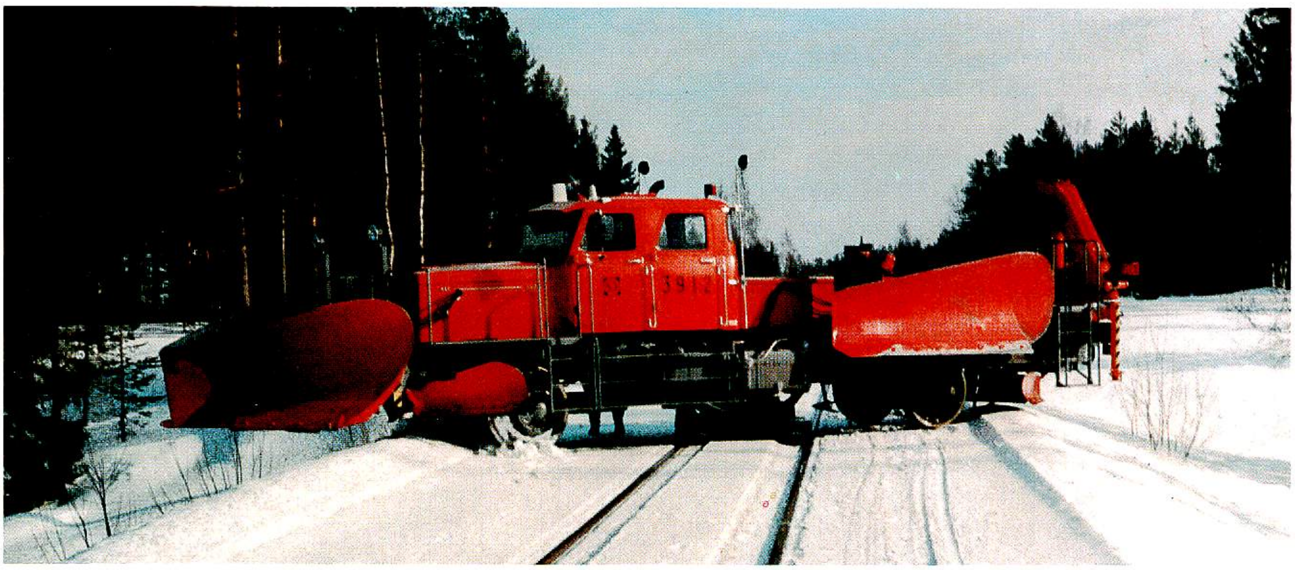


The STEFO recording car with its measuring trolleys with the reference points

SNOW CLEARANCE

Winters in Sweden can be severe, particularly in the far north. 30 special, heavy snow ploughs (two sizes) ensure fast, efficient snow clearance.

SJ also has 20 light snow ploughs mounted on heavy lorries fitted with railway wheels. A further 30 vehicles of this type will be delivered.

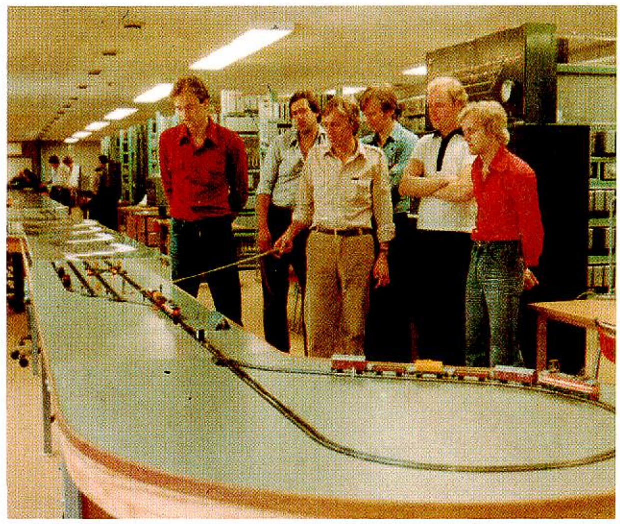


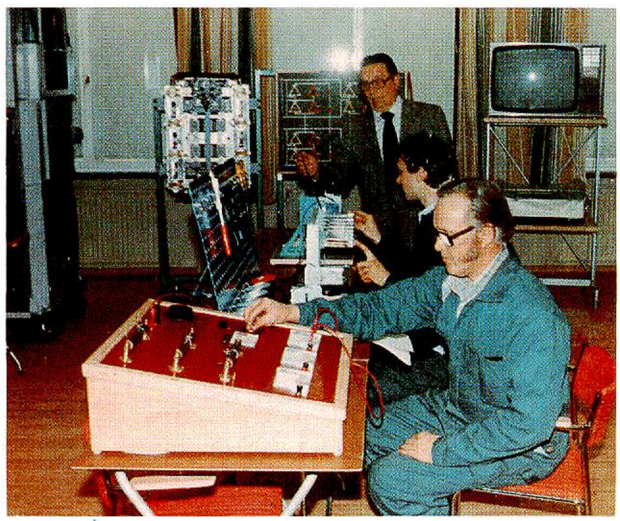
▲ During the summer MTR 101 is used for internal transports

▼ Diesel snow plough (type Tc)

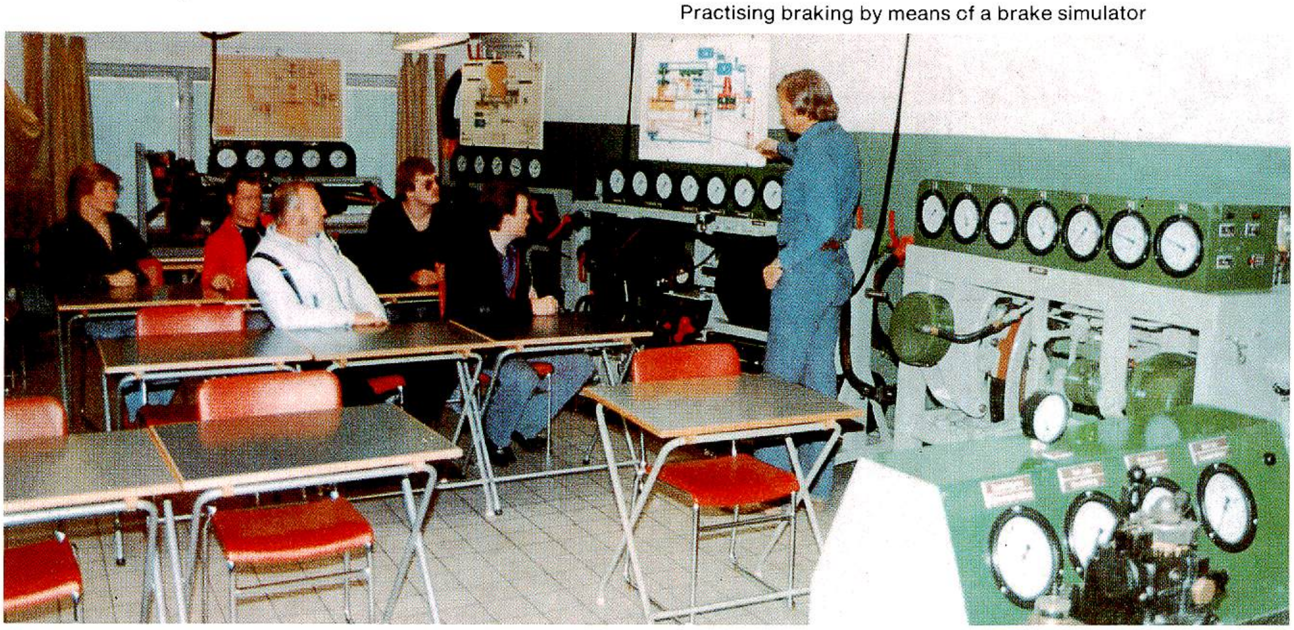
TRAINING

Each year, 15 000 to 20 000 employees attend different types of training courses conducted by SJ. These courses cost more than SEK 100 million per year, including wages, salaries and per diem allowances for trainees and instructors. The overall annual cost of training has been estimated at nearly SEK 150 million. For more formal training, SJ has three training centres – one at Ängelholm, one at Mjölby and one in Stockholm. Technicians, engineers, servicemen, etc., are trained at the Ängelholm centre. Locomotive personnel are trained at Mjölby, while the Stockholm centre concentrates on administrative, financial and commercial training. On the average, about 450 trainees attend the SJ training centre at Ängelholm each day. At the Mjölby centre and the Stockholm centre respectively the figure is about 170. Continuous planning over a period of years, based on quantitative and qualitative analyses of SJ's requirements, has led to the development of a comprehensive training programme. Some 500 different types of courses are being offered today. They vary widely with regard to both length and content. At present the central training department employs about 200 who plan and give these courses.


Part of the miniature railway. Interlocking installations to the right.


Training in following up the control circuits in a modern electric locomotive class Rc 4

Practising braking by means of a brake simulator



Sörmlands Grafiska AB 1981